__Original Research Article__

The Response of foliar applied Micronutrients (Zinc, Boron and Iron) on Crop Growth Indices Chlorophyll content, Relative Water Content and Yield of Chickpea (*Cicer arietinum* L.) Varieties

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ABSTRACT

Chickpeas are prized legume crops that are frequently eaten in developing countries. Hence, a field experiment was conducted to study the Impact of Foliar Applied Zinc, Boron and Iron on Growth, Chlorophyll content, Yield attributes and Yield of Chickpea (*Cicer arietinum* L.) Varieties during the *Rabi* season of 2018-19 and 2019-20. The field experiment way laid out in Split Plot Design assigning three varieties in main plots (KGD-1168, Radhey and KWR-108) and seven micronutrients combined in subplots (Control, Zinc @ 0.5%, Boron @ 0.2%, Iron @ 0.1%, Zinc @ 0.5% + Boron @ 0.2%, Zinc @ 0.5% + Iron @ 0.1% and Zinc @ 0.5% + Boron @ 0.2% + Iron @ 0.1%). Thus, total 21 treatment combinations were replicated thrice. The results revealed that the variety Radheyshowed significantly higherin growth indices and yield viz., dry weight of plant (21.06, 21.56g at maturity), crop growth rate (0.230, 0.236 g plant^{-1} day^{-1}at 75-100DAS), relative growth rate (0.177, 0.177 g g^{-1} day^{-1}at 75-100DAS) and net assimilation rate (0.0303, 0.0335 g plant^{-1} day^{-1} at 100 to maturity), chlorophyll content, relative water content, seed yield plant^{-1}and seed yield (2118, 2228 kg ha^{-1}) of chickpea during both the years, respectively. Among various micronutrients, the foliar application of Zinc @ 0.5% + Boron @ 0.2 % + Iron @ 0.1 % exerted significantly higher in growth indices and yield viz., dry weight of plant (21.26, 21.74g at maturity), crop growth rate (0.212, 0.224g plant^{-1} day^{-1} at 75-100DAS), relative growth rate (0.207, 0.195 g g^{-1} day^{-1} at 75-100DAS), net assimilation rate (0.0305, 0.0342 g plant^{-1} day^{-1} at 100 to maturity), chlorophyll content, relative water content, seed yield plant^{-1}and seed yield (2162, 2276 kg ha^{-1}) of chickpea both the years 2018-19 and 2019-20, respectively. The interaction effect of varieties and micronutrients was found to be non-significant.On the basis of observed results, instructed togrow chickpea variety Radhey with foliar applications of Zinc @ 0.5% + Boron @ 0.2% + Iron @ 0.1% for higher growth and yield.

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Keywords: *Boron; CGR; Chickpea; Dry Weight; Growth indices; Iron; NAR;RGR; Yield; Zinc*

Comment [i5]: Instead of the elements (Boron, Iron and Zinc), Micronutrients are written

INTRODUCTION

Pulses are an important dietary ingredient in Oriental cuisine due to their high protein content, and their significance is even greater in countries like India where the majority of the population is vegetarian. Pulses are a cost-effective source of not only protein but also carbohydrates, minerals, and β-complex vitamins, making them a crucial component of a vegetarian diet. Pulses typically contain 20-25% protein in their dry seeds, which is 2.5-3.0 times higher than that found in cereals. This makes grain legumes an essential element in ensuring the nutritional security of the country's poor masses, as they are the primary source of protein for the predominantly vegetarian Indian population. Pulses are often referred to as the "poor man's meat" and the "rich man's vegetables" due to their versatility and nutrient content. Additionally, their contribution to maintaining soil fertility through biological nitrogen fixation is significant, making them a crucial part of sustainable agriculture (Gaur *et al*., 2010). However, pulse production in the country has not kept pace with the increasing population, leading to a sharp decline in per capita availability of pulses from 71g in 1995 to 34.4g per day in 2009. This low consumption of pulses is partly attributed to low productivity, and increasing pulse production remains a crucial area of focus. Pulses occupy an area of about 95.16 million hectares, contributing 95.97 metric tons of production to the world food basket (FAO, 2020).

Comment [i6]: Due to their adaptability and nutrient density, pulses are frequently referred to as the "poor man's meat" and the "rich man's vegetables." Additionally, they play a critical role in sustainable agriculture by significantly contributing to biological nitrogen fixation, which helps maintain soil fertility.

Chickpea, also known as *Cicer arietinum* L., is a highly valued pulse crop in the Indian subcontinent. It is commonly consumed as a pulse, and its dried form is used in the preparation of a variety of snacks, sweets, and condiments. Additionally, its fresh green form is consumed as a vegetable. This crop is primarily grown in semi-arid and tropical climates and is of great economic importance. India is the world's largest producer and consumer of chickpeas, accounting for 36.76% of the area and 26% of global pulse production. Furthermore, India is the largest producer of pulses worldwide, occupying an area of 34.99 million hectares and producing a total of 24.21 million tons with productivity of 806 kg ha^{-1} (Agricultural Statistics at a Glance 2019). It is noteworthy that during the 20th century, the world's population increased fourfold, along with a 4.5-fold increase in economic activity per person. The world's population is expected to increase by 50% in the next four to five decades, necessitating a doubling of food output to accommodate this human expansion and those moving up the food chain (Thavarajah and Thavarajah, 2015).

