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RESEARCH ARTICLE

Growth, Seed Yield and Quality of Mungbean as Influenced by Foliar Application of Iron Sulfate

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ABSTRACT

Mungbean (*Vigna radiata* L.) is an imperative legume crop in Asia. Iron (Fe) deficiency is a yield-limiting factor for a variety of field crops across the world. To increase Fe concentration in edible portions of food crops, foliar application of Fe-containing solutions might be sustainable and economical strategy; however, little information is available in the literature. So, the present work was conducted to evaluate the effect of foliar application of iron sulfate ($FeSO_4$) on growth, yield and quality of mungbean. The experiment was consisted of foliar applications of 0.5%, 1% and 1.5% solutions of $FeSO_4$ both at branching and flowering stages. The results revealed that various $FeSO_4$ treatments increased growth and yield components like plant height, number of pod bearing branches per plant, number of pods per plant, number of seeds per pod, 1000-grain weight and seed yield. Moreover, application of $FeSO_4$ also improved the quality of mungbean by increasing protein and iron contents in grains. Application of 1.5% foliar $FeSO_4$ both at branching and flowering stages gave higher number of pods per plant (44.64%), number of seeds per pod (45.31%), 1000-grain weight (18.97%), and grain yield (38.66%) and also improved the quality of grains by increasing protein contents (6.60%) and iron contents (46.39%) in grains as compared to control. Thus, we conclude that application of $FeSO_4$ improves the growth, yield and iron contents in different parts of mungbean.

INTRODUCTION

Pulses are vital food crops and offer a cheap source of protein. In Asia, mungbean (*Vigna radiata* L.) is an important pulse crop ranked as the second most drought resistant crop after soybean. It has more protein contents and better digestibility than any other pulse crop (Tabasum et al., 2010). It can be grown under drought stress conditions, where, the short time is available for growth. It grows well under both irrigated as well as rain fed conditions. Salt affected soils are fit for its production, while, it cannot grow well in waterlogged condition (Yadave et al., 1998). Mungbean grains contain 51% carbohydrates, 26% protein, 10% moisture and 3% vitamins. The residues of mungbean are also used as feed for animals and enhance the soil fertility as well (Asaduzzaman, 2008). A balanced fertilization program with macro- and micro-nutrients in plant nutrition is very important in the production of high yield with high quality products (Sawan et al., 2001). Micronutrients, such as zinc (Zn), selenium (Se), and iron (Fe) play an important role in human growth, development, and maintenance of the immune system (Shenkin, 2006). Iron (Fe) is one of the most important micronutrients and approximately 2 billion people suffer from Fe deficiency worldwide, which has often been claimed to be the predominant cause of anemia (Welch and Graham, 1999). It comprises approximately 5% of the earth's crust and is the fourth most abundant element in the lithosphere (Tisadale et al., 1993). Fe is an essential nutrient element for plant growth and development, and is involved in chlorophyll (Chl) and thylakoid synthesis and chloroplast development. Although the total Fe content of soils is much higher than plants require but its bioavailability is limited (Guerinot and Yi, 1994), particularly in calcareous soils, which cover about 30% of the earth's surface (Vose, 1982). As a result, Fe deficiency chlorosis is evident in about 30% of crops worldwide (Imsande, 1998). Catalase has major role in photorespiration reactions, as well as in glycolate pathway and involved in the protection of chloroplast from the free radicals produced during the water splitting reaction of photosynthesis (Allen et al., 2007). Fe is a cofactor for approximately 140 enzymes that catalyze unique biochemical reactions (Brittenham, 1994). Foliar feeding is a relatively new and controversial technique of feeding plants by applying liquid fertilizer directly to their leaves (Bernal et al., 2007; Baloch et al., 2008). The main advantage of foliar applied Fe is that the fixation reactions of Fe in alkaline/calcareous soils are avoided (Mengel, 1995). The foliar nutrition to decrease deficiency problem is an alternative option in case of failure to do so in soil application (Cakmak, 2008). In open environment, the factors affecting nutrients uptake are different, fertilization to leaf can give considerable results. The application of Fe and zinc on the leaves of plant decreases the effect of drought (Sultana et al., 2001). In plants, micronutrients uptake and transport can be enhanced by the use of fertilizer through leaf. The foliar application is beneficial and reactive method to supply the nutrients to crop grain. To decrease the micronutrients deficiencies in plants, fertilization through leaf have been used (Godsey et al., 2003). The aim of present study was to examine the effects of Fe-containing solution on growth, yield and its impacts on protein and iron contents in grains of mungbean under field condition.

