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RESPONSE OF FOLIAR APPLICATION OF TOCOPHEROL AND MICRONUTRIENTS ON MORPHOPHYSIOLOGICAL PARAMETERS AND YIELD OF CHICKPEA

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ABSTRACT

In order to investigate tocopherol and micronutrients (Zn, Fe) foliar application effects on chickpea on morphophysiological traits and yield, a field experiment was conducted at farm of Botany Section, College of Agriculture, Nagpur, during *rabi* 2018-2019 season. The experiment was arranged in randomized block design and replicated three times. Research design comprised of 18 treatments of tocopherol (100 ppm, 200 ppm, 300 ppm,400 ppm and 500 ppm) and micronutrients (0.5 % Zn and 0.5 % Fe) spray individually and in their combinations. Parameters measured were plant height, leaf area, total dry matter production, number of branches at harvest, harvest index and seed yield hectare^{-1}. Results have shown that treatment T_9 (100 ppm tocopherol+0.5% $ZnSO_4$)significantly enhanced all the parameters under study.Considering the Benefit : Cost ratio foliar application of 100 ppm tocopherol+0.5% $ZnSO_4$(T_9) was found more economical having B:C ratio of 2.61 as compared to 1.97 in control.

(Key words : Chickpea, tocopherol, micronutrients,foliar application, morpho-physiological parameters, yield)

INTRODUCTION

Chickpea is a legume of family Fabaceae, sub family Papilionaceae, genus *Cicer* and species *arietinum.* It is also known as gram or Bengal gram in English, chana in Hindi and garbanzo in Spanish.After its domestication in Middle East this crop progressed further throughout the Mediterranean region, India and Ethiopia (Ladizinsky, 1975). Based on seed size and colour, cultivated chickpeas are of two types i.e. the white seeded "Kabuli" and the brown seeded Desi types.

Tochopherols are lipophilic antioxidants and together with tricontenols belong to vitamin "e" family. á-tocopherol is most biologically active form of vitamin-E. Thus, is found most abundantly in wheat germ oil, sunflower and safflower oils.Vitamin-E exist in eight different forms, four tocopherols and four tocotrienols. The four forms of tocopherols consists of a polar chromanol ring and lipophilic prenyl chain with differences in position and number of methyl groups (Lushchack and Semchuk, 2012). There is a hydroxyl group that can donate hydrogen atom to reduce free radicals and a hydrophobic chain which allows for penetration into biological membrane.

Zinc is one of the micronutrients plants need to grow efficiently.It is an essential component of enzymes involved in metabolic reaction. Zinc plays a special role in synthesizing proteins, RNA and DNA (Kobraee *et al.,* 2011).Zinc sulphate is most commonly used source of zinc in granular fertilizer due to its high solubility in water and its relatively low cost of production. Zinc sulphate is an inorganic compound with molecular formula $ZnSO_4$. It is colourless and available in liquid form.Zinc affects several biochemical processes in the plant, such as cytochrome and nucleotide synthesis, auxin metabolism, chlorophyll production, enzyme activation and membrane integrity. Growth is severely affected. Zinc plays very important role in plant metabolism by influencing the activities of hydrogenase and carbonic anhydrase, stabilization of ribosomal fractions and synthesis of cytochrome. It also has active role in production of an essential growth hormone, auxin (Hafeez *et al.,* 2013). Combined application of zn with organic manures and foliar applications proved more beneficial among any sole mode of application with respect to increment in plant growth, yield and production of pulse crop (Yashona, 2018).

Iron is an essential micronutrient for all living organisms. It plays a critical role in metabolic processes such as DNA synthesis, respiration and photosynthesis. Further many metabolic processes are activated by iron and it is the prosthetic group constituent of many enzymes. It plays a significant role in various physiological and

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biochemical pathways in plants. It serves as a component of many vital enzymes such as cytochromes of the transport chain. In plants, iron is involved in the synthesis of chlorophyll and it is essential for the maintenance of chloroplast structure and function.

