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INFLUENCE OF FERROUS SULPHATE AND ZINC SULPHATE ON MORPHO - PHYSIOLOGICAL PARAMETERS AND YIELD IN CHICKPEA (*Cicer arietinum* L.)

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ABSTRACT

Field trial was conducted at College of Agriculture, Nagpur during *rabi* season of 2020-2021 to study the probable response of ferrous sulphate and zinc sulphate for improving morpho-physiological and yield parameters in chickpea (*Cicer arietinum* L.). The experiment was laid out in randomized block design with three replications. Research design comprised of ten treatments of ferrous sulphate (0.25%, 0.5% and 1.0%) and iron sulphate (0.25%, 0.5% and 1.0%) sprayed individually and in their combination. The foliar sprays at 25 and 45 DAS showed significant changes in all the growth parameters i.e. plant height, number of branches plant^{-1}, days to flower initiation, days to maturity, total dry matter production plant^{-1}, leaf area, leaf area index, RGR, NAR, CGR, seed yield plot^{-1}and harvest index. Application of 0.5% $FeSO_4$ + 0.5 % $ZnSO_4$ gave significantly higher results in all parameters studied.

(Key words; Ferrous sulphate, zinc sulphate, chickpea, morpho-physiological, spray, parameters)

INTRODUCTION

Chickpea is one of the most important pulses in the world and also in India. (*Cicer arietinum* L.) (2n=16) belongs to genus *Cicer*, tribe cicereae, family Leguminosae and subfamily Papilionaceae. The genus Cicer comprises one cultivated species, the chickpea (*Cicer arietinum* L.) and 42 wild species. Chickpea probably originated from South East Turkey (Ladizinsky, 1975). The major chickpea growing continents are Asia, Africa, and Australia. The major chickpea producing countries are India, Pakistan, Australia, and Turkey. India ranked first in area and production in the world, but the highest productivity observed in China. Due to low production cost, wide climate adaptation, use in crop rotation, and atmospheric nitrogen fixation ability, chickpea is an important legume plant in a sustainable agricultural system (Farshadfar and Farshadfar, 2008).

Iron is an unavoidable and one of the most prominent constituents of many proteins and enzymes that play important roles in key metabolic processes, including cellular respiration, oxygen transport, lipid metabolism, the tricarboxylic acid (TCA) cycle, gene regulation, synthesis of metabolic intermediates, and DNA biosynthesis as well as making it essential for photosynthesis and chlorophyll biosynthesis (Jeong and Connolly, 2009).

Zinc plays an eminent role in cell division, cell expansion, and protein synthesis and carbohydrate, nucleic acid and lipid metabolism. It also plays an important role in auxin metabolism (Oguchi *et al*., 2004). Sulphur plays a pivotal role in regulating the metabolic and enzymatic processes including photosynthesis, respiration and legume rhizobium symbiotic nitrogen fixation, energy transformation, activation of enzymes and also carbohydrate metabolism which reflected in increased yield.

MATERIALS AND METHODS

A field experiment was conducted at farm of Botany section, College of Agriculture, Nagpur in a Randomized Block Design with ten treatments and three replications. Treatments consists of T1- Control, T2- 0.25% $FeSO_4$, T3- 0.5% $FeSO_4$, T4- 1.0% $FeSO_4$, T5- 0.25% $ZnSO_4$, T6- 0.5% $ZnSO_4$, T7- 1.0% $ZnSO_4$, T8- 0.25% $FeSO_4$ + 0.25% $ZnSO_4$, T9- 0.5% $FeSO_4$ + 0.5% $ZnSO_4$ and T10- 1.0% $FeSO_4$ + 1.0% $ZnSO_4$. The gross plot size was 2.10 m × 2.20 m and net 1.50 m × 2.00 m with spacing of 30 cm x 10 cm. Two foliar sprays of ferrous sulphate and zinc sulphate were given at 25 and 45 DAS. Five plants from each plot were selected randomly and data were collected at 25, 45, 60 and 75 DAS on plant height, number of branches plant^{-1}, number of leaves plant^{-1}, days to flower initiation, total dry matter production plant^{-1}, days to maturity, leaf area and leaf area index of plant. RGR, NAR and CGR were calculated at 25-45, 45-60

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and 60-75 DAS. Seed yield plot^{-1} was recorded after harvest. Harvest index was also calculated. Data were analysed by statistical method suggested by Panse and Sukhatme (1954).

RESULTS AND DISCUSSION

Plant height

Plant height is one of the visible measurements and is a function of internodes and leaf emergence. Since leaves are born on stem, leaf area development and biomass production show a close relationship with plant height. It is the shortest distance between the upper boundary of the photosynthetic tissue on a plant and ground level, expressed in centimeters or meters.

