Foliar applications for amelioration of iron deficiency in peanut (Arachis hypogaea L.)

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ABSTRACT

In present study, different foliar treatments were applied on peanut to check their ameliorative effect on Fe deficiency. In hydroponics experiments, foliar applications of FeSO4, Fe-EDTA, sequestrene and ferric chloride were applied to check their effect on Fe deficiency chlorosis in two varieties of peanut already screened as BARI-2000 (Fe deficiency tolerant) and BARD-699 (Fe deficiency sensitive). Sequestrene proved to be more effective in increasing the growth of plant. Photosynthetic rate increased up to 58 and 70% in BARI-2000 and BARD-699 respectively as compared to control with foliar application of sequestrene. Similarly higher active Fe concentration was recorded in both genotypes. Up to 14 and 41% increase in active Fe concentration was observed. Various morpho physiological parameters including root length, shoot length, root fresh weight, root dry weight, shoot fresh and shoot dry weights, SPAD values, photosynthetic and transpiration rates showed that BARD-699 was more responsive to foliar applications, while foliar application of sequestrene can be used in correcting Fe deficiency in both genotypes. Active Fe was significantly correlated with different morphological parameters in both genotypes. The results of present experiment suggested that foliar applications were helpful in correction Fe deficiency in peanut and growth can be enhanced.

Key words: FeSO4, Foliar applications, Hydroponics experiments, Iron deficiency, Peanut.

INTRODUCTION

Iron (Fe)deficiency chlorosis is a widespread problem in calcareous soils resulting in significant reduction of yield (Boodi et al., 2016; Inalet al., 2007). Peanut is susceptible to Fe deficiency in calcareous soils of Pothwar tract of Pakistan (Akhatar et al., 2013; Rashid et al., 1997). At high pH and high bicarbonates, Fe becomes unavailable. The problem can be solved either by improving the mechanism of Fe uptake or by increasing amount of Fe in soil solution. Among various fertilizers used, EDDHA and analogues (the most stable chelates) can maintain Fe in the soil solution and transport it to the roots of plants (Lucena, 2003).

Different remediation strategies include improving Fe uptake mechanism genetically by either breeding (Ciancio, 1995) or genetic modifications (Robinson et al., 1999). Genetic variations play an important role in nutritional profile of pulses (Sharma et al., 2018). These strategies are time consuming, hence other solutions should also be considered. Fe can also be supplied to the plant by foliar application or by trunk injection. Foliar applications has been studied by various researchers (Barcelos et al., 2017; Rajaie and Tavakoly, 2017). In few cases foliar applications produced good results and are also practical where the use of chelate is uneconomical (Song et al., 2017; Lucena, 2003). Trunk injection is very expensive, however, the strategy is used for garden trees (Fernández-Escobar et al., 1993).

Foliar applications of various chemicals are useful in combating Fe deficiency. Foliar applications of FeSO4 can increase leaf Fe concentration, while basal treatments are more effective for long results (Mann et al., 2017). Under 21 days of Fe deficiency treatment, foliar applications of salicylic acid and sodium nitroprusside in combination increased the level of chlorophyll, active Fe and increased Fe accumulation was observed in cell organelles showing less symptoms of interveinal chlorosis (Kong et al., 2014).

Different foliar applications containing (FeSO4.7H2O, Fe(III)-citrate, Fe(III)-EDTA, Fe(III)-DTPA, Fe(III)-IDHA) and a surfactant were able to correct Fe deficiency in Prunus persica L. Foliar applications always resulted in leaf chlorophyll increase, although different degrees of re-greening were observed for the various Fe-compounds tested. Best results were obtained with
Fe(II)sulfate, Fe(III)-citrate, Fe(III)-EDTA, Fe(III)-IDHA and Fe(III)-DTPA in descending order (Fernández et al. 2006).