This experiment aimed to investigate the effect of foliar applications of tocopherol and micronutrients on morphophysiological characters and yield of chickpea.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* season of year 2018-19 at experimental farm of Agricultural Botany Section, College of Agriculture, Nagpur to asses the effect of foliar sprays of tocopherol and micronutrients on morphophysiological parameters and yield of chickpea. This experiment was carried out in RBD with 3 replications. Research design comprise of 18 treatments viz.,T_1 (control), T_2 (100 ppm tocopherol), T_3 (200 ppm tocopherol), T_4 (300 ppm tocopherol), T_5 (400 ppm tocopherol), T_6 (500 ppm tocopherol), T_7 (0.5% $ZnSO_4$), T_8 (0.5% $FeSO_4$), T_9 (100 ppm tocopherol+0.5% $ZnSO_4$), T_{10} (200 ppm tocopherol+0.5% $ZnSO_4$), T_{11} (300 ppm tocopherol+0.5% $ZnSO_4$), T_{12} (400 ppm tocopherol+0.5% $ZnSO_4$), T_{13} (500 ppm tocopherol+0.5% $ZnSO_4$), T_{14} (100 ppm tocopherol+0.5% $FeSO_4$), T_{15} (200 ppm tocopherol+0.5% $FeSO_4$), T_{16} (300 ppm tocopherol+0.5% $FeSO_4$), T_{17} (400 ppm tocopherol+0.5% $FeSO_4$) and T_{18} (500 ppm tocopherol+0.5% $FeSO_4$). Two foliar sprays at 25 and 40 DAS were given. JAKI-9218 cultivar of chickpea was used in the experiment. Observations on morphophysiological parameters like plant height, leaf area, total dry matter production were recorded at 25, 45, 65 and 85 DAS.Whereas, number of secondary branches plant^{-1} were recorded at the time of harvest.RGR and NAR were calculated at 25-45, 45-65 and 65-45 DAS. Seed yield hectare^{-1} was also recorded. The observed data were analyzed statistically using analysis of variance at 5% level of significance (Panse and Sukhatme, 1967).

RESULTS AND DISCUSSION

Plant height

Plant height is a crucial component of plant species. It is the shortest distance between upper boundary of the photosynthetic tissue on a plant and ground level, expressed in centimeters or meter. It is an important measure to determine growth.

Plant height was recorded at 85 DAS. At 85 DAS treatment T_9 (100 ppm tocopherol + 0.5% $ZnSO_4$) was found significantly superior followed by treatment T_{11} (300 ppm tocopherol + 0.5% $ZnSO_4$) over control.

Primary function of á-tocopherol is to maintain the integrity of cell membrane by protecting its physical stability (Fryer, 1992). This compound is also involved in several biological activities which partially resulted in increasing growth and yield in consequence (Kruk *et al*., 2000).Tocopherols play a role in a range of different physiological phenomena including plant growth and development, senescence, preventing lipid peroxidation and to interact with the signal cascade that convey abiotic and biotic signals (Sattler *et al*., 2004; Baffel and Ibrahim, 2008).

Zinc is directly and indirectly involved in the synthesis and metabolism in living organisms and plants. Increase in plant height is mainly attributed due to higher shoot growth through cell elongation, cell differentiation and apical dominance promoted by zinc. Zinc is also supposed to be involved in the hormone synthesis, hence indirectly related to translocation and metabolism of carbohydrate finally contributing to additional growth compared to control (Padma *et al*., 1989 and Deotale *et al*., 1998). These might be the reasons for getting more plant height by the application of á-tocopherol and Zinc.

In 2018, Purushottam *et al.* stated that the most significant plant height (41.03 cm) at 90 DAS was obtained by foliar application of zinc sulphate @ 0.5%.

Leaf area plant^{-1}

Leaf area is an important variable affecting light interception, and hence increased photosynthesis and carbohydrate production. Area of leaf depends upon the number and size of leaves. It is an important parameter in determining the plant productivity.