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The choice of chickpea variety is crucial for achieving maximum productivity, as different varieties have varying growth and development patterns due to their unique genetic makeup. In modern agriculture, the use of high-yield crop varieties and intensive fertilization has led to a depletion of micronutrients, such as Manganese (Mn), Iron (Fe), Copper (Cu), and Boron (B), which are crucial for plant growth and development. Micronutrient deficiencies have been shown to adversely affect plant growth, metabolism, and reproduction, as well as human and animal health. Fe and Zn deficiencies are particularly common in developing Asian countries, including India. Foliar application of micronutrients, such as Zn, Fe, Mg, B, and Mn, has been found to improve plant growth and yield, with the best results obtained when they are applied in combination with nitrogen. Studies have shown that foliar application of micronutrient mixtures can increase the number of pods and seeds per plant, seed weight per plant, seed yield per hectare, harvest index, and 100-seed weight. Spray application of boron has been found to increase pod number per plant and 100-seed weight. It is noteworthy that Indian soils are often deficient in micronutrients, with Zn, Fe, Mn, and B deficiencies reported in 49%, 12%, 5%, and 3% of soils, respectively.The selection of appropriate chickpea varieties is crucial for optimal

Comment [i8]: with nitrogen being applied in addition to them producing the best results.

pulse production, as each variety has unique genetic traits that affect growth and development under specific agro-climatic conditions. However, modern agricultural practices that rely on high-yielding crops and synthetic fertilizers have led to micronutrient deficiencies, which can reduce crop productivity and degrade produce quality. Four essential micronutrients - Manganese, Iron, Copper, and Boron - are required for optimal plant growth, development, and biochemical pathways. Micronutrient deficiencies can severely affect plant growth, metabolism, and reproductive phases, which can ultimately impact animal and human nutrition. In developing countries, more than half of the population suffers from micronutrient malnutrition, particularly in Fe and Zn, which are widespread in developing Asian countries, including India. Foliar application of micronutrient mixtures, such as Zn, Fe, Mg, B, and Mn, in combination with nitrogen, has been shown to improve plant growth, yield, and yield attributes, including number of pods plant^{-1}, number of seed plant^{-1}, and seed weight plant^{-1}. The application of micronutrients has also been shown to increase seed yield ha^{-1}, harvest index, and 100-seed weight. Additionally, foliar application of multi micronutrients has been found to increase seed protein content, pod number plant^{-1}, and 100-seed weight. In India, the soil is potentially deficient in essential micronutrients, such as Zn, Fe, Mn, and B, which can be addressed through foliar application of micronutrients. With the following objectives viz., to study the impact of micronutrients on growth and yield attributes of chickpea, to find out of micronutrients on yield of chick pea varieties.

Comment [i9]: For the best pulse production, the right chickpea varieties must be chosen because they each have distinctive genetic characteristics that affect growth and development under particular agro-climatic conditions. However, high-yielding crops and synthetic fertilizers used in modern agricultural practices have resulted in micronutrient deficiencies, which can lower crop productivity and impair the quality of produce.

Comment [i10]: For optimum plant development, growth, and biochemical pathways, four key micronutrients—manganese, iron, copper, and boron—are needed. Micronutrient deficiencies can have a significant impact on the growth, metabolism, and reproductive stages of plants, which can ultimately affect the nutrition of animals and people.

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Comment [i12]: Where is the aim of study

2. MATERIALS AND METHODS

2.1 Experimental site: The Student's Instructional Farm (SIF) at Chandra Shekhar Azad University of Agriculture and Technology in Kanpur, Uttar Pradesh, India, was the site of the field experiment. The farm is located in the alluvial tract of the Indo-Gangetic plains in the central part of Uttar Pradesh, between 25º 26' to 26º 58' North latitude and 79º 31' to 80º 34' East longitude, at an elevation of 125.9 m above mean sea level. The region is classified as agro-climatic zone V (Central Plain Zone) of Uttar Pradesh. The experimental field was located in the same area for both years of the study, as shown in Figure 1.

Comment [i13]: The farm is situated at a height of 125.9 m above mean sea level in the alluvial tract of the Indo-Gangetic plains in the central region

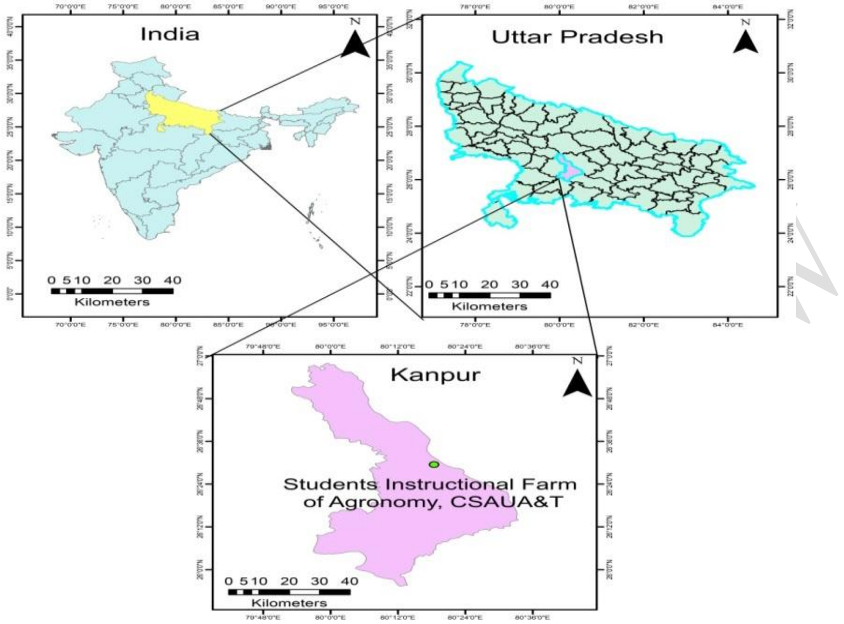

Fig. 1 LOCATION MAP OF THE STUDY AREA

2.2 Climate and weather conditions: The study site falls within a semi-arid climate zone with fertile alluvial soil. Annual rainfall averages around 890 mm, with the majority falling between mid-July and the end of September. Winters are characterized by cooler temperatures, occasional rain, and frost from the last week of December to mid-January. In contrast, temperatures in May and June can reach as high as 44-47^{o}C or more, while winters experience a certain degree of temperature drop. Mean relative humidity at 7:00 A.M. is relatively stable between 80-90% from July to the end of March, and then gradually drops to 40-50% by the end of April, before stabilizing again at 80% throughout May.