At 75 DAS the range of plant height was observed 42.80-50.63 cm. The significantly superior plant height was registered in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatments T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$), T_3 (0.5% $FeSO_4$) and T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$) over control and rest of the treatments under study. But, treatments T_5 (0.25% $ZnSO_4$), T_2 (0.25% $FeSO_4$), T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with control.

The increase in plant height might be due to an increase in the photosynthetic activity, chlorophyll formation, nitrogen metabolism and auxin contents in the plants which ultimately improving the plant height.

Similar results were reported by Saini and Singh (2017) on green gram that maximum plant height recorded by the application of 40 kg S ha^{-1} as gypsum + 0.5% $FeSO_4$ foliar spray at 25 DAS. However, Purushottam *et al*. (2018) found more plant height at 90 DAS by the foliar application of 0.5 % $ZnSO_4$ on chickpea (*Cicer arietinum* L.) and Pal *et al*. (2019) found maximum plant height of 65.1 cm in the first year and 66.5 cm in the second year with the application of $ZnSO_4$ (25 kg ha^{-1}) at sowing + foliar spray of $ZnSO_4$ (0.5%) at flowering and pod formation stages in chickpea and it was statistically at par with other $ZnSO_4$ application methods during both the years but significantly higher than control.

Number of branches plant^{-1}

Branches are the sites of leaves, flowers and pod formation. Hence, they are closely associated with the photosynthetic activity and yield of the plant. So, a number of branches are a desirable attribute for higher biomass production and yield.

At 75 DAS effective enhancement in number of branches plant^{-1} was obtained in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatments T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$), T_3 (0.5% $FeSO_4$) and T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$) over control and remaining treatments. But, treatments T_5 (0.25% $ZnSO_4$), T_2 (0.25% $FeSO_4$), T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with control.

Positive effect of foliar application of zinc and iron interaction with RDF on metabolic activities like a synthesis of IAA, metabolism of auxins and synthesis of nitrate reductase enzyme in the leguminous crop increased the availability of other nutrients and accelerated the translocation of photo assimilates.

These results are in accordance with Ali and Mahmood (2012), who found that foliar application of zinc (500 ppm) on mungbean significantly increased number of branches plant^{-1} when compared with control plants. Sale and Nazirkar (2013) investigated the effect of different micronutrients on growth traits of soybean under rainfed conditions in vertisol. Foliar application of zinc (0.5%) and iron (0.5%) with seed fortification of molybdenum showed an increase in the branching of soybean.

Days to flower initiation

Flower initiation is the physiological process in the plant by which the shoot apical meristem becomes competent to develop flowers. The days to flower initiation was determined by recording the number of days after sowing to at least one open flower.

The data recorded about days to flower initiation were found statistically significant. The range of days to flower initiation recorded was 34.93–39.33 days. The number of days for flower initiation was recorded lowest with the treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatments T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$), T_3 (0.5% $FeSO_4$) when compared control and rest of the treatments. Next to these treatments significantly lower days for flower initiation was also recorded in treatments T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$), T_5 (0.25% $ZnSO_4$) and T_2 (0.25% $FeSO_4$) when compared with control. But treatments, T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with control.

Days to Maturity

The result obtained during investigation of days to maturity found significantly increased in the treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatments T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$) over control and other treatments. Next to these treatments the treatment T_3 (0.5% $FeSO_4$) also showed increased in days to maturity content significantly over treatment T_1 (control). Similarly treatments T_5 (0.25% $ZnSO_4$), T_2 (0.25% $FeSO_4$), T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were also found at par with control (T_1).

Kobraee (2019) found that the spraying of 0.5% Zn and 0.5% Mn elements have a significant effect on the time from emergence to maturation in chickpea.

Total dry weight plant^{-1}

At 45 DAS the range of dry matter production recorded was 1.07–1.73 g. Significantly maximum dry matter plant^{-1} was noticed with the foliar application of 0.5 % $FeSO_4$ +0.5 % $ZnSO_4$ (T_9) followed by treatment T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$) when compared with control (T_1) and the rest of the treatments under study. Similarly treatments T_6 (0.5% $ZnSO_4$), T_3 (0.5% $FeSO_4$) and T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$) also significantly increased total dry weight plant^{-1} when compared with treatment T_1 (control) and rest of the treatments under study. Similarly, treatments T_5 (0.25% $ZnSO_4$), T_2 (0.25% $FeSO_4$) and T_7 (1.0% $ZnSO_4$) also recorded significantly maximum dry matter production plant^{-1} in a descending manner when compared with control (T_1). But treatment T_4 (1.0% $FeSO_4$) was found at par with treatment T_1 (control) in dry matter production.