Data regarding leaf area production was noted at 25, 45, 65 and 85 DAS.At 45 DAS plants sprayed with 100 ppm tocopherol + 0.5% $ZnSO_4$ (T_9) was found to be best among all treatments followed by treatments T_{11} (300 ppm tocopherol + 0.5% $ZnSO_4$), T_{10} (200 ppm tocopherol + 0.5% $ZnSO_4$), T_{16} (300 ppm tocopherol + 0.5% $FeSO_4$), T_{15} (200 ppm tocopherol + 0.5% $FeSO_4$), T_{12} (400 ppm tocopherol + 0.5% $ZnSO_4$), T_{13} (500 ppm tocopherol + 0.5% $ZnSO_4$) andT_3 (200 ppm tocopherol) in a decreasing trend. Treatments T_2 (100 ppm tocopherol) and T_4 (300 ppm tocopherol) also exhibited significantly more leaf area when compared with control (T_1). At 65 DAS and 85 DAS treatment T_9 (100 ppm tocopherol + 0.5% $ZnSO_4$) significantly enhanced leaf area followed by treatments T_{11} (300 ppm tocopherol + 0.5% $ZnSO_4$), T_{10} (200 ppm tocopherol + 0.5% $ZnSO_4$), T_{16} (300 ppm tocopherol + 0.5% $FeSO_4$), T_{15} (200 ppm tocopherol + 0.5% $FeSO_4$), T_{12} (400 ppm tocopherol + 0.5% $ZnSO_4$), T_{13} (500 ppm tocopherol + 0.5% $ZnSO_4$) and T_3 (200 ppm tocopherol) in reducing manner when compared to control (T_1). While, treatments T_3 (200 ppm tocopherol), T_2 (100 ppm tocopherol), T_4 (300 ppm tocopherol) and T_{17} (400 ppm tocopherol + 0.5% $FeSO_4$) also gave significantly more leaf area plant^{-1} as compared to the control (T_1).

α-Tocopherol is low molecular weight lipophillic antioxidant which mainly protect membrane from oxidative damage (Asada, 1999). Zinc has important role in chlorophyll formation which enhanced chlorophyll content in leaf of the plants (Sharma *et al*., 2010). Thus, area of leaf is also increased.

Similar results were obtained with the experiments done by many scientists. Nagwa *et al.* (2013) studied that foliar application of vitamin E at (100 ppm) resulted in maximum leaf area in onion plants. Purushottam *et al.* (2018) found that the leaf area index of chickpea was significantly influenced by spraying of zinc @ 0.5%. At 70 DAS leaf area Index of chickpea plants with foliar spray of 0.5% zinc sulphate was significantly higher than that of other treatments.

Total dry matter production

Total dry production is one of the factors that determines economic yield of plants. Partitioning and distribution of dry matter is integral part of growth and development over entire growth period.

The dry matter accumulation of individual plant was studied at each sampling i.e. 25, 45, 65 and 85 DAS. At 45 DAS dry matter production was found maximum in treatment T_9 (100 ppm tocopherol + 0.5% $ZnSO_4$) followed by treatments T_{11} (300 ppm tocopherol + 0.5% $ZnSO_4$) and T_{10} (200 ppm tocopherol + 0.5% $ZnSO_4$). Similarly, treatments T_{16} (300 ppm tocopherol + 0.5% $FeSO_4$), T_{15} (200 ppm tocopherol + 0.5% $FeSO_4$), T_{12} (400 ppm tocopherol + 0.5% $ZnSO_4$), T_{13} (500 ppm tocopherol + 0.5% $ZnSO_4$), T_3 (200 ppm tocopherol), T_2 (100 ppm tocopherol), T_4 (300 ppm tocopherol), T_{17} (400 ppm tocopherol + 0.5% $FeSO_4$) and T_5 (400 ppm tocopherol) also showed their significance over control (T_1). At 65 DAS highest dry matter accumulation plant^{-1} was recorded under the treatment T_9 (100 ppm tocopherol + 0.5% $ZnSO_4$) followed by treatment T_{11} (300 ppm tocopherol + 0.5% $ZnSO_4$). Treatments T_{10} (200 ppm tocopherol + 0.5% $ZnSO_4$), T_{16} (300 ppm tocopherol + 0.5% $FeSO_4$), T_{15} (200 ppm tocopherol + 0.5% $FeSO_4$), T_{12} (400 ppm tocopherol + 0.5% $ZnSO_4$), T_{13} (500 ppm tocopherol + 0.5% $ZnSO_4$), T_3 (200 ppm tocopherol), T_2 (100 ppm tocopherol), T_4 (300 ppm tocopherol), T_{17} (400 ppm tocopherol + 0.5% $FeSO_4$), T_5 (400 ppm tocopherol) andT_6 (500 ppm tocopherol) showed significantly more drymatter accumulation compared to the untreated (T_1) and other treatments under observation. Similar trend was observed at 85 DAS.

