Micro-nutrient enrichment through foliar application at different stages of chickpea

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Abstract- Low zinc and iron availability due to alkaline soil, having high pH limiting crop production. Field experiment was conducted at the farmer field in Karak, for two consecutive years, 2016-17 and 2017-18. The experiments were laid out in RCB design having three replications. The factors included iron levels (1.5, 2, 2.5 kg ha^{-1}), zinc (1, 2, 3 kg ha^{-1}) applied at two growth stages vegetative (V3) and reproductive stages (R3) applied on Fakhr-e-Thal chickpea. The results showed that the iron applied at 2.5 kg ha^{-1} significantly increased grains pod^{-1}, grains weight, iron content, zinc content, grain and biological yield. The application of zinc applied at the rate of 3 kg ha^{-1} increased grains weight, grain yield, biological yield, harvest index, iron content and zinc content. The micronutrients (iron and zinc) applied at the reproductive stage improved iron content, zinc content, biological yield.

Keywords: iron, zinc, chickpea, yield, foliar, growth stages

1. Introduction

Chickpea plays important role in protein and mineral nutrition, but like other legumes chick pea production is low because of micro-nutrient deficiencies in the world (Roy et al., 2006 and Ahlawat et al., 2007). Plant nutrient availability is dependent on soil texture, organic matters content and specially pH of soil. Due to the un-availability of some plant nutrients is greatly affected by soil pH. The zinc and iron were unable in the high alkaline and calcareous soil. This is why soil applied zinc and iron micro-nutrients often do not successfully correct deficiencies. By avoiding the soil and applying the micro-nutrients to the leaves, the small amount of plant-required micro-nutrient are successfully introduced into the crop. Micronutrients play substantially role in achieving more production through their special impact on plant them self, they play an important functions in the symbiotic nitrogen-fixation, where deficiencies of micronutrient can limit nitrogen fixation by legume-rhizobium symbiosis, and influence efficient taking of the primary and secondary nutrients. Iron is essential for natural fixing of nitrogen by nodules. It is an important constituent of several proteins like nitrogenase, legmoglobin and ferredoxin. In ground nut arrested nodule growth shortly after their initiation occurred due to high alkaline nature of soil and iron shortage due to which delay or inhibits production of nitrogenase (O'Hara et al., 1988). Due to limiting iron supply poor growth of (*Lupinus angustifolius* L.) was identified on alkaline soil (White et al., 1989) and could have resulted from poor nodulation. The application of iron levels significantly increased harvest index (%) of chickpea and lentil (Kobaraee, 2019). The iron sulfate considerably enhanced the Fe contend up to 100% in grains and 173% in shoots than control (Khalid et al., 2015). The iron sulfate applied at 1.5 % at branching as well as flowering attained maximum number of pods plant^{-1}, number of seeds, number of seeds pod^{-1}, thousand grain weight, and grain yield and enhanced grains quality with protein contents and grain Fe concentration than untreated ones (Ali et al., 2014).

Foliar application of micro-nutrients especially Zn could have significant role in improving the yield and dependent characteristics in chickpea that helped in enhancing yield and yield components of chickpea (Sarbandi et al., 2014). Foliar spraying is an advance technique for crop nutrients nourishment applied to the leaves (Nasiri et al., 2010). Foliar application by multi micronutrients gave the maximum seed yield and seed protein content of chickpea (Kachave et al. 2018). Meanwhile, less amounts required to apply and will attain simply and nutrients response will rapidly than soil application (Zayed et al., 2011). Zinc foliar application increase grain yield and seed protein content up to 25 and 40%, respectively (Bejandi et al. 2012 and Pathak et al. 2012). Application of foliar Zn for chickpea had positive effects on branch number and seed yield (Hadi et al. 2013). Foliar application of micronutrients mixtures (Zn, Fe, Mg, Cu, B and Mn) in combination with nitrogen improved the plant growth, yield and yield components (Rahman et al. 2017). This method of micro-elements works very usefully in situations where roots cannot obtain essential micronutrients (Kinaci et al., 2007; Babaeian et al., 2011). The application of zinc as foliar improved soybean seed production when it is use in vegetative stage (Nadergholi et al., 2011). Zinc plays a significant role in reproductive development, floral growth, fertilization, and seed development, El Habbasha et al. (2013) also reported that foliar applications of Zn at flowering and grain-filling stages increased grain yield in chickpea. The aim of this research work was to determine suitable levels of iron and zinc with their application stages on yield and yield components of chickpea under rain-fed condition.

2.MATERIALS AND METHODS

Expermental Site and Design

The experiment was conducted at a farmer field in district Karak, Khyber Pakhtunkhwa province, Pakistan during winter season 2016-17 and 2017- 2018. The experiment was carried out in randomized complete block design (RCBD) having three replications with a plot size of 7. 2 m^{-2} (6 rows 30 cm with 4 m length). Three levels of iron (1.5, 2 and 2.5 kg ha^{-1}) and three levels of zinc (1, 2 and 3 kg ha^{-1}) were used on both vegetative (V3) and reproductive stages (R3). The local desi variety (Fakhar e Thal) was sown. Zinc sulphate and iron sulphate were used as sources of micronutrients zinc and iron respectively with control. A basal dose of nitrogen (25 kg ha^{-1}) and phosphorous (60 kg ha^{-1}) were applied at the time of sowing. The field was already inoculated with nitrogen fixing bacteria. The experimental site had pH (7.7), EC (390 µS/cm), bulk density (1), organic matter (0.60%), water holding capacity (40%), silt (58.5), sand (58.5%), clay (5.2%), soil texture (sandy loam), nitrogen (0.12 mg kg^{-1}), phosphorous (2.7 mg kg^{-1}) and potassium (6 mg kg^{-1}). All other agronomic practices were kept constant for all experimental units. Mean monthly maximum and minimum temperature (ºC), rainfall (mm), and relative humidity (%) of the experimental sites of Karak during 2016-17 to 2017-18 (Fig. 1 & Fig. 2).