At 60 DAS highest dry matter production plant^{-1} was recorded under the treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatments T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$) and T_3 (0.5% $FeSO_4$) when compared with treatment control and rest of the treatments. But treatments, T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$), T_5 (0.25% $ZnSO_4$), T_2 (0.25% $FeSO_4$), T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with control.

Observations recoded at 75 DAS indicated significant variation. The most pronounced effect observed in plant exposed to the treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatments T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$) and T_3 (0.5% $FeSO_4$) in total dry weight plant^{-1} over control and rest of the treatments under study. Treatments T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$), T_5 (0.25% $ZnSO_4$), T_2 (0.25% $FeSO_4$), T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with control.

Dry matter production and its partitioning towards reproductive parts is an important attributing character and a basic vegetative phase is essential for the development of the reproductive parts. Although the dry matter production, in general, is inductive of the efficiency of genotype, the pattern in which it is distributed in different plant parts that do more towards the reproductive parts would give a better understanding of its productivity potential. The application of nutrients and plant growth regulators helps in improving the canopy structure and also increases productivity through the manipulation of the source-sink relationship. These might be the reasons for the increase in dry matter production in the present investigation.

Similar results were also discovered by many scientists in their experiments. Purushottam *et al.* (2018) found that foliar application of zinc sulphate @ 0.5% significantly enhanced dry matter accumulation (216.96 g m^{-2}) at 90 days after sowing in chickpea. Blesseena *et al.* (2020) studied the significant and beneficial effect of two foliar sprays of 100 ppm tocopherol + 0.5% $ZnSO_4$ at 25 and 40 DAS on dry matter production of chickpea (*Cicer arietinum* L.) at 85 DAS over the control.

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 plant productivity.

Observations recoded at 45 DAS indicated significant variation. The most pronounced effect observed in plant expose to the treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatments T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$), T_3 (0.5% $FeSO_4$) and T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$) in leaf area plant^{-1} over control and rest of the treatments under study. But treatments T_5 (0.25% $ZnSO_4$), T_2 (0.25% $FeSO_4$), T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with control.

The significantly highest leaf area plant^{-1} over control was observed at 65 DAS in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatments T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$), T_3 (0.5% $FeSO_4$) and T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$) in a descending manner over control and other treatments. Next to these treatments significantly more leaf area plant^{-1} was also recorded in treatments T_5 (0.25% $ZnSO_4$) over control. But treatment T_2 (0.25% $FeSO_4$), T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with control.

At 75 DAS significantly highest leaf area plant^{-1} was registered in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatments T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$) and T_3 (0.5% $FeSO_4$) over control and rest of the treatments under study. Next to these treatments significantly more leaf area was recorded in a treatments T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$), T_5 (0.25% $ZnSO_4$) and T_2 (0.25% $FeSO_4$) when compared with control. But treatments T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with control.

Leaf area was significantly increased by zinc and iron possibly because it helps in greater assimilation of food material by the plant which resulted in greater meristematic activities of cells and consequently the number of leaves, length and width of the leaf of the plant.

A field experiment was conducted by Mondal *et al.* (2013) studied the effect of 0.1% foliar Zn application on leaf area of mung bean and reported significantly higher leaf area over control.Lakshmi *et al.* (2017) studied the effect of foliar sprays of secondary nutrients and zinc nutrition on the growth of black gram. The data revealed that combined spray of nutrients *i.e.* T_6 (RDF + Foliar application of 1% each of $CaNO_3$, $MgNO_3$ and Sulphur) + foliar application of $ZnSO_4$ @ 0.2 per cent (T_8) treatment recorded highest leaf area.

Leaf Area Index

Leaf Area Index is the ratio of the total area of all leaves on a plant to the area of ground covered by the plant. LAI is related to photosynthesis and biomass production.

The data recorded about the LAI were found statistically significant at 45 DAS. The range of LAI recorded was 0.316-0.677.Significantly maximum LAI was noticed in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatment T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$) when compared with treatment T_1 (control) and other treatments. Treatments T_6 (0.5% $ZnSO_4$), T_3 (0.5% $FeSO_4$), T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$), T_5 (0.25% $ZnSO_4$) and T_2 (0.25% $FeSO_4$) also increased LAI significantly when compared with control. But treatments T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with control.

At 60 DAS the range of leaf area index recorded was 1.030-1.480 g. Significantly maximum LAI was registered in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatments T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$), T_3 (0.5% $FeSO_4$) and T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$) over control and rest of the treatments. But, treatmentsT_5 (0.25% $ZnSO_4$), T_2 (0.25% $FeSO_4$), T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with control.

At 75 DAS the range of LAI recorded was 1.670-2.620 g. Significantly maximum LAI was registered in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$), T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$), T_3 (0.5% $FeSO_4$), T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$) and T_5 (0.25% $ZnSO_4$) when compared with treatment T_1 (control) and rest of the treatments. Also, treatment T_2 (0.25% $FeSO_4$) was found significant over treatment T_1 (control) in LAI. But, treatments T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with control.

