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Anil Jadhav
M.Sc. (Agri.), Department of Crop Physiology, AC, Raichur, Karnataka, India

Amaregouda A
Department of Soil Science and Agricultural Chemistry, AC, Raichur, University of Agricultural Sciences, Raichur, Karnataka, India

Patil RP
Department of Soil Science and Agricultural Chemistry, AC, Raichur, University of Agricultural Sciences, Raichur, Karnataka, India

Meena MK
Department of Soil Science and Agricultural Chemistry, AC, Raichur, University of Agricultural Sciences, Raichur, Karnataka, India

Beladhadi RV
Department of Soil Science and Agricultural Chemistry, AC, Raichur, University of Agricultural Sciences, Raichur, Karnataka, India

Correspondence
Anil Jadhav
M.Sc. (Agri.) Department of Crop Physiology, AC, Raichur, Karnataka, India

Influence of foliar nutrition of ZnSO4 and GA3 on Physiological, biochemical and yield parameters of maize (*Zea maize* L.)

Anil Jadhav, Amaregouda A, Patil RP, Meena MK and Beladhadi RV

Abstract
A field experiment was carried out at Agriculture College Farm, Raichur during *kharif* 2018. an enttitled Influence of foliar nutrition of $ZnSO_4$ and GA_3 on physiological, biochemical 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 stages (V5, V6, V5 & V6). Among the different treatments, foliar application of $ZnSO_4$ (1.0%) at V5 stage revealed a significant effect on physiological parameters such as photosynthetic rate, normalized difference vegetative index (NDVI) and biochemical parameters *viz.*, chlorophyll a, chlorophyll b, total chlorophyll of leaves, ultimately leading to increasing in the yield. Physiological and biochemical parameters except transpiration rate were increased when foliar nutrition was given at early stages (V5 & V6 stage). It was concluded from the results that foliar nutrition during 25 to 30 days after sowing could increase maize productivity significantly by increasing physiological and biochemical activity.

Keywords: Foliar application, leaf area index, Photosynthesis rate, transpiration rate, NDVI, chlorophyll content, and yield

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. In India, maize occupies an area of 9.2 m ha, production of 23.6 million tonnes with the productivity of 2564 kg/ha. In Karnataka, it is cultivated in an area of 1.34 million ha with a production of 3.91 million tonnes and the productivity of 2921 kg/ha (Anon., 2017). It is cultivated throughout the year in all states of the country for various purposes. The predominant maize growing states are Andhra Pradesh, Karnataka, Tamil Nadu, Rajasthan, Maharashtra, Bihar, Uttar Pradesh, Madhya Pradesh and Gujarat.

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) [3], stomata (Eichert and Burkhardt, 1999) [6] and through hydrophilic pores within the leaf cuticle (Tyree *et al.*, 1990). 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 micronutrient mainly controls the reproductive growth of plant. Zinc plays an important role in the phloem translocation and also helps in the starch sugar synthesis. 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. Timing of nutrient demand and acquisition by maize is nutrient specific and associated with key vegetative or reproductive growth stages. Thus, 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 planned to evaluate the Influence of foliar nutrition of $ZnSO_4$ and GA_3 on physiological biochemical and yield parameters of maize (*Zea mays* L.).

Material 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. Physiological and biochemical parameters were estimated at, 60 days after treatment during the cropping period. The physiological parameters *viz.*, photosynthetic rate and transpiration rate were measured using infra-red gas analyzer (IRGA) (TPS-2 portable photosynthesis system version 2.01). Normalized Difference Vegetation Index (NDVI) was measured using the hand held Green seeker. The biochemical parameterlike total chlorophyll content of the leaves determined by following dimethyl sulphoxide (DMSO) method as devised by Hiscox and Israelstam (1979) [10].

The experimental data collected was subjected to statistical analysis using Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984) [9].