Data collection procedure

Data on number of pods were recorded by counting the numbers of pods in five plants randomly taken in each plot at maturity, and were then averaged it. Data regarding grain pod^{-1} were recorded by counting grains randomly selected five pods in each plot and averaged it accordingly. Data regarding thousand grains weight was recorded on sensitive electronic balance after counting thousand grains with the help of seed counter for each plot. Data on grain yield recorded by harvesting the three central rows in each plot sun dried, weighed, threshed and converted in to grain yield kg ha^{-1} using the following formula (Eq. 1):

Grains yield (kg ha^{-1}) =

$$\frac{\text{Grain yield per three rows (kg)}}{\text{R-R distance (cm)} \times \text{No. of rows} \times \text{Row length (m)}} \times 10000 \quad \text{(Eq. 1)}$$

Data on biological yield was obtained by harvesting the three central rows in each plot sun dried and weighed. The dry weight converted to kg ha^{-1} by using the following formula (Eq. 2).

Biological yield =

$$\frac{\text{Biological yield per three rows (kg)}}{\text{R-R distance (cm)} \times \text{No. of rows} \times \text{Row length (m)}} \times 10000 \quad \text{(Eq. 2)}$$

Harvest index data was calculated as ratio of grain to total above ground biomass by using the following formula (Eq. 3).

Harvest index (%)=

$$\frac{\text{Grain yield}}{\text{Biological yield}} \times 100 \quad \text{(Eq. 3)}$$

For iron and zinc determination atomic absorption spectrophotometer was used. The sample of chick pea leaves were dried and then digested with nitric acid and perchloric acid. Wet digestions of all samples were carried out by the method of Dell et al., (1972). Exact weight of 1 g sample was poured in a beaker and mixed with 10 mL concentrated HNO3 and then kept for overnight. After that five ml perchloric acid was added and placed for 25 minutes. Heater was used to digest the sample and then distilled water was added to make the volume up to 100 mL. The solution were then analysed for iron and zinc.

Statistical Analysis

The data was statistically analyzed using the procedure appropriate for randomized complete block (RCB) design. Means were compared using least significance difference (LSD) test at 5 % level of probability when F values were significant (Jan et al., 2009). The interaction graphs were prepared in MS-Excel.

3.RESULTS AND DISCUSSION

pods $plant^{-1}$

The experimental data for pods $plant^{-1}$ of chickpea as affected by foliar application of iron (Fe), zinc (Zn) and their application stages (AS) during 2016-17 and 2017-18 is presented in table 1. The interaction between Fe x AS and control vs rest were found significant. The treated plots have more number of pods $plant^{-1}$ (46) as compared to untreated plots (40). The zinc applied as foliar had significantly increased the number of pods, weight of pods $plant^{-1}$ and seed index followed by Mo, Fe and Mn (Sawires, 2001). The application of Zn and Fe levels has no significant effect on pods $plant^{-1}$. The interactive effect of iron x application stages showed significant effect on number of pods $plant^{-1}$. The application of iron, showed increasing trend for pods $plant^{-1}$ at reproductive stage as compared to vegetative stage (Fig.3 (A)). The results are matched with Kumar et al., (2009) who stated that increasing the levels of iron, the branches $plant^{-1}$, number of pods $plant^{-1}$, number of grains pod^{-1} and weight also increased in chickpea.

Number of grains pod^{-1}

Number of grains pod^{-1} of chickpea as affected by foliar application of iron (Fe), zinc (Zn) and their application stages (AS) during 2016-17 and 2017-18 is presented in table 1. Statistical analysis showed that number of grains pod^{-1} in chickpea were significantly affected by iron application. The control vs rest was also found significant. The results presented that iron used at 2.5 kg ha^{-1} had higher number of grains pod^{-1} (2.0) as followed by 2 kg Fe ha^{-1} and 1.5 kg Fe ha^{-1} (1.0). The treated plots and control plots have same number of grain pod^{-1} (1). The significant interactions were Fe x AS, Fe x Zn, Fe x AS x Zn and cont. vs rest. Maximum number of grains pod^{-1} was recorded when zinc application increased from 1 to 3 Kg ha^{-1} at reproductive stage (Fig.3 (B)). The chickpea pods $plant^{-1}$, weight of pods $plant^{-1}$, seed and straw yield $plant^{-1}$ had significantly enhanced by application of micronutrient zinc (El-Habbasha et al., 2013). Application of iron from 1.5 to 2.5 kg ha^{-1} increased grains pod^{-1} at reproductive stage (Fig.4 (C)). The iron application improved plant height, number of branch $plant^{-1}$, number of pods $plant^{-1}$, number of seeds pod^{-1} and seed test weight in chickpea (Pingoliya et al., 2014).

Thousand grains weight (g)

Data on thousand grains weight (g) of chickpea as affected by foliar application of iron (Fe), zinc (Zn) and their application stages (AS) during 2016-17 and 2017-18 are presented in table 1. The iron significantly affected the thousand grains weight (g) of chickpea. The control vs rest was also significant. Foliar application of micronutrients (Fe, Zn and Mn) significantly increased hudred grains weight in wheat (Soylu et al., 2005). More thousand grains weight (259.4 g) were found in plots where iron was used at 2.5 kg ha^{-1} followed by 2 kg Fe ha^{-1} (255.8 g) and 1.5 kg Fe ha^{-1} (250.8 g). The treated plots had heavier grains (255.4 g) than untreated plots (226.7 g). The soybean grain yield was increased by influencing number of seeds $plant^{-1}$ and seed weight, enhanced by application of iron through foliar method (Kobraee et al., 2011). Maximum thousand grains weight (257.2 g) was recorded where zinc was applied at 3 kg ha^{-1} followed by 2 kg Zn ha^{-1} (256.1 g) and 1 kg Zn ha^{-1} (252.8 g). Iron and zinc applied at reproductive stage had more thousand grains weight (256.9 g) as compared to applied at vegetative stage (253.9 g). Foliar application of micronutrients (Fe, Zn and Mn) significantly increased hundred grains weight in wheat (Soylu et al., 2005). By increasing the levels of ferrous sulphate application there were increased in the number of pods plant^{-1}, number of seeds pod^{-1}, number of seeds plant^{-1}, pod weight plant^{-1} and seed weight plant^{-1} in legumes (Salam et al., 2004). The application of zinc at 3 kg ha^{-1} showed highest number of grains pod^{-1}. The zinc applied at 15 kg ha^{-1} had significant response to the number of pods plant^{-1} and thousand grains weight over control chickpea plants (Sangwan et al., 2004). More thousand grains weight (257.8 g) were recorded when chickpea was grown in first year as compared to second year (253 g). The possible interaction between control vs rest was found significant.