These results are in accordance with the findings of the following scientists. Nandan *et al.* (2018) examined the influence of zinc and iron fortification on the growth of chickpea (*Cicer arietinum* L.). The treatment RDF followed by foliar application of Zn (0.5%) and Fe (0.05%) at pre-flowering and pod formation stages recorded a significantly higher value of leaf area index at 90 DAS. Gowthami and Rao (2014) investigated a field experiment to study the effect of foliar application of potassium, boron and zinc on the growth analysis of soybean. The results exhibited that foliar application of potassium nitrate @ 2 % + boric acid @ 50 ppm + zinc sulphate @ 1% at 30 and 60 DAS was found to be superior in increasing the LAI.

Growth analysis

Plant growth analysis provides an explanatory, holistic and integrative approach to interpreting plants form and function. It uses simple primary data such as weight, area, volume and content or plant components to investigate processes within and involving the whole plant or crops. The productivity of crops may be related to the parameters such as RGR, NAR, CGR and partitioning of total photosynthates into the economic and non- economic sink.

Relative growth rate (RGR)

Relative growth rate RGR expresses growth in terms of rate of increase in size $unit^{-1}$ of time so that this was originally termed as "efficiency index". It represents total dry weight gained over the existing dry weight in unit time. As such, it permits more equitable comparisons between organisms than does absolute growth rate. Normally, relative growth rate deals with total dry weight of $plant^{-1}$, through other measures of size have also been used. Data revealed that RGR was more during the period of 45-60 DAS.

Considering all treatments under study, significantly maximum RGR was observed in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) *i.e.*, 0.0327 g g^{-1} day^{-1} at 25-45 DAS, 0.0449 g g^{-1} day^{-1} at 45-60 DAS, 0.0238 g g^{-1} day^{-1} at 65-75 DAS respectively. But it was lowest in control *i.e* 0.0202g g^{-1} day^{-1}at 25-45 DAS, 0.0390g g^{-1} day^{-1} at 45-60 DAS and 0.0189 g g^{-1} day^{-1} at 60-75 DAS.

At first stage i.e. 25-45 DAS range of RGR recorded was 0.0202-0.0327 g g^{-1} day^{-1}. Significantly highest RGR was registered in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatments T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$), T_3 (0.5% $FeSO_4$), T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$), T_5 (0.25% $ZnSO_4$) and T_2 (0.25% $FeSO_4$) over control and rest of the treatments. But, treatments T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with control.

At second stage i.e. 45-60 DAS range of RGR recorded was 0.0390-0.0449 g g^{-1} day^{-1}. Significantly maximum RGR was noticed in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) over control and rest of the treatments. But, treatmentsT_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$), T_3 (0.5% $FeSO_4$), T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$), T_5 (0.25% $ZnSO_4$), T_2 (0.25% $FeSO_4$), T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with control.

At 60-75 DAS RGR was significantly influenced by different treatments. The range of RGR recorded was 0.0189–0.0238 g g^{-1} day^{-1}. At this stage significantly maximum RGR was observed in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$), T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$) and T_6 (0.5% $ZnSO_4$) when compared with treatment T_1 (control) and rest of the treatments under study. But treatmentsT_3 (0.5% $FeSO_4$), T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$), T_5 (0.25% $ZnSO_4$), T_2 (0.25% $FeSO_4$), T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with each other in RGR.

Gowthami and Rao (2014) found that foliar application of potassium nitrate @ 2% + boric acid @ 50 ppm + zinc sulphate @ 1% (T_7) at 30 and 60 DAS was found to be superior in increasing the RGR in soybean. Whereas,Raut *et al.* (2019) investigated the effect of ascorbic acid and zinc as a foliar application on chickpea and recorded significant increase in relative growth rate by the application of 200 ppm ascorbic acid + 0.5% $ZnSO_4$.

Net assimilation rate (NAR)

Net assimilation rate (NAR), synonymously called as unit leaf rate expresses the rate of dry weight increase at any instant on a leaf area basis with leaf representing an estimate of the size of the assimilatory surface area. An increase in NAR during reproductive phases might be due to increasing efficiency of leaves for photosynthesis as a response of photosynthetic apparatus to increase demands for assimilates by growing seed fraction and also due to photosynthetic contribution by pod and sink demand on the photosynthetic rate of leaves.

