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Influence of foliar nutrition of $ZnSO_4$ and GA_3 on bio - chemical, quality and yield of maize (*Zea mays* L.)

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Abstract
A field experiment was carried out at Agriculture College Farm, Raichur during *kharif* 2018. “Influence of foliar nutrition of $ZnSO_4$ and GA_3 on biochemical, quality and yield parameters of maize (*Zea mays* L.)”. The experiment was laid out in Factorial randomized complete block design (RCBD) with eighteen treatments. The treatments were foliar nutrition of $ZnSO_4$ @ 0.25 per cent, $ZnSO_4$ @ 0.5 per cent and $ZnSO_4$ @ 1.0 per cent and GA_3 @ 25 ppm, GA_3 @50 ppm sprayed at different leaf stages (V5, V6, V5 & V6). Among the different treatments, foliar application of $ZnSO_4$ (1.0%) at V5 stage revealed a significant effect on biochemical and quality parameters such as reducing and non-reducing sugars, protein, starch content in grains. yield parameters of maize crop were increased when foliar nutrition was given at early stages (V5 & V6 stage). Foliar nutrition at the early vegetative stage improved the cob development and grain yield pertaining to the significant variation in early silking, increased the sugar contents and dry matter production. In addition, the foliar nutrients improved translocation and assimilation of nutrients by maize plants leading to significant increase in grain yield. It was concluded from the results that foliar nutrition during 25 to 30 days after sowing could increase maize productivity.

Keywords: Foliar application, reducing and non-reducing sugars, protein content, starch content, and yield parameters

Introduction
Maize (*Zea mays* L.) is an important cereal in the agricultural economy after rice and wheat, in the world as well as in India. It is a versatile crop grown in diverse environmental conditions, has multiple uses and yield potential far higher than any other cereal and hence it is referred as the ‘queen of cereals’. Among all the cereals, maize in general and hybrids in particular are responsive to nutrients of maize. It is an exhaustive crop which consumes large quantity of nutrients at different growth stages for growth and development. Under the present trend of exploitive agriculture in India, inherent soil fertility can no longer be maintained on the sustainable basis. It is said that nutrient supplying capacity of soil declines steadily under continuous and intensive cropping system. Foliar application of the major nutrients appeared to increase yield and quality of different crops. Nutrient uptake occurs both via leaf cuticle (Brasher *et al*., 1953) [7], stomata (Eichert and Burkhardt, 1999) [9] and through hydrophilic pores within the leaf cuticle (Tyree *et al*., 1990) [27]. Several nutrient elements are readily absorbed by leaves when they are dissolved in water and sprayed on them. Foliar application technique is a particular way to supply macro and micro-nutrients in rapid absorption (Ahmed *et al*., 1994). If applied properly, foliar spraying can be considered practical to supply nutritional plant requirements. Zinc application stimulates protein synthesis and enhances the remobilization from stored carbohydrates in vegetative organs to grain. Zinc mainly controls the reproductive growth of plant.

It is needed for the growth, utilization of sugar and starch, photosynthesis, cell division, nucleus formation, fat and albumen formation. Zinc plays an important role in the phloem translocation and also helps in the starch sugar synthesis. Zinc exerts a great influence on basic plant life processes, such as nitrogen metabolism uptake on nitrogen and protein quality, photosynthesis chlorophyll synthesis, carbon anhydrase activity, development and function of floral tissues and resistance to abiotic and biotic stresses protection against oxidative damage. Higher yield and profits can be obtained by supplying the nutrients to the plant at critical stages of development. The yield of maize is based on the number of kernels per ear and kernel weight. These factors are predetermined at the particular leaf stage and are influenced by the availability of nutrients and environmental conditions. Timing of nutrient demand and acquisition by maize is nutrient specific and associated with key vegetative or reproductive growth stages. Thus, the knowledge of dynamics of nutrient accumulation to sink organs and the fate of foliar-applied nutrients at specific growth stages would provide useful information to deliver nutrients more efficiently to meet requirement, thus improving nutrient management and sustainable intensification and obtaining greater yield. with the above background an experiment was conducted to evaluate the Influence of foliar nutrition of $ZnSO_4$ and GA_3 on biochemical, quality and yield parameters of maize (*Zea mays* L.)"