Grain yield (kg ha^{-1})

Data on grain yield of chickpea was significantly affected by foliar application of iron (Fe) levels (Table 1). Higher grain yield (2816 kg ha) was noticed where iron was applied at 2.5 kg ha^{-1} as compared to 2 kg Fe ha^{-1} (2804.1 kg ha^{-1}) and 1.5 kg Fe ha^{-1} (2714.1 kg ha^{-1}). The zinc levels applied showed significant affect on grain yield of chickpea. The zinc applied at 3 kg ha^{-1} have more grain yield (2815.9 kg ha^{-1}) as compared to 2 kg Zn ha^{-1} (2772.8 kg ha^{-1}) and 1 kg Zn ha^{-1} (2745.5 kg ha^{-1}). The micro-nutrient applied at different stages showed significant effect on grain yield. The foliar application of iron increased grain yield by effecting number of seeds plant^{-1} and weight of soya bean seed (Kobraee et al. 2011). Abo-Shetaia et al., (2001) showed similar results of improvement in yields of seed and straw in chickpea. Iron and zinc applied at reproductive stage had more grain yield (2804.1 kg ha^{-1}) as applied at vegetative stage (2752.1 kg ha^{-1}). More grain yield (2916.9 kg ha^{-1}) was found in second year sown chickpea, while lowest grains yield were observed during first year (2639.3 kg ha^{-1}). The treated chickpea have more grain yield (2781.2 kg ha^{-1}) than untreated (2055.2 kg ha^{-1}). Micronutrients particularly zinc and manganese through foliar application in small amounts had significant effect on plant height, thousand seed weight, biological yield, grain yield, harvest index and oil content of sunflower (Babaeian et al., 2011). The zinc application enhanced yield attributes pods plant^{-1}, thousand seed weight and chickpea seed yield (Valenciano et al., 2010). The interaction between Fe x AS, Fe x Zn and cont. vs rest were found significant. Maximum grain yield was recorded when iron doses increased at reproductive stage (Fig.4 (D)). Grain yield increased with increasing zinc and iron levels (Fig.5 (E)). The foliar application of micronutrients (iron and zinc) on lentil significantly improved yield components (Zeidan et al., 2006). It may be due to the increasing in enzymatic activities, micro elements effect in increasing in photosynthesis and assimilates translocation to seed. Similar results are presented by Akay, (2011) and Das et al., (2012) reported yield advantages due to zinc and iron spray in chickpea. Application of micronutrient (iron and zinc) and biofertilizer inoculation increased both vegetative and grain yield of chickpea increased (Janmohammadi et al., 2012). The application of iron and zinc play important role in process of photosynthesis and having important functions in the enzyme activities (Babaeian et al., 2011). Iron works in sun flower for a basic enzyme and plant hormone and contributes greatly in various reactions in electron transport chain as a cofactor (Kerkeb et al., 2006). The application of iron fertilizer increased the grain yield by 17.3% over the untreated with iron of chickpea (Kumar et al., 2009). The foliar zinc application during reproductive phase improved the grain yield, thus showing its beneficial effect on chickpea during fertilization as pollen grains also contain a higher amount of zinc (Ali et al., 2017). The results are also similar to El-Habbasha et al., (2013) presented similar results that zinc applied by foliar method on reproductive phase improved the yield and related traits of chickpea.

Biological yield kg ha^{-1}

Data on biological yield kg ha^{-1} of chickpea as affected by foliar application of iron (Fe), zinc (Zn) and their application stages (AS) during 2016-17 and 2017-18 is presented in table 2. Iron and application stages have significant effect on biological yield (kg ha^{-1}) of chickpea. The effect of years and the control vs rest were also found significant. The iron application at 2.5 kg ha^{-1} have maximum biological yield (7834.7 kg ha^{-1}) as compared to 2 kg Fe ha^{-1} (7657.4 kg ha^{-1}) and 1.5 kg Fe ha^{-1} (7459.3 kg ha^{-1}). The iron application had increased the number of pods plant^{-1}, pods weight, number of seeds plant^{-1}, seed and protein yield of soybean as compared to no treatment were applied (Mehasen et al., 2003). Micronutrients applied on reproductive stage gives higher biological yield kg ha^{-1}. More biological yield (7772.5 kg ha^{-1}) were observed at the 3 kg Zn ha^{-1} as followed by 2 kg Zn ha^{-1} (7619.7 kg ha^{-1}) and 1 kg Zn ha^{-1} (7559.3 kg ha^{-1}). The foliar application of zinc increased grain yield in chickpea (Pathak et al., 2012). The grain yield significantly increased by application of various levels of zinc compared with the untreated chickpea (Sangwan et al., 2004). The zinc have important functions in growth of crop like in photosynthesis processes, respiration and other biochemical and physiological activities and hence foliar application of zinc increased higher yield in wheat (Zeidan et al., 2010). The application of zinc at physiological maturity having more total dry matter production and seed yield due to increment in pod dry matter (Valenciano et al., 2011). The grain as well as straw yields of chickpea increased with increasing the application of zinc (Shivay et al., 2014). The iron and zinc applied at reproductive stage had more biological yield (7777.9 kg ha^{-1}) as compared to applied on vegetative stage (7523.1 kg ha^{-1}). The chickpea sown during second year have more biological yield (8129.9 kg ha^{-1}) as compared to first year (7171.1 kg ha^{-1}). Application of zinc, iron and manganese particularly by foliar spraying in a little amount of nutrients increased significantly the crop yield (Sarkar et al., 2007). Higher biological yield (7650.5 kg ha^{-1}) was found in treated plots than control (5909.7 kg ha^{-1}). The interactive effect between Fe x AS and control vs rest were found significant. Biological1 yield increased with increasing iron at reproductive stage (Fig.5 (F)).