Above results are in agreement with the experimental studies of many scientists. Soltani *et al.* (2012) observed highest dry weight was recorded with spraying of á-tocopherol at 100 ppm concentration. The increase effect on dry weight of *Calendula officinalis* (L.) by application of á-tocopherol at 100 ppm was 22.24% compared to control.

Purushottam *et al.* (2018) indicated that dry matter accumulation was significantly affected by foliar application of zinc sulphate. The most significant dry matter accumulation (216.96 g m^{-2}) at 90 days after sowing was obtained by foliar spray of zinc sulphate @ 0.5%.

Relative growth rate (RGR)

RGR is a measure to quantify the speed of plant growth. It is measured on dry weight basis. This was originally termed as "efficiency index" as it expresses growth in terms of rate of increase in size unit^{-1} time. It is a prominent indicator of plant strategy with respect to productivity.

Data pertaining to RGR was calculated at 25-45 DAS, 45-65 DAS and 65-85 DAS. At 25-45 DAS significantly maximum RGR was recorded in treatment T_9 (100 ppm tocopherol + 0.5% $ZnSO_4$) followed by treatment T_{11} (300 ppm tocopherol + 0.5% $ZnSO_4$) as compared to control (T_1) and rest of the treatments under observation. Treatments T_{10} (200 ppm tocopherol + 0.5% $ZnSO_4$), T_{16} (300 ppm tocopherol + 0.5% $FeSO_4$), T_{15} (200 ppm tocopherol + 0.5% $FeSO_4$), T_{12} (400 ppm tocopherol + 0.5% $ZnSO_4$), T_{13} (500 ppm tocopherol + 0.5% $ZnSO_4$), T_3 (200 ppm tocopherol), T_2 (100 ppm tocopherol), T_4 (300 ppm tocopherol), T_{17} (400 ppm tocopherol + 0.5% $FeSO_4$), T_5 (400 ppm tocopherol) ,T_6 (500 ppm tocopherol), T_7 (0.5% $ZnSO_4$),T_{14} (100 ppm tocopherol + 0.5% $FeSO_4$) were also found significantly more RGR compared to the untreated control (T_1). At 45-65 DAS T_9 (100 ppm tocopherol + 0.5% $ZnSO_4$) was found significantly superior among all treatments followed by treatments T_{11} (300 ppm tocopherol + 0.5% $ZnSO_4$), T_{10} (200 ppm tocopherol + 0.5% $ZnSO_4$) and T_{16} (300 ppm tocopherol + 0.5% $FeSO_4$) in a decreasing manner. At 65-85 DAS significantly maximum RGR was observed in treatment T_9 (100 ppm tocopherol + 0.5% $ZnSO_4$) followed by treatments T_{11} (300 ppm tocopherol + 0.5% $ZnSO_4$), T_{10} (200 ppm tocopherol + 0.5% $ZnSO_4$), T_{16} (300 ppm tocopherol + 0.5% $FeSO_4$), T_{15} (200 ppm tocopherol + 0.5% $FeSO_4$), T_{12} (400 ppm tocopherol + 0.5% $ZnSO_4$), T_{13} (500 ppm tocopherol + 0.5% $ZnSO_4$), T_3 (200 ppm tocopherol), T_2 (100 ppm tocopherol), T_4 (300 ppm tocopherol) and T_{17} (400 ppm tocopherol + 0.5% $FeSO_4$) in reducing manner when compared to control and other treatments.