Materials and Methods

The experiment was conducted at Agricultural College Farm, University of Agricultural Sciences, Raichur situated in North Eastern Dry Zone of Karnataka at latitude of 16º15′ North, longitude of 77º21′ East with an altitude of 389 meters above mean sea level. Maize hybrid RCRMH2 was used for the experimental purpose. The experiment was laid out in Factorial randomized complete block design with five replications consisting of eighteen treatments including control. The details of the treatments were T_1–No foliar spray at V5 stage, T_2 - No foliar spray at V6 stage, T_3 - No foliar spray at V5 & V6 stage, T_4 -$ZnSO_4$ (0.25 %) at V5 stage, T_5 - $ZnSO_4$ (0.25 %) at V6 stage, $T_6$$ZnSO_4$ (0.25 %) at V5 & V6 stages, $T_7$$ZnSO_4$ (0.5 %) at V5 stage -, T_8 -$ZnSO_4$ (0.5 %) at V6 stage, T_9 -$ZnSO_4$ (0.5 %) at V5 & V6 stages, T_{10} -$ZnSO_4$ (1.0 %) at V5 stage, T_{11} -$ZnSO_4$ (1.0 %) at V6 stage, T_{12} - $ZnSO_4$ (1.0 %) at V5 & V6 stages, T_{13} -GA_3 (25 ppm) at V5 stage, T_{14} - GA_3 (25 ppm) at V6 stage, T_{15} - GA_3 (25 ppm) at V5 & V6 stages T_{16} - GA_3 (50 ppm) at V5 stage T_{17} - GA_3 (50 ppm) at V6 stage, T_{18} - GA_3 (50 ppm) at V5 & V6 stages. Biochemical & quality parameters were estimated at harvest. Reducing and non- reducing sugars content in seeds were estimated with the standard procedure given by Nelson and Somogyi (1952) [19]

The experimental data collected was subjected to statistical analysis using Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984) [12].

Results and discussion

Reducing and non-reducing sugars in seeds

The production and consequent compound function of carbon is determined by phenological stage, edapho climatic condition and plant nutritional status (Pimentel, 2004) [21].

The present investigation showed that plants treated with $ZnSO_4$ @ 1.0 per cent recorded significant increase in the level of reducing and non-reducing sugar in seeds at all the stages at different times of observation as compared to control. The higher level of reducing and non-reducing sugar content in maize seeds might be probably due to foliar application of macro and micronutrients which have stimulated the rate of photosynthesis leading to higher rate of production of photosynthates in the seeds. Among the foliar nutrients, zinc proved more beneficial expression. These changes in the concentration of total and non-reducing sugars in the treated plants are attributed to the role of zinc, starch and nucleic acid metabolism and activities of various enzymes involved in these biochemical reactions (Alloway, 2008) [4].

These results showed resemblance with the consequence of Singh *et al.* (2012) [23] who illustrated that the significant improvement in reducing and non-reducing sugar was noticed by applying micro nutrients and the fruits of treated trees showed more reducing sugar as compared to control. These results are agreement with the findings of Nalini *et al.* (2013) [18] in black gram and Ali *et al.* (2017) [3] in mustard.

Starch content

Starch content is an important factor that contributes towards the yield and quality of maize grain. In the present investigation, application of different foliar nutrients at various vegetative stages resulted in increase in starch content. However the highest content of starch were recorded in the foliar application of $ZnSO_4$ at early vegetative stages (V5 & V6 stage) compared to the control.

Formation of NADPH or NADH depending on the foliar nutrition might have involved in trapping and converting the radiation energy for photosynthetic activities and increased formation of sugars and starch. Starch content in grains was found more in early stages of foliar application which might be due to zinc that has contributed for higher photosynthesis, chlorophyll, metabolism of starch formation and enzyme carbonic anhydrase accelerating carbohydrate (sugars and starch) formation and translocation to sink. Similar results were found with Stalin *et al.* (2014) [24] in rice, Ali *et al.* (2016) [2] in maize, Debnath *et al.* (2016) [8] in maize and Ghasal *et al.* (2017) [11] in wheat.