Harvest index %

The data on harvest index % of chickpea as affected by iron and zinc foliar application are presented in table 2. All factors were non-significant. The interactions between AS x Zn and Fe x AS x Zn were significant while others were non-significant. However, when application of iron was increased from 1.5 to 2.5 kg ha^{-1}, the harvest index (%) was also increased from 37.7 to 38.7 %. In the same way, when zinc was increased from 1 to 3 kg ha^{-1}, the harvest index (%) was also increased from 38 to 38.3%. The application of micronutrient at vegetative stage increased the harvest index (%) as compared to reproductive stage. The crop grown during first year showed lower harvest index (%) as compared to second year. The crop treated with micronutrients had maximum harvest index (%) as compared to control. Harvest index (%) become maximum when highest doses of iron was applied at reproductive stage (Fig.6 (G)). The application of zinc increased the grains and straw yields of chickpea (Shivay et al., 2014). Foliar application of zinc may also help in physico-chemical processes in the plant body of cereals (Cakmak, 2008).

Iron content

Data of iron content in chickpea leaf as affected by foliar application of iron (Fe), zinc (Zn) and their application stages (AS) during 2016-17 and 2017-18 is presented in table 2. Iron and application stages have significant effect on iron content in chickpea leaf. The control vs rest was also significant. The results showed that maximum iron content (2.23 mg 100 g^{-1}) were found where Fe was applied at 2.5 kg ha^{-1} as followed by 2 kg Fe ha^{-1} (2.08 mg 100 g^{-1}) and 1.5 kg Fe ha^{-1} (2.06 mg 100 g^{-1}). The application of foliar iron clearly improved concentration of iron in leaves, stem and root of chickpea (Khan et al., 2003). A significant positive correlation of grain zinc with grain iron content in rice (Nagesh et al., 2013). Zinc application at the rate of 3 kg ha^{-1} have maximum iron content (2.16 mg 100 g^{-1}) compared with 2 kg Zn ha^{-1} (2.11 mg 100 g^{-1}) and 1 kg ha^{-1} (2.10 mg 100 g^{-1}). Iron and zinc applied at reproductive stage had showed more iron content (2.18 mg 100 g^{-1}) as compared to applied at vegetative stage (2.07 mg 100 g^{-1}) the chickpea sown on second year have more iron content (2.13 mg 100 g^{-1}) as compared to first year (2.12 mg 100g^{-1}). The treated plot have more iron content (2.12 mg 100 g^{-1}) as compared to untreated plots (1.77 mg 100 g^{-1}). The interaction between Fe x AS, Fe x Zn, AS x Zn and control vs rest were found significant. The zinc and application stages have significant effect on iron content, as iron content increased with the increased application of zinc (2-3 kg ha^{-1}) at reproductive stage (Fig.6 (H)). The iron x application stages had significantly increased iron content, when iron doses increased at reproductive stage (Fig. 7 (I)). Fe x Zn levels had significantly increased iron content, when their doses increased gradually (Fig. 7 (J)). The iron application significantly increased iron concentration in chickpea plant (Fasaei et al., 2015). The application of $FeSO_4$ significantly improved the iron content in shoot and grain respectively than control of chickpea (Khalid et al., 2015).

Zinc content

Data of zinc content in chickpea leaf as affected by foliar application of iron (Fe), zinc (Zn) and their application stages (AS) during 2016-17 and 2017-18 is presented in table 2. The iron and application stages have significant effect on zinc content in chickpea leaf. The control vs rest was also significant. The results showed that by the application of 2.5 kg Fe ha^{-1} had more zinc content (1.69 mg 100 g^{-1}) as compared to applied at the rate of 2 kg Fe ha^{-1} (1.61 mg 100 g^{-1}) and 1.5 kg Fe ha^{-1} (1.52 mg 100g^{-1}). Zinc applied at the rate of 3 kg ha^{-1} had maximum zinc content (1.64 mg 100 g^{-1}) as followed by 2 kg Zn ha^{-1} (1.60 mg 100 g^{-1}) and 1 kg Zn ha^{-1} (1.59 mg 100 g^{-1}). The application of $ZnSO_4$ through foliar method increased the zinc concentrations in vegetative part of the plants and seed, which might be due to the important role of zinc in physiological processes of plant cell (Alloway, 2004). The application stages showed that iron and zinc applied at reproductive stage have more zinc content (1.68 mg 100 g^{-1}) as compared to applied at vegetative stage (1.54 mg 100 g^{-1}). The foliar zinc application increasing in zinc content in the chickpea grains and leaves (Pathak et al., 2012). The zinc application to tomato plants at optimum levels increased the zinc concentration in plant organs (Kaya et al., 2002). Chickpea sown on second year showed more zinc content (1.62 mg 100 g^{-1}) as compared to first year (1.59 mg 100 g^{-1}). The treated plots were having more zinc content in leaf (1.61 mg 100 g^{-1}) as compared to control plots (1.13 mg 100 g^{-1}). The possible interactions between Fe x AS, Fe x Zn, AS x Zn, Fe x AS x Zn and cont. vs rest were found significant. Zinc x application stages have significantly increased zinc content, when zinc levels increased at the reproductive stage (Fig. 8 (K)). The iron and application stages significantly increased zinc content during applied at reproductive stage (Fig. 8 (L)). The zinc into iron interaction had significantly increased zinc content when their doses increased (Fig. 9 (M)). Zinc concentration in chickpea stems, leaves and roots significantly enhanced by applying zinc (Singh et al., 2015).

4. Conclusions

It is concluded from the above results that foliar application of 2.5 kg Fe ha^{-1} significantly increased number of grains pod^{-1}, thousand grains weight (g), grain yield (kg ha^{-1}), biological yield (kg ha^{-1}), iron content (mg 100 g^{-1}) in leaf and zinc content (mg 100 g^{-1}) in leaf. Foliar application of iron and zinc applied at reproductive stage significantly enhanced biological yield (kg ha^{-1}), iron content (mg 100 g^{-1}) in leaf and zinc content (mg 100 g^{-1}) in leaf. On the basis of the above conclusions we can recommend application of 2.5 kg Fe ha^{-1} at reproductive stage for chickpea yield and its seed nutritional quality in the Karak locality of Khyber Pakhthunkhwa province, Pakistan.