Fe-sulphate (1.0% and 0.5%), Fe-citrate (1.0% and 0.5%) and Fe-EDTA (0.1% and 0.2%) were sprayed to the affected leaves of peach (Prunus persica). After 1 week of spraying, observations were recorded for various physiological and biochemical parameters including photosynthetic rate, stomatal conductance, total leaf chlorophyll content, superoxide dismutase and peroxidase activity. Application of 1.0% Fe-sulphate and 0.5% Fe-sulphate had similar effects for most of the effects under study. Different responses of peach cultivars were recorded with different treatments. Maximum recovery was recorded with Fe sulphate followed by Fe citrate and Fe-EDTA (Chakraborty et al. 2012).

The most common strategy is to select genotypes with better ability to uptake required Fe under field conditions. The strategy has been advocated by (Akhtar et al. 2013; Gao and Shi 2007). Another useful strategy is foliar applications of Fe. Present study was aimed at to explore the effect of different foliar applications in correcting Fe deficiency in BARI-2000 and BARD-699.

MATERIALS AND METHODS
Selection of genotypes: In present study, two selected genotypes (BARI-2000 and BARD-699) with contrasting characters were subjected to various foliar applications to Fe deficiency chlorosis. These genotypes were selected on the basis of hydroponics and pot experiments (Akhtar et al. 2014; Akhtar et al. 2013).

Lay out of experiment: The experiments were performed to study the effect of various foliar applications on the morpho-physiological characteristics of both genotypes. Seeds of two genotypes were germinated on wet sterile sand at 25°C in the dark after surface sterilization with H₂O₂ and thorough washing with tap water followed by distilled water. After germination uniform seedlings were transferred to aerated Hoagland’s nutrient solution (Epstein, 1972). The seedlings were aerated for 24 h. The setup was kept in controlled conditions of 14/10 light/dark period with 30%/20°C ± 2°C temperature and 800 cd of light.

Treatments applied: Two weeks after emergence, the seedlings were treated as follows (a) Control (without any treatment i.e –Fe conditions), (b) Foliar application of 1.5% FeSO₄, (c) Foliar application of 2% Fe-EDTA, (d) Foliar application of 5% Sequestrene [NaFeEDDHA (ethylenediamine di(o-hydroxy-phenylacetic acid) containing 6% Fe and (e) FeCl₃ 1.43%. The experiment was replicated thrice. As sequestrene contained 6% Fe i.e 0.06 parts of Fe so we equalize all the treatments to 0.3 parts of Fe by using the formula for different treatments.

Sequestrene (6%) Fe=6/100=0.06 parts=0.06*5=0.3 parts of Fe=5% Molecular mass of Fe/molecular mass of chemical FeSO₄ 7H₂O=56.5/278=0.20*1.5=0.3 parts of Fe=1.5% Fe-EDTA=56.5/367=0.15*2=0.3 parts of Fe=2% FeCl₃ 6H₂O=56.5/270=0.21*1.43=0.3 parts of Fe=1.43%

Observations: Following observations were made
(1) SPAD Values: SPAD values were recorded at different time intervals with SPAD-502 Minolta, Japan. All the data of SPAD values was averaged.
(2) Active Fe concentration: Active Fe concentration from young fully expanded leaves was measured by the method used by (Gao and Shi, 2007). For the purpose young fully expanded leaves were cut into uniform pieces and 1 g sample was extracted with 1N HCl (in 1:10 tissue:extractant) shaken for 5 h and filtered. The filtrate was used to measure Fe concentration by using atomic absorption spectrophotometer.
(3) Photosynthetic and transpiration rate: Photosynthetic rate (A) and transpiration rate (E) were recorded upon first detection of chlorotic symptoms using Infra-Red Gas Analyzer (LCA4 Bioscientific Ltd.). Three weeks later (before the anthesis stage), seedlings were harvested and number of leaves were counted.
(4) Total Fe content: Total Fe content was measured by using dry ash method (Rashid et al., 2001). SPSS was used to correlate active Fe and total Fe content with different morphological parameters.
(5) Morphological parameters: Root lengths, plant height and root and shoot fresh weights were recorded. Dry weights of root and shoot were recorded after drying the samples at 60°C for three days.

Statistical analysis: Percentage increase in different parameters was measures as compared to plants in –Fe treatments. Correlation was recorded using SPSS.