Protein content

Maize protein is deficient in lysine and tryptophan but has fair amounts of sulphur containing amino acids (methionine and cysteine). Several essential metal ions are redox- active that is the basis for their occurrence as catalytically active cofactors in many enzymes. Other metals (like zinc) fulfill in addition to their catalytic role, a structural role in stabilizing proteins. Micronutrients are constituent of a particular protein.

The treatment that received foliar spray of ZnSO4 @ 1.0 per cent recorded higher protein content in V5 stage (8.40%) in grain samples. foliar applied micronutrients may have also responsible for increased protein content. Similar findings and observations were also reported by Mohsin *et al*. (2014) [16], Khattak *et al.* (2015) [14] with soil and foliar fertilization of zinc in wheat and Harender *et al*. (2018) [13] with different dose of plant nutrients.

Grain yield

Grain yield is an ultimate end product of many yield-contributing components, physiological and morphological processes taking place in plants during growth and development. Grain yield depends on the synthesis and accumulation of photosynthates and their distribution among various plant parts. The synthesis, accumulation and translocation of photosynthates depend upon efficient photosynthetic structure as well as the extent of translocation into sink (grains) and also on plant growth and development during early stages of crop growth. This may be attributed to fulfillment of the demand of the crop by higher assimilation and translocation of photosynthates from source (leaves) to sink (grains) through supply of required nutrients by foliar spray.

In the present investigation, it is clear that foliar application of nutrients increased the grain yield compared to control where only recommended dose of fertilizers was applied. Among the different treatments, foliar spray of $ZnSO_4$ at early vegetative stages (V5 & V6) increased the grain yield by 5.87 and 5.27 per cent respectively as compared to control.

Foliar nutrition at the early vegetative stage improved the cob development and grain yield pertaining to the significant variation in early silking, increased chlorophyll contents, photosynthesis rate which in turn increased the sugar contents and dry matter production. In addition, the foliar nutrients improved translocation and assimilation of nutrients by maize plants leading to significant increase in grain yield. Similar results were obtained by El-Azab (2015) [10], who reported that foliar application of $ZnSO_4$ at 5th leaf stage significantly increased the grain yield of maize hybrid. These results are also in consonance with a study which exhibited that foliar application of $ZnSO_4$ is better to increase the grain yield of maize hybrids (Tariq *et al*., 2014) [26]. Similar findings were reported by Mohsin *et al.* (2014) [16], Manasa and Devaranavadagi (2015) [15], Munirah *et al.* (2015) [17], Anees *et al.* (2016) [2] and Wasaya *et al.* (2017) [28].

Stover yield

Stover yield was increased with the foliar application of different nutrients during various vegetative stages as compared to control where only recommended dose of fertilizer was applied. Foliar $ZnSO_4$ at early vegetative stages (V5 & V6) showed higher stover yield.

The vigorous vegetative growth and improved plant height and leaf area index lead to higher total dry matter production per plant which attributed to higher stover yield over other treatments.

The results are in line with Parasuraman (2008) [20] who reported higher stover yield of maize due to the foliar nutrition of multi-nutrients over recommended dose of fertilizer. Manasa and Devaranavadagi (2015) [15] and Subhanullah *et al.* (2017) [25] also noticed the higher stover yield of maize by foliar nutrition of zinc.

Harvest index

From the present investigation, it was also noted that harvest index were also significant due to foliar nutrition at different vegetative stages compared to control. This might be due to the effective translocation of photosynthates and partitioning in different parts of the plant attributing to the increased grain yield. This result is in accordance with Anjum *et al.* (2017) [6] who reported that foliar application of zinc and boron at 9th leaf stage increased carboxy peptidase which might maintain adequate carbohydrate availability by catalyzing irreversible reactions in glycolysis and ultimately sufficient carbohydrates are partitioned towards grains and improved grain yield. The results are in line with the findings of Anees *et al.* (2016) [5].