Net assimilation rate (NAR)

NAR depends upon the excess dry matter gained, over the loss in respiration. Increase in NAR is related with the increase in total dry weight of the plant unit^{-1} of leaf area. It is measured in plant dry weight unit^{-1} area of assimilatory tissue unit^{-1} time. Increase in NAR during reproductive phase may be due to increase in efficiency of leaves for photosynthesis as a response to photosynthetic apparatus to increase demand for assimilates by growing seed fraction and also due to photosynthetic contribution by pod and sink demand on photosynthetic rate of leaves.

Data regarding NAR at 25-45 DAS, 45-65 DAS and 65-85 DAS have shown significant variation. Treatment receiving 100 ppm tocopherol + 0.5% $ZnSO_4$ (T_{10}) exhibited significantly more NAR at 25-45 DAS and 45-65 DAS. At 25-45 DAS treatments T_{11} (300 ppm tocopherol + 0.5% $ZnSO_4$), T_{10} (200 ppm tocopherol + 0.5% $ZnSO_4$), T_{16} (300 ppm tocopherol + 0.5% $FeSO_4$), T_{15} (200 ppm tocopherol + 0.5% $FeSO_4$), T_{12} (400 ppm tocopherol + 0.5% $ZnSO_4$), T_{13} (500 ppm tocopherol + 0.5% $ZnSO_4$), T_3 (200 ppm tocopherol), T_2 (100 ppm tocopherol), T_4 (300 ppm tocopherol), T_{17} (400 ppm tocopherol + 0.5% $FeSO_4$), T_5 (400 ppm tocopherol), T_6 (500 ppm tocopherol), T_7 (0.5% $ZnSO_4$) andT_{14} (100 ppm tocopherol + 0.5% $FeSO_4$) also increased NAR significantly when compared with control and other treatments. At 65-85 DAS significantly maximum NAR was noted in treatments T_9 (100 ppm tocopherol + 0.5% $ZnSO_4$) followed by treatments T_{11} (300 ppm tocopherol + 0.5% $ZnSO_4$) and T_{10}

(200 ppm tocopherol + 0.5% $ZnSO_4$). Results of NAR at 45-65 and 65-85 DAS showed that the treatments T_{11} (300 ppm tocopherol + 0.5% $ZnSO_4$), T_{10} (200 ppm tocopherol + 0.5% $ZnSO_4$), T_{16} (300 ppm tocopherol + 0.5% $FeSO_4$), T_{15} (200 ppm tocopherol + 0.5% $FeSO_4$), T_{12} (400 ppm tocopherol + 0.5% $ZnSO_4$), T_{13} (500 ppm tocopherol + 0.5% $ZnSO_4$), T_3 (200 ppm tocopherol), T_2 (100 ppm tocopherol), T_4 (300 ppm tocopherol), T_{17} (400 ppm tocopherol + 0.5% $FeSO_4$) and T_5 (400 ppm tocopherol) were noticed significantly high NAR when compared with control and rest of treatments.

Number of secondary branches

The branches originating from the primary branches are termed as secondary branches. They are sites of leaves, flowers, and thus pods formation. So, it is a desirable character for higher biomass production and yield in plants.

Data regarding number of secondary branches plant^{-1} at harvest was recorded. Treatment T_9 (100 ppm tocopherol + 0.5% $ZnSO_4$) was found significantly superior over the control (T_1) followed by treatments T_{11} (300 ppm tocopherol + 0.5% $ZnSO_4$), T_{10} (200 ppm tocopherol + 0.5% $ZnSO_4$), T_{16} (300 ppm tocopherol + 0.5% $FeSO_4$), T_{15} (200 ppm tocopherol + 0.5% $FeSO_4$) and T_{12} (400 ppm tocopherol + 0.5% $ZnSO_4$) in a decreasing order.