RESULTS AND DISCUSSION
Fe deficiency is a wide spread problem in calcareous soils (Inal et al. 2007). The problem is more pronounced in the Pothwar region of Pakistan (90% peanut area out of total area under cultivation) (Imtiaz et al. 2010; Rashid et al. 1997). Based on our previous experiments BARI-2000 was declared as Fe deficiency tolerant and BARD-699 as Fe deficiency sensitive genotypes (Akhtar et al. 2014; Akhtar et al. 2013). In present experiment, the response of these two genotypes to various foliar applications was studied. Foliar application of Fe is a common mean to correct Fe deficiency in agricultural crops (Mann et al. 2017; Alvarez-Fernández et al. 2005).

Both genotypes showed an increase in photosynthetic rate (µmol m⁻²s⁻¹) with application of different foliar sprays. Foliar applications of Fe(III), FeSO₄, Fe-EDTA and sequestrene resulted of 5, 20, 48 and 58% increase in photosynthetic rate of BARI-2000 as compared to Fe deficient conditions. The same treatments resulted 39, 38,
50 and 70% increase in photosynthetic rate of BARD-699 as compared to Fe limited conditions (Fig. 1). Our results showed that sequestrene was more effective for increasing photosynthetic rate of both genotypes as compared to Fe limited conditions. Photosynthetic rate of both genotypes was significantly correlated with SPAD values. It may be concluded that higher SPAD values would result in more photosynthates, as a result of higher Fe concentration and more plant growth (Fig 5). Moreover, absence of any chlorosis marks on the leaves would have increased green area, hence increased the photosynthetic rate. Foliar applications of Nitric oxide and Fe increased the photosynthetic rate and re greening in peanut in hydroponic culture (Song et al., 2017).

Transpiration rate of both genotypes increased significantly with foliar application of sequestrene (35%) for both genotypes as compared to Fe limited conditions. BARI-2000 resulted increase in transpiration rate upto 3,11 and 27% as compared to Fe deficient conditions. However, BARD-699 resulted in 5, 21 and 19% increase in transpiration rate with foliar application of Fe(III), FeSO4, and Sequestrene respectively (Fig 2). BARI-2000 exhibited better responsive to foliar application of Fe-EDTA with an increase of 27% transpiration rate as compared to Fe deficient conditions, while BARD-699 showed 19% increase in transpiration rate as compared to Fe deficient conditions (Fig 2). Transpiration rate was positively correlated with SPAD values ($R^2=0.53$). Higher SPAD value resulted higher
photosynthetic rate consequently resulted higher transpiration rate (Fig. 5). Higher SPAD values resulted greater photosynthetic and transpiration rate, hence improved the enzymatic activity and produced better yield (Singh and Sahu, 1993).

When subjected to Fe deficiency, plants responded in different ways (Rombolà et al. 2002), such as chlorophyll synthesis inhibition and disturbed enzyme activities, which requires Fe as cofactor (Bisht et al. 2002). SPAD values of BARI-2000 and BARD-699 increased with different foliar applications. Sequestrene significantly increased the SPAD values of BARD-699 i.e. 32% higher values was recorded as compared to Fe limited conditions. Fe(III), FeSO₄, and Fe-EDTA resulted increase in SPAD values up to 13, 22, and 20% in BARD-699 as compared to Fe limited conditions. Similarly, BARI-2000 exhibited higher values 2, 5, and 20%. Sequestrene increased the SPAD values of BARI-2000 up to 18% as compared to –Fe conditions (Fig. 3). Correlation was significant between SPAD values and photosynthetic rate ($R^2=0.68$) as well as SPAD values and transpiration rate.
Fig 5: Correlation between SPAD values and photosynthetic rate and between SPAD values and transpiration rate of peanut genotypes.

(R²=0.53). It showed that when SPAD values increased photosynthetic as well as transpiration rate increased (Fig 6). Glutamine, citric acid and sequestrene increased the SPAD values and reduced Chlorosis in young leaves of Plantago orientalis (Salahi et al., 2017).