2.3 Soil Characteristics: The properties of the soil, as a medium for plant growth, are bound to profoundly affect the rate of plant growth and ultimately the final yield. The soil in the experimental field was characterized as sandy loam with a pH of 7.83-7.87, electrical conductivity of 0.26-0.27 dSm^{-1} at 25ºC, bulk density of 1.39-1.40 g cm^{-3}, particle density of 2.64-2.63 g cm^{-3}, organic carbon content of 0.33-0.35%, available nitrogen content of 156.22-161.32 kg ha^{-1}, available P_2O_5 content of 17.24-18.15 kg ha^{-1}, available K_2O content of 175.35-181.49 kg ha^{-1}, available Zn content of 0.56-0.58 mg kg^{-1}, available Fe content of 8.02-8.07 mg kg^{-1}, and available B content of 0.28-0.38 mg kg^{-1}, in both the years 2018-19 and 2019-20?.

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Comment [i15]: Climate and weather: The study site is located in a region with a semi-arid climate and fertile alluvial soil. The majority of the year's precipitation, about 890 mm, falls between mid-July and the end of September. Winters last from the final week of December to the middle of January and are characterized by lower temperatures, sporadic rain, and frost. In contrast, while winters see a certain amount of a temperature decline, May and June temperatures can soar as high as 44–47ºC or higher. From July until the end of March, the mean relative humidity at 7:00 a.m. remains largely steady between 80 and 90%. From then until the end of April, it progressively declines to 40 to 50% before stabilizing again at 80% for the entire month of May.

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2.4 Experimental Details: The experimental design was split- split plot design with three replications. The experiment consisting of Twenty-One treatment combinations, were three chickpea varieties (V1-KGD-1168, V2-Radhey, V3-KWR-108) are allocated in the main plots and micronutrients (M1-Control), (M2- Zinc @ 0.5%), (M3- Boron @ 0.2%), (M4- Iron @ 0.1%), (M5- Zinc @ 0.5% + Boron @ 0.2 %), (M6- Zinc @ 0.5% + Iron @ 0.1 %) and (M7- Zinc @ 0.5% + Boron @ 0.2 % + Iron @ 0.1 %) were allocated in the sub-plots. The size of each plot was (12 m^2), 4.0 m long and 3.0 m width.

2.5 Crop Varieties:

Comment [i18]: It is better to include Crop Varieties of threevariety of chickpea in a table instead to explaining

a) KGD-1168: it is also known as Alok variety of chickpea developed by Chandra Shekhar Azad University of Agriculture and Technology, Kanpur in the year of 1996 for cultivation in north western plain zones (Punjab, Haryana, Delhi, North Rajasthan and Western Uttar Pradesh) of India. It is medium in plant height, resistant to wilt disease and root node nematode. Important features areDuration: (140-145 days), Plant height: (55-60 cm), Yield: (19-21 q ha^{-1}), Seeds: Medium and bold, Husk (14.14%), Dhal recovery (72%), Protein (23%), Seed index: (15.48g).

b) Radhey: It is variety of chickpea released in the year of 1968 by crossing of T-197 x 76. It is good for Uttar Pradesh area. It has light green foliage and semi-spreading in nature. The pods are generally two-seeded, grains are bold, light brown in colour and smooth and flowers are pink in colour. Important features viz., Plant height: (60-70 cm), Yield: (26-30 q ha^{-1}), Seeds: Medium and bold, Husk: (13.18%), Dhal recovery (78.8%), Protein: (21.50%).

c)KWR-108: It is variety of chickpea developed by Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh in the year of 1996 for cultivation in north eastern plain zones (Eastern Uttar Pradesh, Bihar and West Bengal) of India. It is medium in plant height, resistant to wilt disease. Some important features of this varietyare Duration: 130-135 days, Plant height: 45-55 cm, Yield: 22-23 q ha^{-1}, Seeds: SmallSeed, color: Dark brown Husk (16%). Dhal recovery (74%), Protein (24.10%), Seed index: 17 g.

2.6 Agronomical Practices Adopted: During the experimental period, the land underwent several steps of preparation. First, a tractor-drawn cultivator was used to plow the field, which was then harrowed. Weeds and stubble were removed, and the field was leveled with a leveler before being divided into plots according to the experimental design. Large clumps of soil were broken down into finer particles, and the surface was smoothed until the desired tilth was achieved. The recommended doses of nitrogen, phosphorus, and potassium (20:60:60 kg ha^{-1}, respectively) were applied using urea, single super phosphate, and muriate of potash, respectively. The entire amount of P_2O_5 and K_2O, as well as half of the nitrogen, were applied as a basal dose. The remaining half of the nitrogen was applied as a top dressing 30 days after sowing. Micronutrients (zinc, boron, and iron) were applied as foliar spray treatments using $ZnSO_4$, boric acid (H_3BO_3), and $FeSO_4$, respectively. The micronutrients were applied twice, at 25 and 50 days after sowing (DAS), using fresh solution at each spray. The spray solution was prepared by dissolving the required amount of micronutrients in distilled water and adding a

Comment [i19]: The field was cleared and leveled with a cultivator and the soil was plowed

Comment [i20]: The remaining portion of the nitrogen was applied as a top dressing 30 days in the wake of planting.

Comment [i21]: It is preferable to mention the quantities used in the experiment sticker for better absorption of the solution by cabbage leaves. The spraying was done with a knapsack sprayer, and all necessary precautions were taken during the process.