The reported positive effect of foliar application of Zn on an enhanced branching in pulses mainly attributed to promotion of bud and branch development by the auxins whereas Zn application ultimately increased the availability of other nutrients and accelerated the translocation of photo - assimilates (Guhey, 1999; Barclay and Mcdavid, 1980).

Similar results were found by many scientists in their experiments. Purushottam *et al*. (2018) have demonstrated that among various treatments, foliar application of zinc sulphate @ 0.5% was found to be significantly superior (5.19) at 90 DAS. Sale and Nazirkar (2013) reported that the foliar application of zinc (0.5%) and iron (0.5%) with seed fortification of molybdenum increased the branching of soybean.

Seed yield hectare^{-1}

Seed yield is the economic yield which is final result of physiological activities of plant. Economic yield is the part of biomass that is converted into economic product. (Nichiporovic, 1960). It is a quantitative trait which is final result of physiological activities of plant Seed yield hectare^{-1} are combined effect of yield attributes and physiological efficiency of plant during the present investigation.

The maximum seed yield hectare^{-1} was recorded in treatment T_9 (100 ppm tocopherol + 0.5% $ZnSO_4$). followed by treatments T_{11} (300 ppm tocopherol + 0.5% $ZnSO_4$), T_{10} (200 ppm tocopherol + 0.5% $ZnSO_4$) and T_{16} (300 ppm tocopherol + 0.5% $FeSO_4$). Treatments T_{15} (200 ppm tocopherol + 0.5% $FeSO_4$), T_{12} (400 ppm tocopherol + 0.5% $ZnSO_4$), T_{13} (500 ppm tocopherol + 0.5% ZnSO4) and T_3 (200 ppm tocopherol) also significantly enhanced seed yield hectare^{-1} as compared to control and rest of the treatments.

Zinc is required for the biosynthesis of plant growth regulator (IAA) and for carbohydrate and N metabolism which leads to improvement in seed quality components (Taliee and Sayadian, 2000).

Above results are in harmony with the experimental studies of many scientists. Kulchan *et al*.in 2016 observed that maximum increase in soybean seed yield was obtained by α-tocopherol (100 ppm) which was 28% and 14.8% over the control in NRC 7 and JS 335 respectively. Nagwa *et al*. (2009) reported similar effect of α-Tocopherol with the increase in yield in geranium. In 2012, Soltani *et al*. showed that the highest increase in seed weight (g plant^{-1}) belongs to the plants treated with 100 ppm á-tocopherol as compared to control and other treatments in *Calendula officinalis* (L.) The increased effect on weight of seed by the application of 100 ppm á-tocopherol was 34.69% when compared with control plants.

Pandey and Gupta in 2012, revealed that foliar application of 0.5% zinc sulphate ($ZnSO_4$) to black gram showed favorable results in yield. Positive effects of foliar Zn (0.5% $ZnSO_4$) application on pigeonpea have also been observed by Sharafi (2015).

Harvest index (HI)

Harvest index is the proportion of biological yield represented by the economic yield. It is a measure of reproductive efficiency representing dry matter partition between seed and vegetative parts. It is measured in per cent.

Harvest index was significantly enhanced in treatment T_9 (100 ppm tocopherol + 0.5% $ZnSO_4$) followed by treatments T_{11} (300 ppm tocopherol + 0.5% $ZnSO_4$), T_{10} (200 ppm tocopherol + 0.5% $ZnSO_4$) and T_{16} (300 ppm tocopherol + 0.5% $FeSO_4$) when compared with control and other treatments under study

Similarly in 2016, Kulchan *et al.* observed maximum increase in soybean seed yield by the application of α-tocopherol (100ppm). A recent study conducted by Purushottam *et al*. (2018) have shown a 15-20% higher harvest index of pigeonpea under the foliar application of zinc (0.50% $ZnSO_4$).