Influence of foliar nutrition of $ZnSO_4$ and GA_3 biochemical changes in the maize hybrid seeds

Treatments		Reducing sugars (mg g^{-1})	Non-reducing sugars (mg g^{-1})
T_1- No foliar spray at V5 stage (F_0S_1)		1.31	3.88
T_2- No foliar spray at V6 stage (F_0S_2)		1.35	3.91
T_3- No foliar spray at V5 & V6 stages (F_0S_3)		1.37	3.96
T_4- $ZnSO_4$ (0.25 %) at V5 stage (F_1S_1)		1.69	4.72
T_5- $ZnSO_4$ (0.25 %) at V6 stage (F_1S_2)		1.76	4.67
T_6- $ZnSO_4$ (0.25 %) at V5 & V6 stage (F_1S_3)		1.82	4.52
T_7- $ZnSO_4$ (0.5 %) at V5 stage (F_2S_1)		1.80	4.53
T_8- $ZnSO_4$ (0.5 %) at V6 stage (F_2S_2)		1.80	4.53
T_9- $ZnSO_4$ (0.5 %) at V5 & V6 stages (F_2S_3)		1.76	4.48
T_{10}- $ZnSO_4$ (1.0 %) at V5 stage (F_3S_1)		1.93	4.89
T_{11}- $ZnSO_4$ (1.0 %) at V6 stage (F_3S_2)		1.88	4.81
T_{12}- $ZnSO_4$ (1.0 %) at V5 & V6 stages (F_3S_3)		1.83	4.60
T_{13}- GA_3 (25 ppm) at V5 stage (F_4S_1)		1.87	4.62
T_{14}- GA_3 (25 ppm) atV6 stage (F_4S_2)		1.71	4.60
T_{15} –GA_3 (25 ppm) at V5 & V6 stages (F_4S_3)		1.75	4.73
T_{16}- GA_3 (50 ppm) at V5 stage (F_5S_1)		1.77	4.60
T_{17}- GA_3 (50 ppm) at V6 stage (F_5S_2)		1.85	4.39
T_{18}- GA_3 (50 ppm) at V5 & V6 stages (F_5S_3)		1.88	4.62
Mean		1.73	4.49
S.Em (±)	Stages of crop (A)	0.02	0.04
	Concentration of treatments (B)	0.03	0.06
	Interaction of (AXB)	0.06	0.11
C.D at 5%	Stages of crop (A)	0.07	0.13
	Concentration of treatments (B)	0.10	0.18
	Interaction of (AXB)	NS	NS

Influence of foliar nutrition of $ZnSO_4$ and GA_3 on starch content & protein content in maize grains

Treatments	Starch content (%)	Protein content (%)
T_1- No foliar spray at V5 stage (F_0S_1)	62.52	4.95
T_2- No foliar spray at V6 stage (F_0S_2)	63.03	5.91
T_3- No foliar spray at V5 & V6 stages (F_0S_3)	63.50	5.02
T_4- $ZnSO_4$ (0.25 %) at V5 stage (F_1S_1)	66.13	8.11
T_5- $ZnSO_4$ (0.25 %) at V6 stage (F_1S_2)	63.34	7.45
T_6- $ZnSO_4$ (0.25 %) at V5 & V6 stages (F_1S_3)	66.63	7.87
T_7- $ZnSO_4$ (0.5 %) at V5 stage (F_2S_1)	65.80	7.14
T_8- $ZnSO_4$ (0.5 %) at V6 stage (F_2S_2)	66.58	8.16
T_9- $ZnSO_4$ (0.5 %) at V5 & V6 stages (F_2S_3)	66.54	6.33
T_{10}- $ZnSO_4$ (1.0 %) at V5 stage (F_3S_1)	67.05	8.40
T_{11}- $ZnSO_4$ (1.0 %) at V6 stage (F_3S_2)	66.80	8.17
T_{12}- $ZnSO_4$ (1.0 %) at V5 & V6 stages (F_3S_3)	66.09	7.58
T_{13}- GA_3 (25 ppm) at V5 stage (F_4S_1)	66.31	7.63
T_{14}- GA_3 (25 ppm) atV6 stage (F_4S_2)	65.75	7.16
T_{15} –GA_3 (25 ppm) at V5 & V6 stages (F_4S_3)	65.79	7.66