2.7 Observations Recorded: During the study, the biometrical observations were collected at various stages of growth, including 25, 50, 75, and 100 DAS as well as at maturity. To minimize any potential sampling error, all necessary precautions were taken. The growth attributes and yield parameters such as dry weight of plant, crop growth rate, relative growth rate, net assimilation rate, seed yield plant^{-1}, and chickpea seed yield were recorded. The obtained data were subjected to appropriate statistical analysis using the method outlined by Gomez and Gomez (1984) to determine any differences among the treatment means. The LSD test was used to compare treatment means at a 5% level of probability. The analysis was performed using SPSS Version 10.0, a statistical software package developed by SPSS, Chicago, and IL.

Comment [i22]: The biometrical observations were gathered throughout the study at several growth phases, including 25, 50, 75, and 100 DAS as well as at maturity.

3. RESULTS AND DISCUSSION

3.1Dry Weight of Plant: The dry weight (Table 1) of chickpea increased progressively with age up to maturity. The interaction effect of different varieties and micronutrients was found to be non-significant. The Radhey variety exhibited higher dry weight production (21.06, 21.56g at maturity) than the KGD-1168 variety, and was statistically similar to the KWR-108 variety. This higher dry weight production in Radhey variety was attributed to enhanced growth characters such as CGR, RGR, photosynthetic rate, and chlorophyll content, along with better utilization of moisture and nutrients from the soil, which had high yield potential and improved characteristics compared to other varieties. Similar results were also reported by (Kumar and Deshmukh, 2006), (Kumar *et al*., 2006), and (Meena and Baldev, 2013). The dry weight (21.26, 21.74g at maturity) of chickpea is the result of luxurious plant growth and assimilation of photosynthesis. Chickpea fertilized with Zinc @ 0.5% + Boron @ 0.2% + Iron @ 0.1% observed higher dry weight production due to sufficient availability of micronutrients, resulting in healthy crop growth. The enrichment of soil with micronutrients made it more efficient in utilizing them. Iron enhanced chlorophyll metabolism, zinc is helpful in carbohydrate and protein synthesis and protected the chickpea crop against photo oxidative damage. Boron also regulated the transport of sugar through the membrane and played an essential role in cell division and cell development. These results are consistent with (Velencianoet *al*., 2010) and (Balaiet *al*., 2017).

Comment [i23]: By adding micronutrients to the soil, it was able to use them more effectively. Zinc aids in the synthesis of proteins and carbohydrates and protects the chickpea crop from photo-oxidative damage. Iron improved the metabolism of chlorophyll. In addition to playing a crucial part in cell division and cell development, boron also controlled the transport of sugar through the membrane. These outcomes are in line with those reported by Velenciano et al. (2010)) and (Balai et al. , 2017).

3.3 Crop Growth Rate: During the initial stage, the lower crop growth rate (Table 2) of chickpea can be attributed to low leaf area, while the higher crop growth rate observed during flowering and seed development stages could be due to higher leaf area index (LAI). The interaction effect of different varieties and micronutrients was found to be non-significant. The reduction in crop growth rate towards maturity may be due to a decrease in leaf area caused by leaf senescence. The variety Radhey exhibited higher crop growth rate (0.230, 0.236 g plant^{-1} day^{-1} at 75-100DAS) during both years, respectively, possibly due to better growth

Comment [i24]: The lower crop growth rate of chickpea during the early stages can be attributed to low leaf area (Table 2), whereas the higher crop growth rate seen during the flowering and seed development stages may be caused by higher leaf area index (LAI). Different varieties and micronutrients were found to interact in a non-significant way.

characteristics such as LAI and higher yield potential compared to other varieties. These findings are consistent with (Bahadur *et al*., 2002); (Durga*et al*., 2005); (Rashid *et al*., 2013). Application of Zinc @ 0.5% + Boron @ 0.2% + Iron @ 0.1% increased the crop growth rate of chickpea (0.212, 0.224g plant^{-1} day^{-1} at 75-100 DAS) during both years, respectively. The increase in crop growth rate with LAI is attributed to increased capture of solar radiation within the canopy and production of dry matter. However, as LAI reaches its maximum, the rate of dry matter production declines due to shading of lower leaves, which contribute more to respiration than photosynthesis. These findings are consistent with (Sangolli*et al*., 2018). Higher dry matter accumulation is reflected in the relative growth rate. This finding is consistent with (Raut*et al*., 2019).

3.4 Relative Growth Rate: It is apparent from the perusal of the results (Table 3) that relative growth rate (RGR) was significantly affected by varieties except for 75-100 DAS and 100 DAS to at maturity and it was decreased with advancement of crop growth and recorded maximum at 75-100 DAS during both the years. The higher relative growth rate (0.177, 0.177 g g^{-1} day^{-1} at 75-100DAS) was observed with variety Radhey of chickpea during both theyears of experiment. The increase in RGR can be attributed to various factors, including an increase in photosynthetic biomass, more leaf area, and availability of soil nutrients. These findings are consistent with those of previous studies by (Durga*et al*., 2005), (Chitanya and Chandrika, 2006), and (Aliloo*et al*., 2012). Application of different micronutrients caused significant variation in RGR at all growth stages. The highest RGR (0.207, 0.195 g g^{-1} day^{-1} at 75-100DAS) was observed with the application of Zinc @ 0.5% + Boron @ 0.2 % + Iron @ 0.1 %, which was statistically on par with Zinc @ 0.5% + Boron @ 0.2 % and Zinc @ 0.5% + Iron @ 0.1 %, and superior to the rest of the treatments during both years of the experiment. The lowest RGR was observed under the control treatment. This trend was also observed at 50-75, 75-100, and 100 DAS until the maturity stage in both experimental years. The interaction effect of different varieties and micronutrients was found to be non-significant.The results are in close association with (Velenciano*et al*., 2010) and (Balai*et al*., 2017).