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Table 1. Number of pods plant^{-1}, number of grains pod^{-1}, thousand grains weight (g) and grain yield (kg ha^{-1}) of chickpea as affected by foliar application of iron (Fe), zinc (Zn) and their application stages (AS) during 2016-17 and 2017-18.

Iron (Fe) kg ha^{-1}	**Pods plant^{-1}**	**Grains pod $^{-1}$**	**TGW(g)**	**Grain yield**
1.5	45	1b	250.8 b	2714.1 b
2.0	46	1 b	255.8 ab	2804.1 a
2.5	46	2 a	259.4 a	2816.0 a
LSD for Fe	NS	0.10	6.02	68.76
Zinc (Zn) kg ha^{-1}				
1	45	1	252.8	2745.5
2	46	1	256.1	2772.8
3	46	1	257.2	2815.9
LSD for Zn	NS	NS	NS	NS
Application stages (AS)				
Vegetative Stage (V3)	45	1	253.9	2752.1
Reproductive stage (R3)	46	1	256.9	2804.1
LSD for AS	NS	NS	NS	NS
Year (Y)				
2016-17	45	1	257.8	2639.3
2017-18	46	1	253.0	2916.9
LSD for Y	NS	NS	NS	51.06
Planned Mean Comparison				
Control	40	1	226.7	2055.2
Rest	46	1	255.4	2781.2
Sig Level	**	**	**	**

TGW=Thousand grains weight,

Means of the same category followed by different letters are significantly different at 5 % level of probability using LSD (0.05) test

** Significant, NS: Non-Significant

Table 2. **Biological yield (kg ha^{-1}), harvest index (%), iron content in leaf (mg 100 g^{-1}) and zinc content in leaf (mg 100 g^{-1}) of chickpea as affected by foliar application of iron (Fe), zinc (Zn) and their application stages (AS) during 2016-17 and 2017-18.**

Iron (Fe) kg ha	**Biological yield**	**H. I (%)**	**Fe in leaf**	**Zn in leaf**
1.5	7459.3 b	37.72	2.06 b	1.52 c
2.0	7657.4 ab	38.17	2.08 b	1.61 b
2.5	7834.7 a	38.75	2.23 a	1.69 a
LSD for Fe	278.41	NS	0.06	0.06
Zinc (Zn) kg ha^{-1}				
1	7559.3	38.06	2.10	1.59
2	7619.7	38.25	2.11	1.60
3	7772.5	38.33	2.16	1.64
LSD for Zn	NS	NS	NS	NS
Application stages (AS)				
Vegetative Stage (V3)	7523.1	38.61	2.07	1.54
Reproductive stage (R3)	7777.9	37.81	2.18	1.68
LSD for AS	227.32	NS	0.05	0.05
Year (Y)				
2016-17	7171.1	37.93	2.12	1.59
2017-18	8129.9	38.50	2.13	1.62
LSD for Y	252.02	NS	NS	NS
Planned Mean Comparison				
Control	5909.7	37.00	1.77	1.13
Rest	7650.5	38.21	2.12	1.61
Sig Level	**	NS	**	**

Means of the same category followed by different letters are significantly different at 5 % level of probability using LSD (0.05) test

** Significant, NS Non-Significant

Table 3. Analysis of variance for number of pods plant^{-1}, number of grains pod^{-1}, thousand grains weight (g) and grain yield (kg ha^{-1}) of chickpea as affected by foliar application of iron (Fe), zinc (Zn) and their application stages (AS) during 2016-17 and 2017-18.

SOV	DF	P/P	G/P	TGW	G.Y
Year (Y)	1	8.429	0.001	505.26	2059599**
Rep within Year	4	14.096	0.099	375.44	9637.833
Treatments (T)	{18}	86.115**	0.311*	483.43**	233028.2***
Iron (Fe)	2	11.444	0.164*	673.15**	111838.1**
Application stages (AS)	1	30.083	0.094	237.04	72904.04
Zinc (Zn)	2	3.083	0.111	192.60	45419.15
Fe x AS	2	358.777**	0.890**	489.81	257223.3***
Fe x Zn	4	58.986	0.247**	109.26	59317.45*
AS x Zn	2	85.027	0.117	14.81	33677.37
Fe x AS x Zn	4	45.763	0.310**	150.93	4369.426
Cont. Vs Rest	1	184.320**	0.718**	4683.24**	2970541***
Y x T	{18}	6.559	0.013	275.63	50474.82**
Y X Fe	2	4.703	0.005	595.37*	23621.73
Y X AS	1	0.453	0.001	0	28162.37
Y x Zn	2	0.898	0.037	114.81	27690.7
Y x Fe x AS	2	13.814	0.010	686.11**	145809.3**
Y x Fe x Zn	4	16.912	0.006	142.59	26592.45
Y x AS x Zn	2	2.842	0.001	211.11	19945.37
Y x Fe x AS x Zn	4	1.245	0.028	247.22	75110.43*
Y x Cont. Vs Rest	1	0.468	7.5E-05	187.33	39438.6
Error	72	29.948	0.046	164.32	21412.49
Total	113				

P/P: Pods plant^{-1}, G/P: Grains pod^{-1}, TGW: Thousand grain weight, G.Y: Grain yield

Table 4. Analysis of variance for biological yield (kg ha^{-1}), harvest index (%), iron content in leaf (mg 100 g^{-1}) and zinc content in leaf (mg 100 g^{-1}) of chickpea as affected by foliar application of iron (Fe), zinc (Zn) and their application stages (AS) during 2016-17 and 2017-18.