The results elucidated that foliar spray of 100 ppm tocopherol + 0.5% $ZnSO_4$ (T_9) could be considered most suitable to expect promising improvement regarding morphophysiological parameters, seed yield hectare^{-1}and harvest index in chickpea.The analysis of B:C ratio due to expenditure incurred under different treatments of tocopherol and micronutrients revealed that highest benefit: cost ratio was calculated 2.61 in treatment (T_9) 100 ppm tocopherol+ 0.5% $ZnSO_4$ as compared to 1.97 in control (T_1).

Table 1. Effect of tocopherol and micronutrients on plant height, number of secondary branches, leaf area and dry matter production in chickpea

Treatments	Plant height plant^{-1} (cm)	Number of secondary branches at harvest	Last area (dm^2)				Total dry matter production plant^{-1} (g)			
	85 DAS		25 DAS	45 DAS	65 DAS	85 DAS	25 DAS	45 DAS	65 DAS	85 DAS
T_1 (Control)	36.97	27.52	0.88	1.14	1.31	1..51	0.96	1.18	2.03	2.59
T_2 (100 ppm tocopherol)	40.34	30.02	1.06	1.46	1.73	1.94	1.12	1.76	3.26	4.52
T_3 (200 ppm tocopherol)	40.98	31.58	1.07	1.48	1.75	1.97	1.13	1.78	3.30	4.60
T_4 (300 ppm tocopherol)	39.81	29.76	1.05	1.40	1.68	1.89	1.11	1.72	3.16	4.35
T_5 (400 ppm tocopherol)	39.04	29.56	0.96	1.30	1.52	1.73	1.05	1.53	2.76	3.68
T_6 (500 ppm tocopherol)	38.74	29.34	0.95	1.29	1.50	1.63	1.01	1.46	2.60	3.42
T_7 (0.5 % $ZnSO_4$)	38.66	29.23	0.93	1.27	1.48	1.61	0.98	1.40	2.49	3.24
T_8 (0.5 % $FeSO_4$)	38.47	28.35	0.91	1.22	1.41	1.55	0.97	1.28	2.23	2.87
T_9 (100 ppm tocopherol+0.5 % $ZnSO_4$)	49.50	34.28	1.13	1.73	2.07	2.33	1.16	2.34	4.74	6.78
T_{10} (200 ppm tocopherol+0.5 % $ZnSO_4$)	43.16	33.87	1.12	1.69	2.02	2.27	1.15	2.10	4.16	5.90
T_{11} (300 ppm tocopherol+0.5 % $ZnSO_4$)	45.85	34.12	1.13	1.71	2.04	2.29	1.15	2.18	4.40	6.27
T_{12} (400 ppm tocopherol+0.5 % $ZnSO_4$)	41.83	32.69	1.09	1.58	1.87	2.11	1.14	1.91	3.58	5.02
T_{13} (500 ppm tocopherol+0.5 % $ZnSO_4$)	41.30	32.65	1.07	1.53	1.82	2.04	1.13	1.84	3.42	4.78
T_{14} (100 ppm tocopherol+0.5 % $FeSO_4$)	38.57	28.36	0.92	1.24	1.44	1.56	0.98	1.35	2.39	3.09
T_{15} (200 ppm tocopherol+0.5 % $FeSO_4$)	42.50	33.06	1.11	1.60	1.91	2.14	1.14	1.97	3.72	5.23
T_{16} (300 ppm tocopherol+0.5 % $FeSO_4$)	42.73	33.52	1.12	1.63	1.96	2.26	1.15	2.04	3.95	5.59
T_{17} (400 ppm tocopherol+0.5 % $FeSO_4$)	39.09	29.63	1.02	1.37	1.60	1.83	1.10	1.69	3.06	4.18
T_{18} (500 ppm tocopherol+0.5 % $FeSO_4$)	38.38	27.58	0.89	1.15	1.35	1.52	0.97	1.22	2.11	2.71
SE(M) ±	2.392	1.805	0.090	0.085	0.100	0.113	0.097	0.103	0.194	0.270
CD at 5%	6.826	5.151	-	0.242	0.286	0.322	-	0.293	0.554	0.771