3.5 Net Assimilation Rate: The data pertaining to net assimilation rate (NAR) are presented in Table 4 the rate decreased with advancement of crop age during both the years. The data indicates that the different varieties had a significant impact on net assimilation rate at all growth stages in both years.Radhey and KWR-108 had significantly higher NAR (0.0303, 0.0335 g plant^{-1} day^{-1} at 100 to maturity) at 25-50 DAS, while KGD-1168 had the lowest NAR at all stages in both years. This trend was consistent at 50-75, 75-100, 100 DAS and maturity stage. These findings align with those of (Bahadur *et al*., 2002), (Durga*et al*., 2005), and (Rashid *et al*., 2013). The micronutrient application also significantly affected NAR at all stages. The treatment with Zinc @ 0.5% + Boron @ 0.2% + Iron @ 0.1% had the highest NAR (0.0305, 0.0342 g plant^{-1} day^{-1} at 100 to maturity) and was statistically comparable to Zinc @ 0.5% + Boron @ 0.2% and Zinc @ 0.5% + Iron @ 0.1%, outperforming all other treatments in both experimental years. The Control treatment had the lowest NAR at all stages. This trend was consistent at 50-

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Comment [i27]: the results are shown in (Table 3)

Comment [i28]: The increase in the overall growth rate of plants can be attributed to various factors including an increase in photosynthetic biomass, leaf area, and availability of soil nutrients.

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Comment [i33]: Net assimilation rate (NAR) data are shown in Table 4. Both years show that the rate decreased with increasing crop age. The data show that different cultivars had a significant impact on net assimilation rates in all growth stages in both years.

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75, 75-100, and 100 DAS until maturity. The interaction effect of varieties and micronutrients was not significant. These results are consistent with those of (Durga*et al*., 2005), (Chitanya and Chandrika, 2006), and (Alilooet *al*., 2012).

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3.6 Chlorophyll Content: The varieties and micronutrients significantly influenced the Chlorophyll content (SPAD value) of chickpea (Table 5) during both the years.The interaction effect of different varieties and micronutrients was found to be non-significant.Among the varieties, The Radhey exerted significantly higher chlorophyll content (36.69 & 36.93at before flowering and 41.29 & 41.52 at after flowering) during both experimental years. This was due to the genetic makeup of variety.The results with the findings are line with (Shaban*et al*., 2012) and (Raut*et al*., 2019). The maximum chlorophyll content was recorded with foliar application of Zinc @ 0.5% + Boron @ 0.2 % + Iron @ 0.1 % (37.06 & 37.39 at before flowering and 41.66 & 41.98 at after flowering) during both of the year of the study. The increase in the values of chlorophyll content may be due to the availability of zinc and boron which aids plant growth hormone and enzyme system, hence it is necessary for chlorophyll formation likewise iron acts as an oxygen carrier and involved in cell division and growth which might have promotes chlorophyll formation. This could be ascribed due to the fact that exogenous application of micronutrients increases of more area for photosynthesis and more accumulation of carbohydrates has directly involved in protein synthesis. The results are in close association with (Aysen, 2011) and (Balai*et al*., 2017).

Comment [i39]: Cultivarandmicronutrientshadasignificantimpactonchickpeachlorophyllcontent(SPADvalue)inbothyears(Table5).Interactioneffectsofdifferentcultivarsandmicronutrientswerefoundtobe non-significant

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Comment [i41]: Among the cultivars, Radhey showed significantly higher chlorophyll content in both test years (36.69 and 36.93 before flowering and 41.29 and 41.52 after flowering). This was due to the genetic makeup of the variety.

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3.7 Relative Water Content: The data regarding relative water content of chickpea (Table 5) were significantly influenced by different varieties and Micronutrients (Zn, B, and Fe).The interaction effect of different varieties and micronutrients was found to be non-significant.A scrutiny of results revealed that relative water content increased after flowering of chickpea. The highest relative water content was recorded after flowering stage in all treatments imposed during both the experimental years. It is evident from the data maximum relative water content (64.58 & 64.65 at before flowering and 69.18 & 69.24 at after flowering) was noted in variety Radhey during both the years. The relative water content is a useful measure of the physiological water status of plants (Ogburn& Edwards, 2012). The Maximum relative water content (64.63 & 64.69 at before flowering and 69.23 &69.28 at after flowering) was noted with foliar application of Zinc @ 0.5% + Boron @ 0.2 % + Iron @ 0.1 %) over rest of the treatment during both the experimental years. But the difference was found to be non-significant both before and after flowering stage of chickpea. Similar trend also followed after flowering of chickpea. Interactions among variables could not reach to the level of significance. Similar results more or less were obtained by (Khan*et al*., 2003)

Comment [i45]: Varieties and micronutrients (Zn, B, and Fe) had a significant impact on the relative water content of chickpeas (Table 5).

Comment [i46]: Analyzing the data showed that after chickpea flowering, the relative water content rose. After flowering, all treatments applied during the two experimental years showed the highest relative water content.

Comment [i47]: After the chickpea flowering, a similar pattern also developed. Variable interactions were unable to reach a significant level. More or less the same outcomes were attained by (Khan et al,2003).

3.8 Seed Yield Plant^{-1}: The data pertaining to seeds yield plant^{-1} as affected by varieties and application of micronutrients are presented in Table 5. The interaction effect was found to be non-significant. The seeds yield plant^{-1} was higher in second year as compared to first year in all the treatments. The perusal of the data revealed that varieties affected seed yield plant^{-1} in each year.The significantly higher seed yield plant^{-1} (13.04 and 13.51 g) was observed with variety Radhey which was statistically at par with KWR-108 while least seed weight plant^{-1} (10.81 and 11.83 g) was observed with variety KGD-1168 during both the experimental years. The results are in line with the findings of (Tahir *et al*., 2013), (Morad*et al*., 2015) and (Balai*et al*., 2017). The data indicates that micronutrients had significantly affected the seed yield plant^{-1} of chickpea. The maximum seed yield plant^{-1} (13.20 and 13.76 g) was recorded with application of Zinc @ 0.5% + Boron @ 0.2 % + Iron @ 0.1 %which was statistically at par with Zinc @ 0.5% + Boron @ 0.2 %) and Zinc @ 0.5% + Iron @ 0.1 %and least seed yield plant^{-1} (9.99 and 10.48 g) was observed with application of Control during both the experimental years. The results are in line with the findings of (Tahir *etal*., 2013), (Morad*et al*., 2015) and (Balai*et al*., 2017).