Results and discussion

The photosynthetic rate under a given environmental condition is a function of the various biophysical and biochemical processes which involves diffusion of CO_2 from atmosphere to chloroplast and subsequent enzymatic reaction. The findings of present study indicated that foliar application of nutrients increased the photosynthesis at all stages compared to control. Foliar application of $ZnSO_4$ @ 1.0 per cent at all the vegetative stages (V5, V6, V5 & V6) increased the photosynthetic rate than other treatments. However, among the different foliar nutrients and different vegetative stages, foliar nutrition of $ZnSO_4$ @ 1.0 per cent at V5 stage increased photosynthetic rate enormously at 60 days after treatment in maize which may be due to its involvement in activation of many enzymes of photosynthesis, cell elongation and cell division (Cakmak, 2008) [4]. Photosynthetic rate was found to be higher when foliar nutrition was given at early vegetative stages (V5 & V6) compared to other vegetative stages. Which may be due to the enhanced photosynthetic enzyme synthesis such as carbonic anhydrase and improved photosystem II performance by the foliar spray of zinc at early stages. Ahmed *et al.* (2009) observed severe reduction in crop photosynthetic activities due to zinc deficiency in cotton. However, foliar application of zinc increased gas exchange parameters and maintained membrane integrity (Khan *et al*., 2004) [11]. This increase in photosynthetic rate may be due to increasing the performance of photo-system II by the foliar spray of zinc. Qiao *et al.* (2014) [18] observed that foliar application of zinc at tillering stage enhanced carbonic anhydrase activity in rice leaves and hence increased photosynthesis. Carbonic anhydrase is considered as zinc containing enzyme involved in photosynthesis. Similar results were reported by Munirah *et al.* (2015) [16]. Anees *et al* (2016) [2] in maize.

The transpiration rate differed significantly among the foliar nutrition. Foliar application of nutrients increased the transpiration rate to a lesser extent compared to control. Foliar application of $ZnSO_4$ @ 1.0 per cent at all the vegetative stages (V5 & V6). Increased the transpiration rate than other treatments. These findings are in agreemented with the results of Wang and Jin (2005) [22], who reported that micronutrients affect gas exchange characteristics like photosynthetic rate, transpiration rate and stomatal conductance which were significantly enhanced by their application. Similar findings were reported by Liu *et al.* (2016) [12] in maize.

Leaf area index is one of the most important and commonly used indices to analyze the growth of crop plant. It depends on the per cent of expansion of crop canopy to utilize the sunlight for photosynthesis.

In the present investigation, among all the treatment studied, the maximum leaf area index was recorded with foliar application of $ZnSO_4$ @ 1.0 per cent at early vegetative stages (V5 & V6). Increased in leaf area index by zinc application might be due to increase in auxin and indole acetic acid hormone which are two main factors in leaf area expansion (Nadergholi *et al*., 2011) [17]. Similar results were reported by Safyan *et al*. (2012) [19] and Mohsin *et al*. (2014) [14] in maize crop. The NDVI, which is a combination of red and NIR reflectance measurements, is one of the most widely used vegetation indices and has been extensively used to analyse the greenness of plant which is related to the amount of chlorophyll present in plant leaf. In the present investigation, foliar application of nutrients at early vegetative stages (V5 &V6) showed significant difference on NDVI. However, there was no significant difference due to foliar application of nutrients at different growth stages. Higher NDVI might be due to higher greenness which is attributed to higher nitrogen content. The higher nitrogen absorption may be due to stimulatory effect of zinc on nitrogen uptake and translocation into plant parts, which might have increased the nitrogen content of plants. These findings are similar to the results of El-Azab (2015) [7] in corn plant and Wiatrak (2013) [23] noticed that wheat seeds coated with micronutrients (Cu, Mn and Zn) and zinc uptake in plants along with increase in NDVI which had positive correlation with grain yield.

Chlorophyll has been rightly designated as "Pigments of life" because of their central role in living systems responsible for harvesting sunlight and transforming its chemical energy into biochemical energy essential for life on earth. In the present study total chlorophyll were significantly improved by the foliar nutrition. In addition, chlorophyll content was significantly higher in leaves of zinc treated plants than that of leaves of control Zinc is important for the formation and activity of chlorophyll and in the functioning of several enzymes and the growth hormone (auxin). Similar increased in chlorophyll total was observed by Mosanna and Behrozya (2015) [15] by the foliar application of zinc.Our results are also in line with findings of Massoud *et al.*, (2005) [13] in pea plants The physiological analysis of photosynthetic pigments like total chlorophyll were significantly increased by application of micronutrients due to enhancement in secondary metabolites (Shitole and Dhumal, 2012) [20]. These findings are also in corroboration with Singh and Bhatt (2013) [21] in lentil Nutrient management at the critical growth stage is an important factor which largely decides the yield of the crop. The economic yield is the manifestation of various biological events involving morphological, growth, biochemical and physiological changes which take place during development in accordance with the supply of light, water, temperature and nutrients (Donald, 1962) [5]. The grain yield depends on the synthesis and accumulation of photosynthates and their distribution among various plant parts. The production and translocation of synthesized photosynthates depend upon mineral nutrition supplied either through soil or foliar application and plant growth and development during early stages of crop growth. The major factors attributing to variation in grain yield of maize are yield components *viz.*, cob characteristics, number rows of per cob, number of kernels per row, & testweight.