SOV	DF	B.Y	H.I	Fe	Zn
Year (Y)	1	26021370***	10.75	0.02	0.039
Rep within Year	4	234827.2	9.75	0.03	0.016
Treatments (T)	{18}	1738167**	13.05**	0.20***	0.354***
Iron (Fe)	2	1269355*	9.56	0.32***	0.272***
Application stages (AS)	1	1752871*	17.12	0.37***	0.500***
Zinc (Zn)	2	434749.8	0.73	0.04	0.025
Fe x AS	2	1866516**	11.79	0.28***	0.278***
Fe x Zn	4	363781.2	5.02	0.08**	0.288***
AS x Zn	2	987348.9	18.45*	0.34***	0.658***
Fe x AS x Zn	4	434402.1	27.08**	0.04	0.238***
Cont. Vs Rest	1	1722545***	8.36	0.71***	1.295***
Y x T	{18}	394482.2	2.56	0.10***	0.061***
Y X Fe	2	310758.1	0.84	0.00	0.047
Y X AS	1	426764.1	4.90	0.03	0.046
Y x Zn	2	94828.48	1.68	0.01	0.002
Y x Fe x AS	2	641718.8	1.29	0.20***	0.042
Y x Fe x Zn	4	632018.9	4.50	0.22***	0.159***
Y x AS x Zn	2	77899.11	0.064	0.04	0.055
Y x Fe x AS x Zn	4	472486.4	3.66	0.08**	0.032
Y x Cont. Vs Rest	1	5485.392	0.82	0.08*	0.003
Error	72	351107.7	5.47	0.02	0.018
Total	113				

B.Y: Biological yield, H.I: Harvest index, Fe: Iron content, Zn: Zinc content

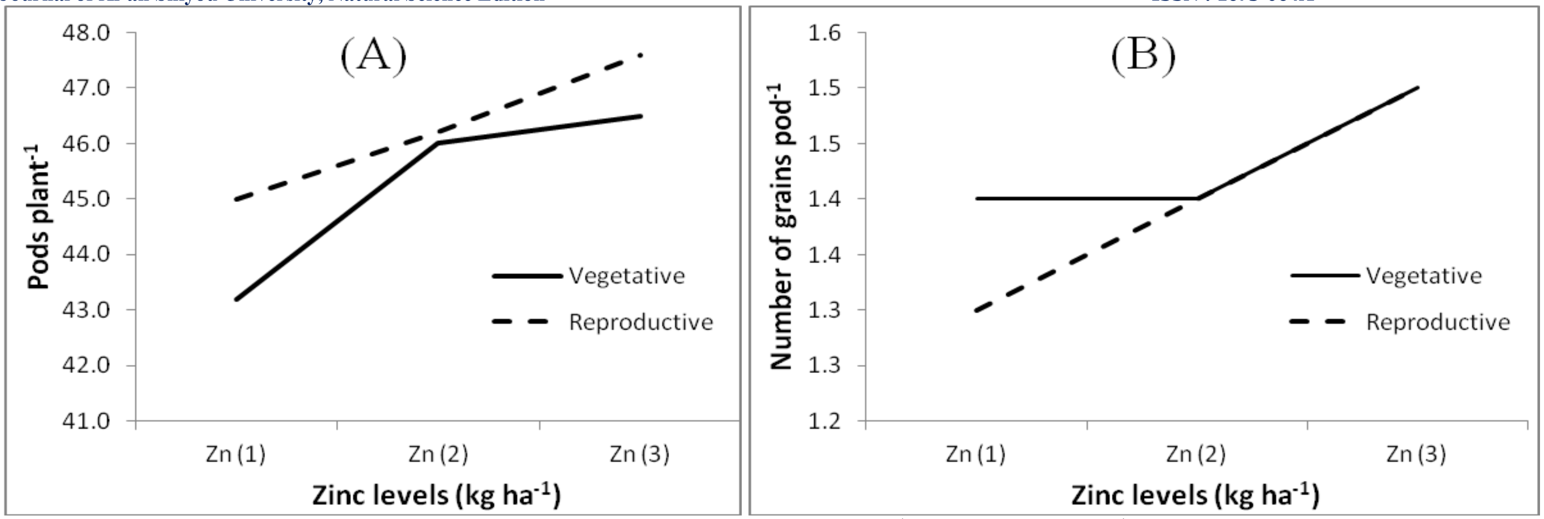

Figure 3. Interactive effect of zinc x application stages on (A) number of pods plant^{-1} and (B) grains pod^{-1}of chickpea.

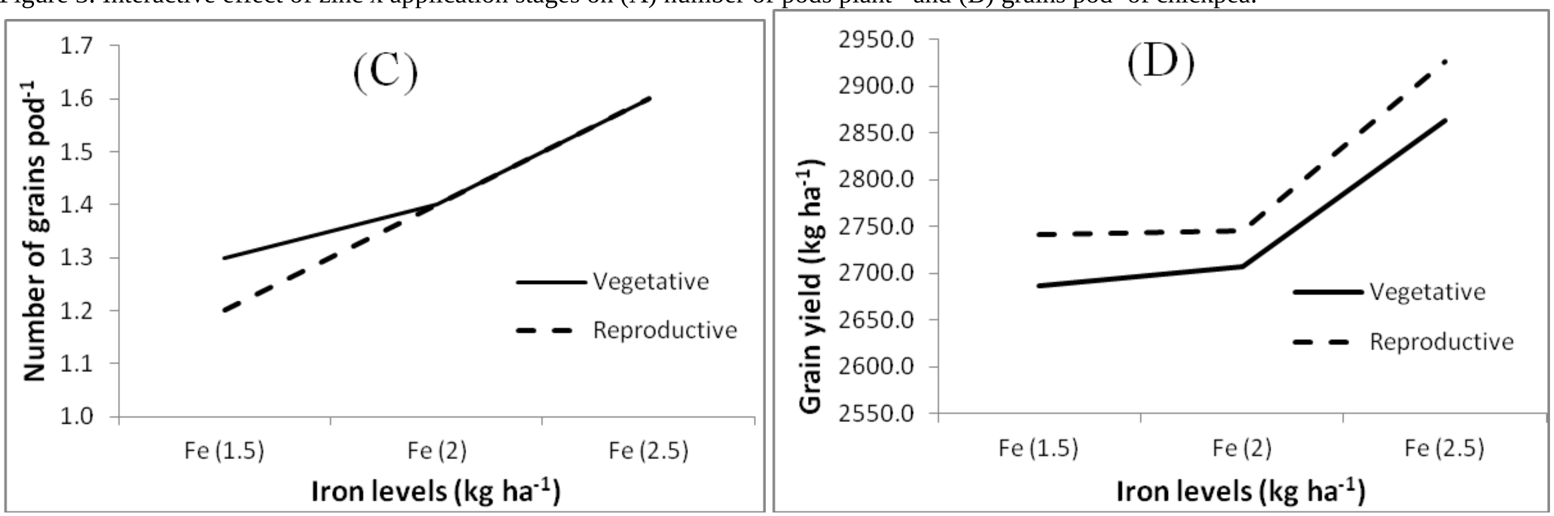

Figure 4. Interactive effect of iron x application stages on (C) number of grains pod^{-1} and (D) grain yield (kg ha^{1}) of chickpea.