3.9Seed Yield: The yield of the crop, which is presented in Table 5, is the ultimate product of the growth and the yield attributing characters. The yield of chickpea was significantly affected by the significant variation in growth and yield attributes brought on by different varieties and micronutrients treatments.The interaction effect of varieties and micronutrients was found to be non-significant. The highest seed yield (2118, 2228 kg ha^{-1}) was produced by Radhey variety while lowest seed yield was noticed in variety KGD-1168 during both the years, respectively. The variety Radhey with more number of branches, number of pods plant^{-1}, number of seed pod^{-1} with higher seed weight has resulted in highest seed yield. The final seed yield is always positively related to the yield attributes like pod number, pod weight, number of seed pod^{-1}, seed weight etc. The similar results were reported by (Panchariya and Lidder, 2000), (Shrivastav*et al.*, 2000) and (Khatun*et al.*, 2010). Among the micronutrients, the foliar application of Zinc @ 0.5% + Boron @ 0.2 % + Iron @ 0.1 % recorded significantly higher seed yield(2162, 2276 kg ha^{-1}) during both the years, respectively.It might be due to application of different micronutrient combinations to increase in yields can be attributed to enhance availability of essential plant nutrients at the required growth stages. Hence, it is increases the rate and efficiency of metabolic activities resulting in high assimilation of proteins and carbohydrates which in turn helps in better nutrient absorption by plants resulting in better yields. The results obtained corroborated with the reports of (Patel and Singh, 2010), (Valenciano*et al.*, 2010), (Gupta and Sahu, 2012) and (Elayaraja, 2014).

Comment [i48]: Table 5 shows the data on seed yield plant-1 as influenced by varieties and application of micronutrients. It was determined that the interaction effect was non- significant. In all of the treatments, plant-1's seed yield was higher in the second year compared to the first year. The analysis of the data showed that each year's seed yield plant-1 was impacted by varieties.

Comment [i49]: What is the evidence that the results are consistent with this researcher?

Comment [i50]: What is the evidence that the results are consistent with this researcher?

Comment [i51]: Recorded in

Comment [i52]: The variety Radhey has the highest seed yield due to its increased number of branches, pod plants, and seed pods as well as higher seed weight.

Comment [i53]: The final seed yield is always correlated favorably with the yield characteristics, such as pod number, pod weight, number of seed pod-1, seed weight, etc.

Comment [i54]: Shrivastava

Comment [i55]: What is the evidence that the results are consistent with this researcher?

Comment [i56]: The application of various micronutrient combinations may have increased yields by improving the availability of crucial plant nutrients at the necessary growth stages. As a result, it boosts the rate and effectiveness of metabolic processes, leading to a high assimilation of proteins and carbohydrates, which in turn helps plants absorb nutrients more effectively, producing better yields.

Table 1:Effect of Varieties and Micronutrients (Zinc, Boron and Iron) on Dry weight (g) of chickpea

Treatments	**Dry weight of plant (g) at 25 DAS**		**Dry weight of plant (g) at 50 DAS**		**Dry weight of plant (g) at 75 DAS**		**Dry weight of plant (g) at 100 DAS**		**Dry weight of plant (g) at maturity**	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Varieties										
V1: KGD-1168	0.76	0.78	4.87	5.01	9.06	9.31	13.12	13.31	17.08	17.36
V2: Radhey	0.83	0.87	5.46	5.68	10.30	10.57	16.06	16.47	21.06	21.56
V3: KWR-108	0.80	0.83	5.23	5.37	9.98	10.12	15.48	15.65	19.18	19.48
SEm±	0.02	0.02	0.15	0.17	0.33	0.35	0.46	0.50	0.70	0.73
LSD (*p*=0.05)	0.06	0.07	0.48	0.51	1.02	1.08	1.41	1.52	2.12	2.19
Micronutrients										
M1: Control	0.79	0.82	4.63	4.77	7.91	8.21	13.28	13.39	16.58	17.02
M2: Zinc @ 0.5%	0.81	0.84	5.21	5.36	9.97	10.20	14.96	15.11	18.96	19.24
M3: Boron @ 0.2%	0.80	0.83	5.06	5.23	9.56	9.75	14.59	14.85	18.61	18.94
M4: Iron @ 0.1%	0.78	0.82	4.97	5.12	8.94	9.14	14.11	14.23	17.94	18.22
M5: Zinc @ 0.5% + Boron @ 0.2 %	0.80	0.83	5.48	5.66	10.77	10.98	15.78	16.08	20.77	20.99
M6: Zinc @ 0.5% + Iron @ 0.1 %	0.79	0.82	5.34	5.49	10.39	10.58	15.29	15.61	19.63	20.12
M7: Zinc @ 0.5% + Boron @ 0.2 % + Iron @ 0.1 %	0.81	0.84	5.62	5.84	10.92	11.15	16.21	16.74	21.26	21.74
SEm±	0.01	0.01	0.11	0.12	0.21	0.22	0.39	0.41	0.62	0.63
LSD (*p*=0.05)	NS	NS	0.33	0.37	0.64	0.67	1.18	1.24	1.86	1.90
Interaction (V x M)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Comment [i57]: There is no need to mention details of each transaction. Abbreviations can be written in the table and referred to at the bottom as tables (and generalized to all tables).