Table 1: Influence of foliar nutrition of $ZnSO_4$ and GA_3 on leaf area index at 60 Days after sowing stage of maize hybrid

Treatments		60 Days After Sowing					
		LAI	**NDVI value**	**Photosynthetic rate (μ mol CO_2 m^{-2} s^{-1})**	**Transpiration rate (m mol H_2O m^{-2} s^{-1})**	**Total Chlorophyll content (mg.g-1F.W.)**	**Yield Kg/ha**
T_1- No foliar spray at V5 stage (F_0S_1)		2.69	0.71	23.05	2.21	2.12	7740.02
T_2- No foliar spray at V6 stage (F_0S_2)		2.60	0.73	23.22	2.18	2.16	7751.78
T_3- No foliar spray at V5 & V6 stages (F_0S_3)		2.69	0.72	22.95	2.15	2.30	7702.42
T_4- $ZnSO_4$ (0.25 %) at V5 stage (F_1S_1)		3.51	0.76	25.81	2.33	2.38	7921.35
T_5- $ZnSO_4$ (0.25 %) at V6 stage (F_1S_2)		3.41	0.73	24.93	2.41	2.42	7902.85
T_6- $ZnSO_4$ (0.25 %) at V5 & V6 stages (F_1S_3)		3.38	0.75	28.51	2.58	2.46	7881.55
T_7- $ZnSO_4$ (0.5 %) at V5 stage (F_2S_1)		3.36	0.76	31.33	2.32	2.48	7857.95
T_8- $ZnSO_4$ (0.5 %) at V6 stage (F_2S_2)		3.56	0.75	24.84	2.33	2.52	8037.99
T_9- $ZnSO_4$ (0.5 %) at V5 & V6 stages (F_2S_3)		3.53	0.76	23.77	2.63	2.55	7870.95
T_{10}- $ZnSO_4$ (1.0 %) at V5 stage (F_3S_1)		3.66	0.79	32.23	2.97	2.58	8194.53
T_{11}- $ZnSO_4$ (1.0 %) at V6 stage (F_3S_2)		3.59	0.75	31.35	2.83	2.56	8159.36
T_{12}- $ZnSO_4$ (1.0 %) at V5 & V6 stages (F_3S_3)		3.43	0.76	23.81	2.50	2.47	8056.19
T_{13}- GA_3 (25 ppm) at V5 stage (F_4S_1)		3.42	0.75	26.92	2.55	2.54	8026.97
T_{14}- GA_3 (25 ppm) atV6 stage (F_4S_2)		3.45	0.76	27.16	2.59	2.55	8023.03
T_{15} –GA3 (25 ppm) at V5 & V6 stages (F_4S_3)		3.50	0.74	28.87	2.48	2.54	8021.95
T_{16}- GA_3 (50 ppm) at V5 stage (F_5S_1)		3.50	0.73	28.79	2.53	2.55	8016.29
T_{17}- GA_3 (50 ppm) at V6 stage (F_5S_2)		3.45	0.76	29.25	2.66	2.52	7957.22
T_{18}- GA_3 (50 ppm) at V5 & V6 stages (F_5S_3)		3.48	0.73	26.80	2.51	2.50	7915.99
Mean		3.34	0.75	26.86	2.48	2.45	7946.58
S.Em (±)	Stages of crop (A)	0.004	0.004	0.036	0.01	0.01	38.15
	Concentration of treatments (B)	0.006	0.006	0.052	0.02	0.02	53.95
	Interaction of (AXB)	0.012	0.012	0.090	0.04	0.04	93.45
C.D at 5%	Stages of crop (A)	0.014	0.014	0.10	0.04	0.04	109.64
	Concentration of treatments (B)	0.019	0.019	0.15	0.07	0.07	155.06
	Interaction of (AXB)	NS	NS	NS	NS	NS	NS