NAR was significantly maximum in treatment T_9 (0.5% $FeSO_4$+ 0.5% $FeSO_4$) *i.e.*, 0.0209 g dm^{-2} day^{-1} at 25-45 DAS, 0.0548 g dm^{-2} day^{-1} at 45-60 DAS and 0.0396 g dm^{-2} day^{-1} at 60-75 DAS. But it was lowest in control i.e. 0.0157 g dm^{-2} day^{-1}at 25-45 DAS, 0.0452 g dm^{-2} day^{-1} at 45-60 DAS and 0.0280 g dm^{-2} day^{-1} at 60-75 DAS.

At first stage i.e. 25-45 DAS range of NAR recorded was 0.0157-0.0209 g dm^{-2} day^{-1}. Significantly highest NAR was registered in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatment T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$)

over control and rest of the treatments. But, treatmentsT_6 (0.5% $ZnSO_4$), T_3 (0.5% $FeSO_4$), T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$), T_5 (0.25% $ZnSO_4$), T_2 (0.25% $FeSO_4$), T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with each other in NAR.

At second stage i.e. 45-60 DAS range of NAR recorded was 0.0452-0.0548 g dm^{-2} day^{-1}. Significantly highest NAR was observed in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatment T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$) and T_3 (0.5% $FeSO_4$) over control and rest of the treatment. But, treatments T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$), T_5 (0.25% $ZnSO_4$), T_2 (0.25% $FeSO_4$), T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with control.

At third stage *i.e.* 60-75 DAS range of NAR recorded was 0.0280-0.0396 g dm^{-2} day^{-1}. Significantly highest NAR was observed in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatment T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$) and T_3 (0.5%$FeSO_4$) over control and rest of the treatment. But, treatments T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$), T_5 (0.25% $ZnSO_4$), T_2 (0.25% $FeSO_4$), T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with control.

Blesseena *et al.* (2019) examined the impact of á – tocopherol and zinc on chickpea. The study showed that highest net assimilation rate obtained by the application of 100 ppm tocopherol + 0.5 % $ZnSO_4$ over control and rest of the treatments.

Crop growth rate (CGR)

CGR is a simple and important index of agricultural productivity or rate of dry matter production. It is unit weight $land^{-1}$ area $time^{-1}$.

CGR was significantly highest in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) i.e. 2.1331 g m^{-2} day^{-1} at 25- 45 DAS, 11.066 g m^{-2} day^{-1} at 45-60 DAS and 15.2429 g m^{-2} day^{-1} at 60-75 DAS, while the values under control were 1.067 g m^{-2} day^{-1} at 25- 45 DAS, 7.621 g m^{-2} day^{-1} at 25- 45 DAS and 10.577 g dm^{-2} day^{-1} at 60-70 DAS respectively.

At 25-45 DAS significantly maximum CGR was recorded in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatment T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$), T_3 (0.5% $FeSO_4$) and T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$) when compared with treatment T_1 (control) and remaining treatments under study. Next to these treatments, T_5 (0.25% $ZnSO_4$) and T_2 (0.25% $FeSO_4$) were also found significantly superior when compared with control (T_1). Similarly treatments T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with control.

At 45–60 DAS significant rise in CGR was observed in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatment T_8 (0.25% $FeSO_4$ + 0.25% $ZnSO_4$), T_6 (0.5% $ZnSO_4$), T_3 (0.5% $FeSO_4$) and T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$) when compared with treatment T_1 (control) and rest of the treatments under observation. Whereas, treatments T_5 (0.25% $ZnSO_4$), T_2 (0.25% $FeSO_4$), T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) and T_1 (control) were found at par with each other in CGR.

At 60–75 DAS significantly maximum CGR was noted with the foliar application of 0.5% $FeSO_4$ (T_9) followed by foliar application of 0.25% $FeSO_4$+0.25% $ZnSO_4$ (T_8), 0.5% $ZnSO_4$ (T_6), 0.5% $FeSO_4$ (T_3) and 1.0% $FeSO_4$ + 1.0% $ZnSO_4$ (T_{10}) was also noted significantly more CGR when compared with control.

The result obtained was in accordance with the findings of Gowthami and Rao (2014). They found that treatment of potassium nitrate @ 2 % + boric acid @ 50 ppm + zinc sulphate @ 1% (T_7) when sprayed at 30 and 60 DAS increased the CGR in soybean.

Seed yield $plot^{-1}$ (kg)

Seed yield is a quantitative trait which is final result of physiological activities of plant. Seed yield is the combined effect of yield attributes and physiological efficiency of plant during the present investigation. It 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. Seed yield is the economic yield which is final result of physiological activities of plant.

Foliar application of ferrous sulphate and zinc sulphate significantly increased seed yield $plot^{-1}$ over control. The highest seed yield (0.74 kg $plot^{-1}$) was recorded in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) as compared to treatment T_1 control (0.49 kg $plot^{-1}$).