Table 2:Effect of Varieties and Micronutrients (Zinc, Boron and Iron) on Crop Growth Rate (g plant^{-1} day^{-1}) of chickpea

Treatments	**Crop Growth Rate**	**Crop Growth Rate**	**Crop Growth Rate**	**Crop Growth Rate**	**Crop Growth Rate**

	(g plant^{-1} day^{-1}) at 0-25DAS		(g plant^{-1} day^{-1}) at 25-50DAS		(g plant^{-1} day^{-1}) at 50-75DAS		(g plant^{-1} day^{-1}) at 75-100DAS		(g plant^{-1} day^{-1}) at 100DAS to Maturity	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Varieties										
V1: KGD-1168	0.030	0.031	0.164	0.169	0.168	0.172	0.162	0.160	0.148	0.152
V2: Radhey	0.033	0.035	0.185	0.192	0.194	0.196	0.230	0.236	0.200	0.204
V3: KWR-108	0.032	0.033	0.177	0.182	0.190	0.190	0.220	0.221	0.158	0.163
SEm±	0.001	0.001	0.005	0.06	0.006	0.007	0.007	0.007	0.005	0.006
LSD (*p*=0.05)	0.002	0.003	0.017	0.019	0.020	0.022	0.022	0.023	0.017	0.018
Micronutrients										
M1: Control	0.032	0.033	0.154	0.158	0.131	0.138	0.215	0.207	0.132	0.145
M2: Zinc @ 0.5%	0.032	0.034	0.176	0.181	0.190	0.194	0.200	0.196	0.160	0.165
M3: Boron @ 0.2%	0.032	0.033	0.170	0.176	0.180	0.181	0.201	0.204	0.161	0.164
M4: Iron @ 0.1%	0.031	0.033	0.168	0.172	0.159	0.161	0.207	0.204	0.153	0.160
M5: Zinc @ 0.5% + Boron @ 0.2 %	0.032	0.033	0.187	0.193	0.212	0.213	0.200	0.204	0.200	0.196
M6: Zinc @ 0.5% + Iron @ 0.1 %	0.032	0.033	0.182	0.187	0.202	0.204	0.196	0.201	0.174	0.180
M7: Zinc @ 0.5% + Boron @ 0.2 % + Iron @ 0.1 %	0.032	0.034	0.192	0.200	0.212	0.212	0.212	0.224	0.202	0.200
SEm±	0.001	0.001	0.003	0.004	0.005	0.005	0.005	0.006	0.004	0.005
LSD (*p*=0.05)	NS	NS	0.011	0.013	0.015	0.017	0.017	0.019	0.014	0.015
Interaction (V x M)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3:Effect of Varieties and Micronutrients (Zinc, Boron and Iron) on Relative Growth Rate (g g^{-1} day^{-1}) of chickpea

Treatments	**Relative Growth Rate (g g^{-1} day^{-1}) at 25-50DAS**		**Relative Growth Rate (g g^{-1} day^{-1}) at 50-75DAS**		**Relative Growth Rate (g g^{-1} day^{-1}) at 75-100DAS**		**Relative Growth Rate (g g^{-1} day^{-1}) at 100DAS to Maturity**	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Varieties								
V1: KGD-1168	0.074	0.074	0.024	0.024	0.148	0.143	0.085	0.086
V2: Radhey	0.075	0.075	0.025	0.025	0.177	0.177	0.108	0.107

V3: KWR-108	0.075	0.074	0.025	0.024	0.175	0.174	0.105	0.107
SEm±	0.021	0.020	0.075	0.073	0.054	0.053	0.032	0.031
LSD (*p*=0.05)	NS	NS	NS	NS	0.163	0.159	0.097	0.093
Micronutrients								
M1: Control	0.070	0.070	0.021	0.021	0.152	0.152	0.088	0.096
M2: Zinc @ 0.5%	0.074	0.074	0.025	0.025	0.162	0.162	0.097	0.098
M3: Boron @ 0.2%	0.073	0.073	0.025	0.024	0.158	0.157	0.096	0.097
M4: Iron @ 0.1%	0.074	0.073	0.023	0.023	0.154	0.155	0.094	0.096
M5: Zinc @ 0.5% + Boron @ 0.2 %	0.076	0.076	0.026	0.026	0.182	0.177	0.109	0.104
M6: Zinc @ 0.5% + Iron @ 0.1 %	0.076	0.076	0.026	0.025	0.169	0.168	0.099	0.101
M7: Zinc @ 0.5% + Boron @ 0.2 % + Iron @ 0.1 %	0.077	0.077	0.027	0.026	0.207	0.195	0.108	0.106
SEm±	0.008	0.008	0.003	0.003	0.043	0.041	0.022	0.021
LSD (*p*=0.05)	0.024	0.024	0.010	0.010	0.129	0.123	0.068	0.065
Interaction (V x M)	NS	NS	NS	NS	NS	NS	NS	NS

Table 4:Effect of Varieties and Micronutrients (Zinc, Boron and Iron) on Net Assimilation Rate (g plant^{-1} day^{-1}) and Yieldof chickpea