T_{16}- GA_3 (50 ppm) at V5 stage (F_5S_1)		66.22	7.43
T_{17}- GA_3 (50 ppm) at V6 stage (F_5S_2)		65.66	6.89
T_{18}- GA_3 (50 ppm) at V5 & V6 stages (F_5S_3)		66.15	7.81
Mean		65.55	7.20
S.Em (±)	Stages of crop (A)	0.42	0.16
	Concentration of treatments (B)	0.59	0.23
	Interaction of (AXB)	1.02	0.40
C.D at 5%	Stages of crop (A)	1.20	0.47
	Concentration of treatments (B)	1.70	0.66
	Interaction of (AXB)	NS	NS

Influence of foliar nutrition of $ZnSO_4$ and GA_3 on grain yield, stover yield, and harvest index of maize hybrid

Treatments		Grain yield (kg ha^{-1})	% increase over control	Stover yield (kg ha^{-1})	% increase over control	Harvest index (%)
T_1- No foliar spray at V5 stage (F_0S_1)		7740.02		8109.03		45.71
T_2- No foliar spray at V6 stage (F_0S_2)		7751.78		8143.94		45.17
T_3- No foliar spray at V5 & V6 stages (F_0S_3)		7702.42		8153.89		45.50
T_4- $ZnSO_4$ (0.25 %) at V5 stage (F_1S_1)		7921.35	2.34	8223.20	1.40	46.01
T_5- $ZnSO_4$ (0.25 %) at V6 stage (F_1S_2)		7902.85	1.94	8189.15	0.55	47.04
T_6- $ZnSO_4$ (0.25 %) at V5 & V6 stages (F_1S_3)		7881.55	2.32	8217.80	0.78	45.76
T_7- $ZnSO_4$ (0.5 %) at V5 stage (F_2S_1)		7857.95	1.52	8177.76	0.84	46.82
T_8- $ZnSO_4$ (0.5 %) at V6 stage (F_2S_2)		8037.99	3.69	8325.67	2.23	47.36
T_9- $ZnSO_4$ (0.5 %) at V5 & V6 stages (F_2S_3)		7870.95	2.18	8344.81	2.34	47.00
T_{10}- $ZnSO_4$ (1.0 %) at V5 stage (F_3S_1)		8194.53	5.87	8376.64	3.26	47.93
T_{11}- $ZnSO_4$ (1.0 %) at V6 stage (F_3S_2)		8159.36	5.25	8360.59	2.66	47.42
T_{12}- $ZnSO_4$ (1.0 %) at V5 & V6 stages (F_3S_3)		8056.19	4.59	8357.67	2.49	47.01
T_{13}- GA3 (25 ppm) at V5 stage (F_4S_1)		8026.97	3.70	8343.95	2.89	47.42
T_{14}- GA_3 (25 ppm) atV6 stage (F_4S_2)		8023.03	3.49	8260.28	1.42	46.03
T_{15} –GA_3 (25 ppm) at V5 & V6 stages (F_4S_3)		8021.95	4.14	8317.81	2.01	47.11
T_{16}- GA_3 (50 ppm) at V5 stage (F_5S_1)		8016.29	3.56	8198.82	1.10	46.18
T_{17}- GA_3 (50 ppm) at V6 stage (F_5S_2)		7957.22	2.65	8258.57	1.40	46.26
T_{18}- GA_3 (50 ppm) at V5 & V6 stages (F_5S_3)		7915.99	2.77	8231.23	0.94	47.20
Mean		7946.58		8255.04		46.61
S.Em (±)	Stages of crop (A)	38.15		27.43		0.31
	Concentration of treatments (B)	53.95		38.79		0.45
	Interaction of (AXB)	93.45		67.19		0.78
C.D at 5%	Stages of crop (A)	109.64		78.84		0.91
	Concentration of treatments (B)	155.06		111.49		1.29
	Interaction of (AXB)	NS		NS		NS

Conclusion

Foliar application of $ZnSO_4$ @ 1.0 per cent at (V5 & V6) stages showed significantly higher performance in all the physiological and biochemical parameters changes in maize which increased the yield and yield components of the maize crop.

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