Among the entire treatments superior seed yield $plot^{-1}$ manifested in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by T_8 (0.25% $ZnSO_4$ + 0.25% $FeSO_4$), T_6 (0.5% $ZnSO_4$) and T_3 (0.5% $FeSO_4$) and T_{10} (1.0% $FeSO_4$ + 1.0% $ZnSO_4$) over control and rest of the treatments. But, treatments T_5 (0.25% $ZnSO_4$ 0.4%), T_2 (0.25% $FeSO_4$), T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) could not achieved their target and were found at par with treatment T_1 (control).

Field experiments were conducted by Anitha *et al.* (2005) reported the response of cowpea to zinc and iron fertilization for augmenting the crop productivity. Results of the study indicated that foliar application of micronutrients like iron and zinc had significant influence on the yield of cowpea. Combined spraying of 0.5% $FeSO_4$ and 0.5% $ZnSO_4$ at 45 DAS proved most effective and increased the seed yield by 43.09 per cent when compared with control followed by combined spraying of 0.5% $FeSO_4$ and 0.5% $ZnSO_4$ at 25 DAS (40.14 %).

Sale and Nazirkar (2013) studied the effect of different micronutrients on yield of soybean and observed that the Zn (0.5%) and Fe (0.5%) combined application increased yield in comparison to their separate application of Zn, Fe and seed fortification of Mo (0.66 g kg^{-1} seed).

Harvest Index

Harvest index (HI) is the genetic character of the crop and varies with cultivar. The harvest index of the crop generally remains unchanged but some crucial management practices make some changes in HI.

Data regarding harvest index was found statistically

Table 1. Effect of ferrous sulphate and zinc sulphate on plant height, number of branches, days to flower initiation, days to maturity, leaf area, leaf area index and total dry matter accumulation in chickpea

Treatments	Plant height (cm)	Number of branches plant^{-1}	Days to flower initiation days	Days to maturity (days)	Leaf area (cm2) plant^{-1}			Leaf area index			Total dry matter accumulation (g) plant^{-1}		
	75 DAS	75 DAS			45 DAS	60 DAS	75 DAS	45 DAS	60 DAS	75 DAS	45 DAS	60 DAS	75 DAS
T_1 (Control)	49.89	5.66	39.33	95.16	94.67	309.67	501.00	0.316	1.030	1.670	1.07	4.50	9.26
T_2 (0.25% $FeSO_4$)	53.43	6.20	37.20	100.03	128.00	354.00	626.00	0.427	1.180	2.087	1.30	5.05	10.50
T_3 (0.5% $FeSO_4$)	55.83	6.53	36.20	105.63	163.00	403.00	718.00	0.542	1.340	2.393	1.45	5.74	12.25
T_4 (1% $FeSO_4$)	50.20	5.76	37.80	96.54	108.00	324.00	552.00	0.360	1.080	1.840	1.10	4.82	9.94
T_5(0.25% $ZnSO_4$)	53.90	6.27	37.07	102.63	139.00	363.00	669.00	0.463	1.210	2.230	1.35	5.21	10.88
T_6(0.5% $ZnSO_4$)	56.00	6.67	35.67	110.23	168.00	415.00	735.00	0.560	1.383	2.450	1.51	5.92	12.78
T_7(1.0% $ZnSO_4$)	50.80	5.93	37.80	99.36	121.00	339.00	569.00	0.403	1.130	1.897	1.23	4.93	10.00
T_8(0.25% $FeSO_4$ + 0.25% $ZnSO_4$)	57.40	6.73	35.20	112.11	189.00	428.00	764.00	0.630	1.427	2.547	1.63	6.30	13.08
T_9(0.5% $FeSO_4$ + 0.5% $ZnSO_4$)	59.07	6.80	34.93	115.39	203.00	444.00	786.00	0.677	1.480	2.620	1.73	6.71	13.22
T_{10}(1.0% $FeSO_4$ + 1.0% $ZnSO_4$)	54.80	6.47	36.53	103.26	154.00	394.00	694.00	0.508	1.313	2.312	1.40	5.39	11.02
SE(m)±	**1.67**	**0.23**	**0.52**	**3.32**	**17.74**	**16.90**	**25.75**	**0.028**	**0.081**	**0.133**	**0.08**	**0.34**	**0.58**
CDat5%	**4.97**	**0.68**	**1.55**	**9.86**	**52.72**	**50.2**	**76.75**	**0.081**	**0.240**	**0.396**	**0.23**	**1.01**	**1.73**

Table 2. Effect of ferrous sulphate and zinc sulphate on RGR, NAR, CGR, seed yield plot^{-1}, per cent increase in yield and harvest index in chickpea