Treatments	**Net Assimilation Rate (g plant^{-1} day^{-1}) at 25-50DAS**		**Net Assimilation Rate (g plant^{-1} day^{-1})at 50-75DAS**		**Net Assimilation Rate (g plant^{-1} day^{-1})at 75-100DAS**		**Net Assimilation Rate (g plant^{-1} day^{-1}) at 100DAS to Maturity**	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Varieties								
V1: KGD-1168	0.0232	0.0233	0.0128	0.0132	0.0179	0.0188	0.0222	0.0244
V2: Radhey	0.0279	0.0282	0.0175	0.0181	0.0245	0.0258	0.0303	0.0335
V3: KWR-108	0.0264	0.0266	0.0160	0.0165	0.0224	0.0235	0.0277	0.0305
SEm±	0.0014	0.0014	0.0005	0.0006	0.0008	0.0009	0.0010	0.0011
LSD (*p*=0.05)	0.0042	0.0044	0.0017	0.0019	0.0024	0.0027	0.0030	0.0033
Micronutrients								
M1: Control	0.0231	0.0233	0.0127	0.0132	0.0178	0.0188	0.0220	0.0244
M2: Zinc @ 0.5%	0.0257	0.0259	0.0153	0.0158	0.0214	0.0225	0.0265	0.0292
M3: Boron @ 0.2%	0.0251	0.0254	0.0147	0.0153	0.0206	0.0218	0.0254	0.0283
M4: Iron @ 0.1%	0.0247	0.0249	0.0143	0.0148	0.0200	0.0211	0.0247	0.0274
M5: Zinc @ 0.5% + Boron @ 0.2 %	0.0274	0.0277	0.0170	0.0176	0.0238	0.0251	0.0294	0.0326
M6: Zinc @ 0.5% + Iron @ 0.1 %	0.0268	0.0270	0.0164	0.0170	0.0229	0.0242	0.0284	0.0313
M7: Zinc @ 0.5% + Boron @ 0.2 % + Iron @ 0.1 %	0.0280	0.0286	0.0176	0.0185	0.0246	0.0264	0.0305	0.0342
sSEm±	0.0007	0.0007	0.0004	0.0005	0.0006	0.0007	0.0008	0.0009
LSD (*p*=0.05)	0.0021	0.0023	0.0012	0.0015	0.0019	0.0022	0.0024	0.0029
Interaction (V x M)	NS	NS	NS	NS	NS	NS	NS	NS

Table 5:Effect of Varieties and Micronutrients (Zinc, Boron and Iron) onChlorophyll (SPAD meter value), Relative Water Content (%), Yield attributes and Yield of chickpea

Treatments	**Chlorophyll content(SPAD value)**	**Relative Water Content (%)**	**Seed Yield Plant^{-1}(g)**	**Seed yield (kg ha^{-1})**

	Before flowering		**After flowering**		**Before flowering**		**After flowering**					
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Varieties												
V1: KGD-1168	33.75	34.07	38.35	38.66	63.85	63.90	68.45	68.49	10.81	11.33	1921	2020
V2: Radhey	36.69	36.93	41.29	41.52	64.58	64.65	69.18	69.24	13.04	13.51	2118	2228
V3: KWR-108	35.42	35.77	40.02	40.36	64.10	64.15	68.70	68.74	11.80	12.32	2063	2156
SEm±	0.70	0.72	0.88	0.91	1.94	1.99	2.32	2.37	0.42	0.44	62	65
LSD (*p*=0.05)	2.12	2.18	2.69	2.74	NS	NS	NS	NS	1.28	1.34	187	196
Micronutrients												
M1: Control	33.69	33.92	38.29	38.51	63.68	63.75	68.28	68.34	9.99	10.48	1869	1939
M2: Zinc @ 0.5%	35.08	35.30	39.68	39.89	64.16	64.22	68.76	68.81	11.86	12.38	2038	2134
M3: Boron @ 0.2%	34.83	34.96	39.43	39.55	64.01	64.05	68.61	68.64	11.64	12.15	2010	2113
M4: Iron @ 0.1%	34.49	34.72	39.09	39.31	63.92	63.97	68.52	68.56	11.23	11.69	1967	2102
M5: Zinc @ 0.5% + Boron @ 0.2 %	36.35	36.59	40.95	41.18	64.46	64.52	69.06	69.11	12.80	13.31	2113	2227
M6: Zinc @ 0.5% + Iron @ 0.1 %	35.52	36.25	40.12	40.84	64.38	64.44	68.98	69.03	12.47	12.95	2096	2152
M7: Zinc @ 0.5% + Boron @ 0.2 % + Iron @ 0.1 %	37.06	37.39	41.66	41.98	64.63	64.69	69.23	69.28	13.20	13.76	2162	2276
SEm±	0.34	0.36	0.40	0.44	0.84	0.93	1.12	1.16	0.25	0.28	37	39
LSD (*p*=0.05)	1.02	1.09	1.24	1.32	NS	NS	NS	NS	0.77	0.84	112	119
Interaction (V x M)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4. CONCLUSION

The two-year study's findings allowed the following conclusions.Among the varieties, Radhey variety resulted highest improvement in growth viz., dry weight of plant, crop growth rate, relative growth rate and net assimilation rate, chlorophyll content, relative water content, Seed yield plant^{-1} and seed yield of chickpea.The foliar application Zinc @ 0.5% + Boron @ 0.2 % + Iron @ 0.1 %) was provedsuperior over rest of the treatments in respect of in growth viz., dry weight of plant, crop growth rate, relative growth rate and net assimilation rate, chlorophyll content, relative water content, Seed yield plant^{-1} and seed yield of chickpea.On the basis of observed results, were instructed to farmers grow the chickpea variety Radhey with foliar applications of Zinc @ 0.5% + Boron @ 0.2% + Iron @ 0.1% for higher growth and yield.

Comment [i58]: The outcomes of the two-year study enabled the following judgments. The Radhey variety outperformed the other varieties in all growth-related metrics, including plant dry weight, crop growth rate, relative growth rate, net assimilation rate, chlorophyll content, relative water content, seed yield plant-1, and chickpea seed yield.

Comment [i59]: In plant growth including

Comment [i60]: Farmers were advised to grow the chickpea variety Radhey with foliar applications of Zinc @ 0.5% + Boron @ 0.2% + Iron @ 0.1% for higher growth and yield based on the observed results.

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Comment [i61]: S.

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