Active Fe concentration is an important physiological parameter to show the concentration of physiologically active Fe in plants (Gao and Shi, 2007). Active Fe concentration significantly increased with the foliar application of Sequestrene where 41% increase was recorded in BARD-699 when compared to Fe limited conditions. While for BARI-2000, 14% increase in active Fe concentration was recorded as compared to Fe deficient conditions. BARI-2000 was more responsive to Fe-EDTA as there was 19% increase in active Fe concentration as compared to Fe deficient conditions, while only 5% increase in active Fe concentration was recorded for BARD-699 with same treatment. Foliar application of Fe (III) and FeSO₄ resulted an increase of active Fe concentration upto 4 and 14% for BARI-2000 while 20 and 31% for BARD-699 as compared to respective Fe deficient conditions (Fig 4). Gao and Shi, (2007) suggested active Fe concentration as an important physiological parameter to show Fe status of plant. Rashid et al. (1997) also suggested that active Fe concentration is more important to present the status of Fe in plant tissue. However, Loop and Finck, (1984) showed the usefulness of total Fe. Our results suggested that active Fe increased with different foliar applications. Lucena (2003) suggested that sequestrene alone can significantly increase Fe concentration as compared to Fe-EDTA in cucumber plants. Active Fe was significantly correlated with root length, shoot length, root fresh weight, Shoot fresh weight and Shoot dry weight in BARI-2000. However, active Fe was non-significant with root dry weight. Total Fe was positively correlated with root length, shoot length, root fresh weight, shoot fresh weight, shoot fresh weight and shoot dry weights (Table 1). Significant correlation was recorded when active Fe was compared with root length, shoot length, root dry weight, shoot dry weight, Shoot fresh weight and shoot dry weights of BARD-699. Similarly total Fe was positively correlated with different morphological parameters (Table 2). The morphological parameters of both genotypes were

<table>
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<tr>
<th></th>
<th>Active Fe</th>
<th>Root Length</th>
<th>Shoot Length</th>
<th>Root Fresh Weight</th>
<th>Root Dry Weight</th>
<th>Shoot Fresh Weight</th>
<th>Shoot Dry Weight</th>
<th>Total Fe</th>
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<tr>
<td>Root Length</td>
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<tr>
<td>Shoot Length</td>
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<td>0.872**</td>
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<td>0.790**</td>
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<td>Root Dry Weight</td>
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<tr>
<td>Shoot Fresh Weight</td>
<td>0.502*</td>
<td>0.691**</td>
<td>0.655**</td>
<td>0.73**</td>
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<td>Shoot Dry Weight</td>
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<td>0.882**</td>
<td>0.824**</td>
<td>0.75**</td>
<td>0.27</td>
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<td>Shoot Length</td>
<td>0.637**</td>
<td>0.767**</td>
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<tr>
<td>Root Fresh Weight</td>
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<td>0.755**</td>
<td>.761**</td>
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<td>Root Dry Weight</td>
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<td>0.237</td>
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<td>0.800**</td>
<td>.700**</td>
<td>0.785**</td>
<td>0.637**</td>
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<tr>
<td>Shoot Dry Weight</td>
<td>0.544*</td>
<td>0.711**</td>
<td>0.850**</td>
<td>0.720**</td>
<td>0.289</td>
<td>0.578**</td>
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<tr>
<td>Total Fe</td>
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<td>0.742**</td>
<td>0.795**</td>
<td>0.884**</td>
<td>0.408</td>
<td>0.749**</td>
<td>0.730**</td>
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significantly correlated with each other (Table 1 and 2). The results suggested that foliar applications resulted in increases morphological parameters and active Fe concentration in both genotypes indicating increased yield. Strong and positive correlation of seed yield per plant with harvest index, morphological and yield parameters resulted in increased yield in pea (Singh et al., 2018).

CONCLUSION

The results of this study suggested that foliar application of sequestrene was more active in regreemng of chlorotic leaves. Fe-EDTA was more effective in reducing chlorosis in BARI-2000. FeSO$_4$ and Fe(III) were also active in increasing morph-physiological parameters as compared to Fe deficiency conditions. It may be concluded from present experiment that BARI-2000 was more responsive to the foliar application of Fe-EDTA, while BARD-699 was more responsive to other treatments. This showed genotypic differences as different genotypes responded differently towards the treatment of different chemicals.

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