Treatments	Relative growth rate ($g\ g^{-1}\ day^{-1}$)			Net Assimilation Rate ($g\ dm^{-2}\ day^{-1}$)			Crop Growth Rate ($g\ dm^{-2}\ day^{-1}$)			Seed yield plot^{-1} (kg)	Per cent increase over control	Harvest index) (%)
	25-45 DAS	45-60 DAS	60-75 DAS	25-45 DAS	45-60 DAS	60-75 DAS	25-45 DAS	45-60 DAS	60-75 DAS			
T_1 (Control)	0.0202	0.0390	0.0189	0.0157	0.0452	0.0280	1.067	7.621	10.577	0.49	-	27.1
T_2 (0.25% $FeSO_4$)	0.0291	0.0393	0.0205	0.0196	0.0468	0.0328	1.600	8.333	12.110	0.56	15.53	30.86
T_3 (0% $FeSO_4$)	0.0315	0.0398	0.0215	0.0202	0.0489	0.0355	1.850	9.532	14.455	0.62	26.75	33.40
T_4 (1% $FeSO_4$)	0.0214	0.0391	0.0193	0.0158	0.0462	0.0308	1.150	8.221	11.266	0.54	10.72	28.62
T_5(0.25% $ZnSO_4$)	0.0292	0.0393	0.0212	0.0200	0.0468	0.0330	1.667	8.577	12.500	0.59	20.41	31.63
T_6(0.5% $ZnSO_4$)	0.0319	0.0402	0.0223	0.0205	0.0506	0.0361	1.950	9.799	14.465	0.66	34.96	34.08
T_7(1.0% $ZnSO_4$)	0.0214	0.0391	0.0194	0.0161	0.0467	0.0313	1.283	8.266	11.577	0.54	11.22	28.94
T_8(0.25% $FeSO_4$ + 0.25% $ZnSO_4$)	0.0324	0.0411	0.0229	0.0206	0.0542	0.0375	2.083	10.377	15.065	0.68	39.82	36.38
T_9(0.5% $FeSO_4$ + 0.5% $ZnSO_4$)	0.0327	0.0449	0.0238	0.0209	0.0548	0.0396	2.133	11.066	15.243	0.74	52.53	37.42
T_{10}(1.0% $FeSO_4$ + 1.0% $ZnSO_4$)	0.0293	0.0396	0.0213	0.0200	0.0478	0.0331	1.816	8.866	12.599	0.60	22.93	33.14
SE(m)±	**0.0012**	**0.0011**	**0.0010**	**0.0013**	**0.0021**	**0.0019**	**0.113**	**0.592**	**0.809**	**0.04**	**-**	**2.11**
CDat5%	**0.0036**	**0.0033**	**0.0030**	**0.0039**	**0.0063**	**0.0057**	**0.336**	**1.760**	**2.403**	**0.12**	**-**	**6.27**

significant. The range of harvest index was significantly maximum in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) and minimum in T_1 (control). The range of increased harvest index was 37.42% in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) to 27.1% in T_1 (control).

Harvest index was significantly increased and was highest in treatment T_9 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatments T_8 (0.25% $ZnSO_4$ + 0.25% $FeSO_4$), T_6 (0.5% $ZnSO_4$) and T_3 (0.5% $FeSO_4$) over control and rest of the treatments. But, treatments T_5 (0.25% $ZnSO_4$), T_2 (0.25% $FeSO_4$), T_7 (1.0% $ZnSO_4$) and T_4 (1.0% $FeSO_4$) were found at par with treatment T_1 (control).

Purushottam *et al*. in 2018, concluded that spraying of zinc sulphate at branching and pre flowering @ 0.5% probably helped the crop to produce good growth and development of chickpea and thereby, it recorded maximum seed yield (840 kg ha^{-1}) and stalk yield (1444 kg ha^{-1}).

Saini and Singh (2017) showed that maximum grain yield (716.67 kg ha^{-1}) and stover yield (1372.67 kg ha^{-1}) were recorded under treatment T_5 (40 kg S ha^{-1} as gypsum + 0.5% $FeSO_4$ foliar spray 25 DAS) in green gram. Pisetal. (2019) also reported that foliar application of 0.5% ZnSO4 to 0.5% $FeSO_4$ at 25 and 40 DAS significantly enhanced yield of Lathyrus.

The highest per cent increase in yield (52.53%) over control was observed by the application of 0.5% $FeSO_4$ + 0.5% $ZnSO_4$ as foliar spray at 25 and 45 DAS. Next to this treatment foliar spray of 0.25% $ZnSO_4$ + 0.25% $FeSO_4$ also enhanced yield by (39.82%) over control. From overall results it can be stated that foliar application of ferrous sulphate and zinc sulphate with different concentrations improved the morpho-physiological, biochemical and yield and yield contributing characters and ultimately yield.