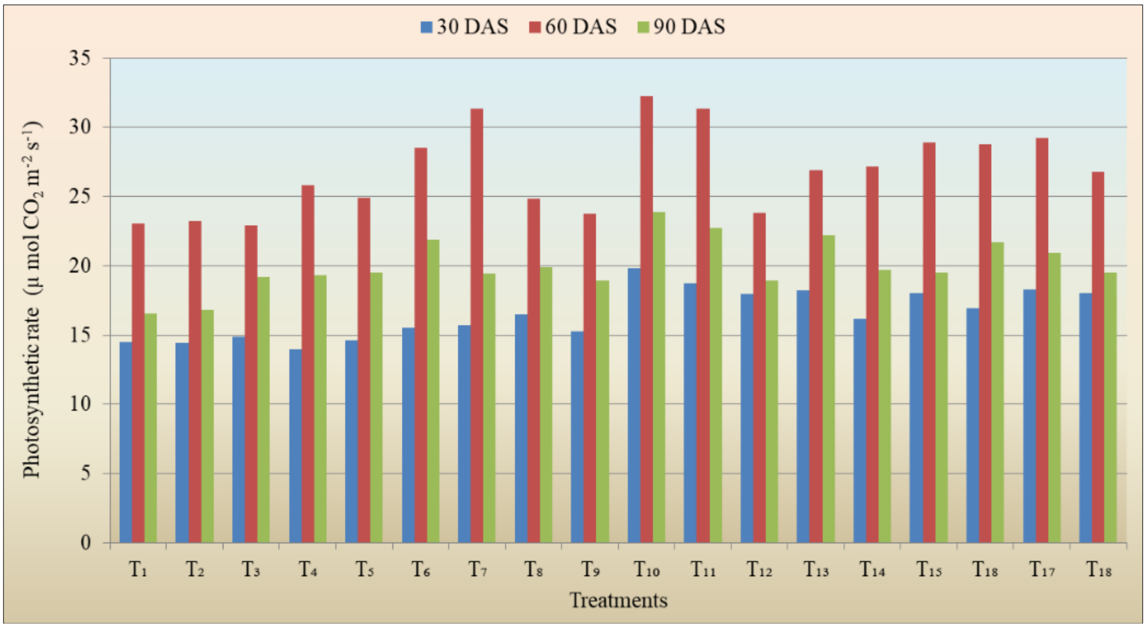

Fig 1: Influence of foliar nutrition of $ZnSO_4$ and GA_3 on Photosynthetic rate (μ mol CO_2 m^{-2} s^{-1}) in maize hybrid

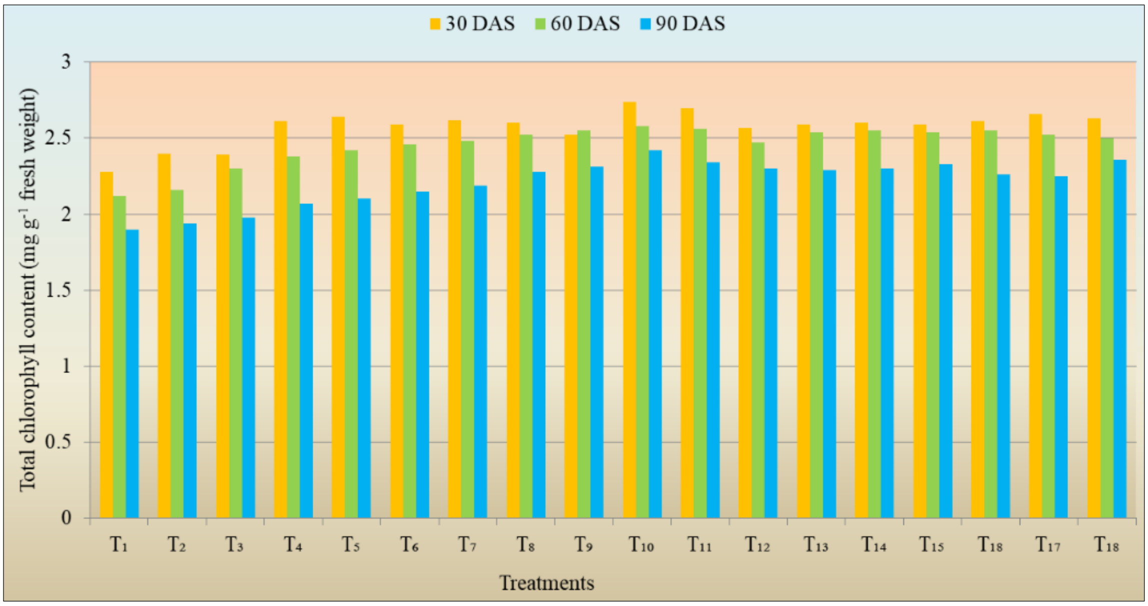

Fig 2: Influence of foliar nutrition of $ZnSO_4$ and GA_3 on total chlorophyll (mg g^{-1} fresh weight) in maize hybrid

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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