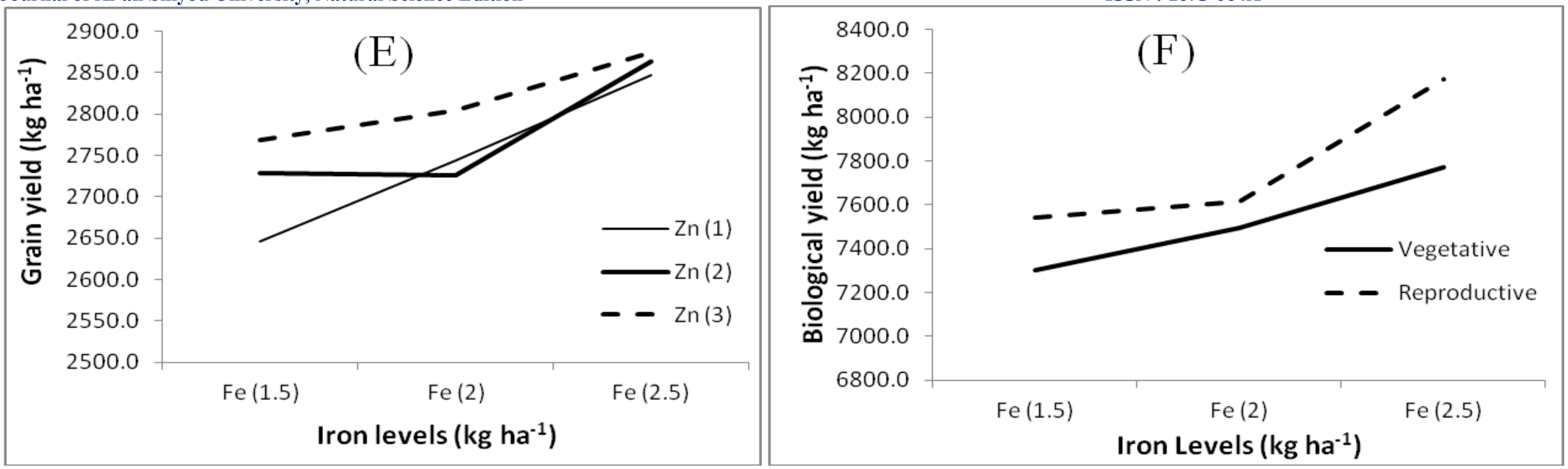

Figure 5. Interactive effect of iron x zinc on (E) grain yield (kg ha^{-1}) and iron x application stages (F) on biological yield

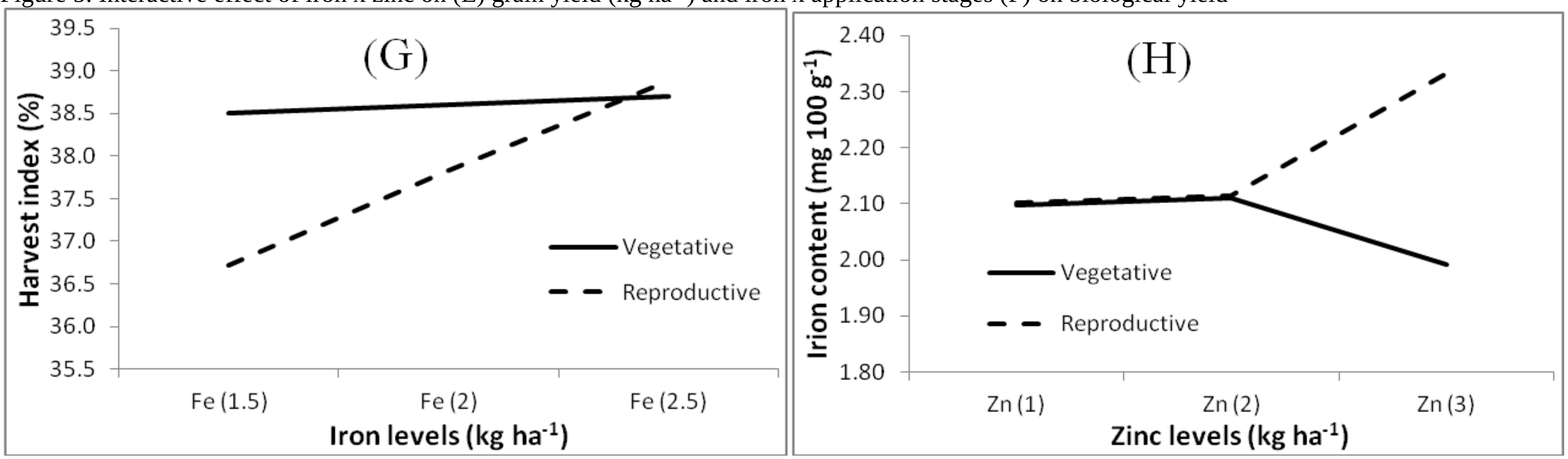

Figure 6. Interactive effect of iron x application stage on (G) harvest index (%) and zinc x application stage on (H) iron content of chickpea.