REFERENCES

Ali, E.A and A. M. Mahmood, 2012. Effect of foliar spray by different salicyclic acid and zinc concentrations on seed yield and yield components of mungbean in sandy soil. Asian J. Crop Sci. **5**(1): 33-40.

Anitha, S., E. Sreenivasan and S.M. Purushothaman, 2005. Response of cowpea (*Vigna unguiculata* (L.) Walp.) to foliar nutrition of zinc and iron in the oxisols of Kerala. Legume Res., **28** (4): 294 -296.

Blesseena, A., R. D. Deotale, D. A. Raut and S. Pise, 2020. Efficiency of foliar fertilization of tocopherol and micronutrient on chemical, biochemical parameters, yield and yield attributing factors in chickpea. J. Soils and Crops. **30**(1): 74-80.

Farshadfar, M. and E. Farshadfar, 2008. Genetic variability and path analysis of chickpea (*Cicer arientinum* L.) landraces and lines. J. Applied Sci. **8**: 3951-3956.

Gowthami, P. and G. R. Rao, 2014. Effect of foliar application of potassium, boron and zinc on growth analysis and seed yield in soybean. Int J. Food, Agric. and Veterinary Sci. **4**(3): 73-80.

Jeong, J. and E. L. Connolly, 2009. Iron uptake mechanisms in plants: functions of the FRO family of ferric reductases. Plant Sci. **176**: 709–714.

Kobraee, S. 2019. Effect of foliar fertilization with zinc and manganese sulfate on yield, dry matter accumulation, and zinc and manganese contents in leaf and seed of chickpea (*Cicer arietinum*). J. App. Biol. Biotech. **7**(3):20-28.

Ladizinsky, G. 1975. A new *Cicer* from Turkey.Notes from the Royal Botanic Gardens, Edinburg. **34**: 201–202.

Lakshmi, E. J., P. V. R. Babu, G. P. Reddy, P. Umamaheshwari and A. P. K. Reddy, 2017. Effect of foliar application of secondary nutrients and zinc on growth and yield of black gram. Int. J. Chem. Stu. **5**(6): 944-947.

Mondal, M. M. M., M. A. Malek, A. B. Puthe and M. R. Ismail, 2013. Foliar application of chitosan on growth and yield attributes of mungbean (*Vigna radiata* (L.) Wilczek). Bangladesh J. Bot. **42**(1): 179-183.

Nandan, B., B. C. Sharma, G. Chand, K. Bazgalia, R. Kumar and M. Banotra, 2018. Agronomic fortification of Zn and Fe in chickpea an emerging tool for nutritional security – a global perspective. Acta. Sci. Nutr. Health.**2**(4): 12-19.

Oguchi, K., N. Tanaka, S. Komatsu and S. Akao, 2004. Methylmalonate semialdehidedehydrogenase is induced in auxin-stimulated and zinc-stimulated root formation in rice. Plant Cell Rep; **22**:848-58.

Pal, V., S. Guriqbal and S.D. Salwinder, 2019. Yield enhancement and biofortification of chickpea (*Cicer arietinum* L.) grain with iron and zinc through foliar application of ferrous sulphate and urea. J. Plant Nutri. **42** (15) : 0190-4167.

Panse, V. G. and P. V. Sukatme, 1954. In statistical method for agricultural worker ICAR publication, New Delhi 2nd edu. pp. 63-66 Philips, J. D. J. 1971. The biochemistry and physiology of plant hormone. Mc. Graw Hill Co., New York.

Pise, S. E, P. V. Shende, R. D. Deotale, A. D. Raut, Blesseena and V. S. Hivare, 2019.Influence of zinc and iron on morphophysiological parameters and yield of latharus.(*Lathyrus sativus* L.). J. Soils and Crops, **29**(2) 360-365.

Purushottam, S. K. Gupta, B. K. Saren, B. Sodi and O.P. Rajwade. 2018. Growth and yield of chickpea (*Cicer arietinum* L.) as influenced by irrigation scheduling and zinc application. IJCS.**6**(1): 1130-1133.

Raut, D. A., R. D. Deotale, A. Blesseena, V. S. Hivare, S. E. Pise and S. A. Yelore. 2019. Morpho-physiological traits and yield in chickpea as influenced by foliar application of ascorbic acid and zinc sulphate.J. Soils and Crops,**29**(2): 312-318.

Saini, A. K. and R. Singh, 2017. Effect of sulphur and iron fertilization on growth of green gram (*Vigna radiata* L.). Int. J. Curr. Microbial. App. Sci. **6**(6): 1922-1929.

Sale, R. B. and R. B. Nazirkar. 2013. Effect of micronutrients application on the growth traits and yield of soybean (*Glycine max* L. Merrill) under rainfed condition in Vertisol. An Asian J. Soil Sci. **8**(2) 422-425.

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