Table 2.Effect of tocopherol and micronutrients on RGR, NAR, seed yield hectare^{-1}, B:C ratio and harvest index in chickpea

Treatments	RGR			NAR			Seed yield ha^{-1} (q)	B:C Ratio	Harvest Index (%)
	25-45 DAS	45-65 DAS	65-85 DAS	25-45 DAS	45-65 DAS	65-85 DAS			
T_1 (Control)	0.0103	0.0271	0.0122	0.0110	0.0347	0.0199	16.27	1.97	28.98
T_2 (100 ppm tocopherol)	0.0226	0.0308	0.0163	0.0256	0.0471	0.0344	19.64	2.11	32.64
T_3 (200 ppm tocopherol)	0.0227	0.0309	0.0166	0.0257	0.0472	0.0350	19.94	1.92	33.34
T_4 (300 ppm tocopherol)	0.0219	0.0304	0.0160	0.0251	0.0469	0.0334	19.53	1.71	31.63
T_5 (400 ppm tocopherol)	0.0188	0.0295	0.0144	0.0214	0.0437	0.0283	18.72	1.50	30.83
T_6 (500 ppm tocopherol)	0.0184	0.0289	0.0137	0.0202	0.0409	0.0262	18.43	1.36	30.02
T_7 (0.5 % $ZnSO_4$)	0.0178	0.0288	0.0132	0.0192	0.0397	0.0243	18.30	2.06	29.83
T_8 (0.5 % $FeSO_4$)	0.0139	0.0278	0.0126	0.0147	0.0362	0.0216	18.11	2.06	29.64
T_9 (100 ppm tocopherol+0.5 % $ZnSO_4$)	0.0351	0.0353	0.0179	0.0419	0.0633	0.0464	25.89	2.61	37.31
T_{10} (200 ppm tocopherol+0.5 % $ZnSO_4$)	0.0301	0.0342	0.0175	0.0343	0.0557	0.0406	23.74	2.16	39.12
T_{11} (300 ppm tocopherol+0.5 % $ZnSO_4$)	0.0320	0.0351	0.0177	0.0368	0.0594	0.0432	24.67	2.05	37.31
T_{12} (400 ppm tocopherol+0.5 % $ZnSO_4$)	0.0258	0.0314	0.0169	0.0292	0.0485	0.0362	21.64	1.66	33.69
T_{13} (500 ppm tocopherol+0.5 % $ZnSO_4$)	0.0244	0.0310	0.0167	0.0276	0.0473	0.0353	20.65	1.46	33.55
T_{14} (100 ppm tocopherol+0.5 % $FeSO_4$)	0.0160	0.0286	0.0128	0.0173	0.0389	0.0233	18.14	1.84	29.67
T_{15} (200 ppm tocopherol+0.5 % $FeSO_4$)	0.0274	0.0318	0.0170	0.0310	0.0500	0.0373	21.74	1.99	35.77
T_{16} (300 ppm tocopherol+0.5 % $FeSO_4$)	0.0287	0.0330	0.0174	0.0327	0.0534	0.0389	22.68	1.90	36.38
T_{17} (400 ppm tocopherol+0.5 % $FeSO_4$)	0.0215	0.0297	0.0156	0.0249	0.0462	0.0327	19.17	1.47	31.57
T_{18} (500 ppm tocopherol+0.5 % $FeSO_4$)	0.0115	0.0274	0.0125	0.0123	0.0357	0.0209	18.08	1.29	29.01
SE(M) ±	0.00152	0.00173	0.00101	0.00174	0.00307	0.00217	1.314	-	2.127
CD at 5%	0.00438	0.00497	0.00290	0.00500	0.00881	0.00625	3.776	-	6.114

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