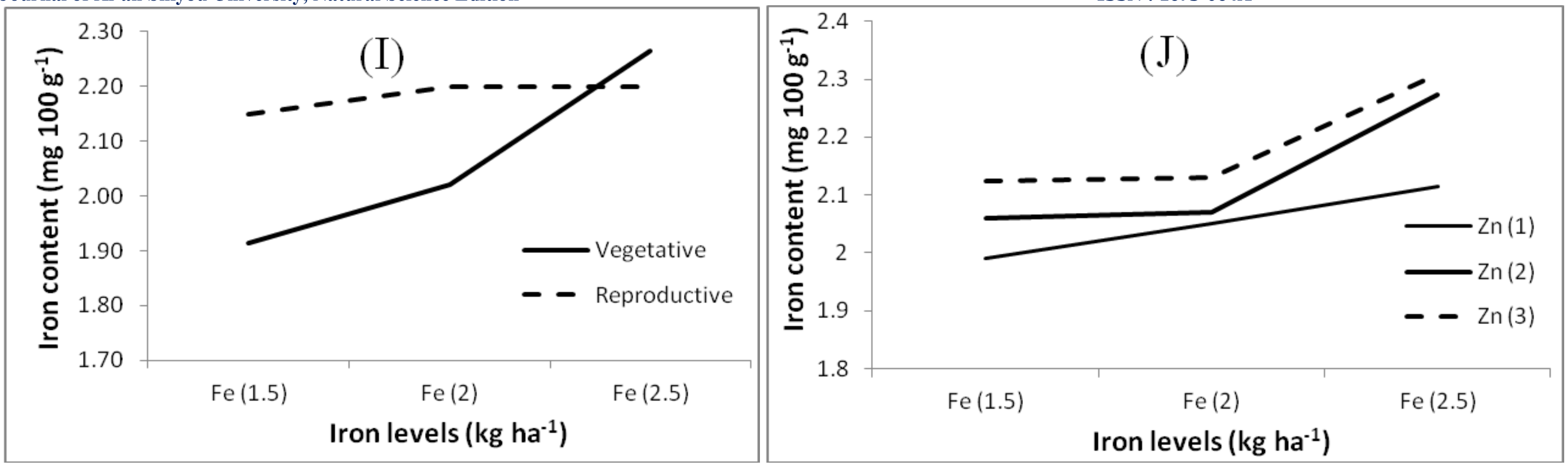

Figure 7. Interactive effect of iron x application stage on (I) iron content and iron x zinc on (J) iron content of chickpea leaf.

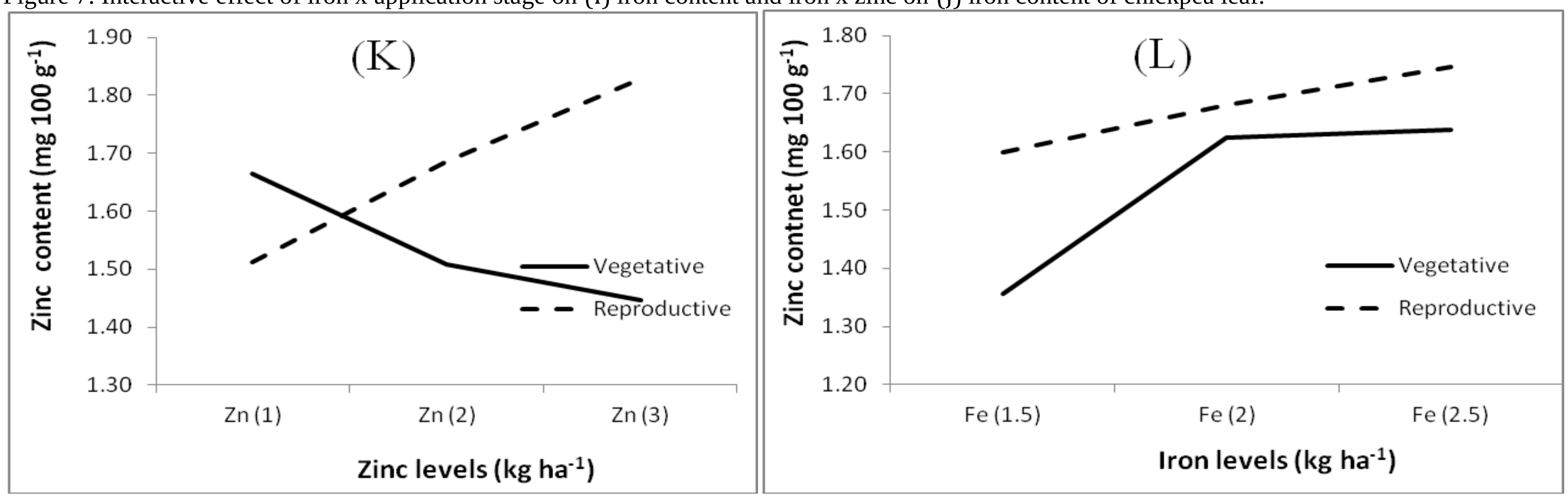

Figure 8.Interactive effect of zinc x application stage on (K) zinc content and iron x application stage on (L) zinc content in chickpea.

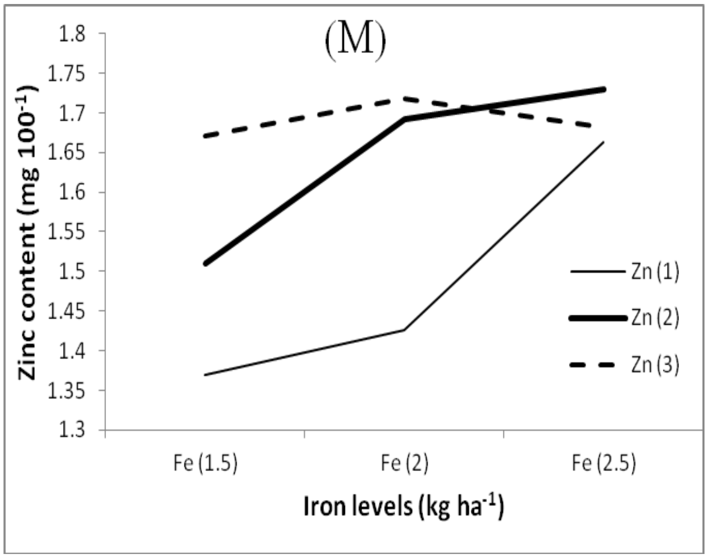

Figure 9. Interactive effect of iron x zinc on (M) zinc content (mg 100 g^{-1}) of chickpea leaf.

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