MATERIALS AND METHODS

The variety of mungbean used in experiment was NIAB Mung-2006. In this study, 30 kg seeds per hectare were applied by hand drill. Mungbean seeds were first surface-sterilized in 1.5% (v/v) sodium hypochlorite for 10 min, rinsed thoroughly in deionized water and imbibed in drum containing a shallow layer of deionized water at room temperature overnight, and next day sowing was carried out by hand drill, maintaining plant-to-plant distance of 10 cm and row-to-row distance of 30 cm. The experiment was conducted in Research Area of Department of Agronomy, University of Agriculture Faisalabad, Pakistan during spring season in 2010 under the loamy soil conditions. The properties of the experimental soil were: pH 7.5, organic matter (OM) 0.96%, available phosphorus (P) 16.7 mg/L, available nitrogen (N) 0.052 mg/L, available potassium (K) 234 mg/L, available iron 3 mg/L, saturation 45%, texture loam, SAR 6.4, ESP 7 and EC 1.26 dS/m. At sowing time, fertilizer was applied to the crop with a dose of 57 kg phosphorus ha^{-1} and 23 kg nitrogen ha^{-1} in the form of diammonium phosphate and urea respectively. The average 4-6 irrigations were applied to field as per needed. The following spray treatments were applied: (1) Control (the deionized water spray); (2) 0.5% $FeSO_4$ at branching; (3) 0.5% $FeSO_4$ at flowering; (4) 0.5% $FeSO_4$ at branching + 0.5% $FeSO_4$ at flowering; (5) 1% $FeSO_4$ at branching; (6) 1% $FeSO_4$ at flowering; (7) 1% $FeSO_4$ at branching + 1% $FeSO_4$ at flowering; (8) 1.5% $FeSO_4$ at branching; (9) 1.5% $FeSO_4$ at flowering; and (10) 1.5% $FeSO_4$ at branching + 1.5% $FeSO_4$ at flowering. The experiment was laid out in randomized complete block design (RCBD) with three replications, having a net plot size of 5 m x 1.5 m each and total 3 liter solution of $FeSO_4$ was applied to each plot.

At maturity stage, all the growth parameters including plant height and yield parameters like number of pod bearing branches, number of pods per plant, number of grains per pod, 1000-seed weight, biological yield and grain yield samples were collected from randomly selected 10 plants from each plot and then averaged them. The number of nodules per plant was also measured according to Tang et al. (1990) at the time of maturity. The grain yield was corrected to 14% moisture content before final weighing was carried out (Olaleye et al., 2009).

Grain samples from each pot were collected. Samples were rinsed thoroughly with 0.01 M hydrochloric acid (HCl) and then washed with the deionized water in order to eliminate the contamination of the foliar fertilizer. Then air dried mungbean grains were grounded with a sample grinder (Model Retsch MM301, Germany). The ground samples were stored in sealed plastic bags at room temperature until they were analyzed. One-half gram of powder sample was loaded in a crucible and then ashed thoroughly in a muffle furnace at 500°C, and dissolved in 0.5% nitric acid (HNO_3) (GR) to 25 mL (Sah and Brown, 1997; Lu, 2000). Iron contents were determined by the inductively coupled plasma mass spectroscopy (ICP-MS, Model Agilent 7500A, Santa Clara, CA, USA). Reference material [the ground samples, GBW (E) 080684] and blanks were included in each ashing process and determination. The soluble protein content was analyzed by using Coomassie Brilliant Blue G-250 as dye and albumin as a standard (Bradford, 1976).

The data recorded was analyzed by using a statistical package, version 16.0 (SPSS, Chicago, IL, USA) and difference among the treatments was compared by Duncan's Multiple Range (DMR) Test (Steel et al., 1997).

RESULTS AND DISCUSSION

It was observed from the results that different treatments of iron sulfate ($FeSO_4$) did not show any effect on the plant population of mungbean. Moreover, results showed that plant height was significantly influenced by the application of $FeSO_4$ (Table 1). The maximum plant height (59.07 cm) was observed in case of T_{10} and minimum plant height (45.00 cm) was observed in control conditions. The data explained that plant height was increased as we increased the $FeSO_4$ concentration. Previously, it was also found that plant height increased due to the application of iron in *Nigella sativa* and in *Vigna radiata* (Khoulenjani and Salamati, 2011; Ohwaki et al., 1997). This finding is in agreement with Brown et al. (1993), who reported that Fe improves the plant growth. In addition, it has been reported that foliar application of micro-nutrients such Fe, increases stem length and also improves dry concentration matter in corn (Whitty and Chambliss, 2005). The maximum number of pod bearing branches (7.27) and nodules per plant (16.07) were obtained under the application of 1.5% $FeSO_4$ at both branching and flowering stages (Table 1). It was proved that application of $FeSO_4$ increased the number of nodules per plant in *Lupinus angtistifolius* (Tank et al., 1990 not in references) and the number of pod bearing branches in mungbean (Fawzi et al., 1993). The increase in pod bearing branches might be due the application of Fe which effect on photosynthesis and play an important role on plant growth (Malakoti et al., 1999). However, legume-Rhizobium symbiosis is a highly integrated system. Deficiencies of mineral nutrients may act on the symbiosis indirectly, by decreasing host plant growth and available metabolites, or directly. Apart from effects on host-legume growth, deficiency of a nutrient may affect the growth and survival of rhizobia, nodule initiation and development, or nodule function (Robson, 1983). Fe is an essential nutrient required by both host legume and bradyrhizobia for a range of physiological and biochemical processes. Its deficiency also resulted in decreased nodule number and nodule mass in chickpea (Rai et al., 1982), lentil (Rai et al., 1984), French bean (Hemantaranjan and Garg, 1986) and peanut (O'Hara et al., 1988), but these studies did not determine the limited nodulation due to Fe deficiency.

The data regarding number of pods, number of seeds per pod and 1000-seed weight of mungbean under different treatments of foliar $FeSO_4$ has been shown in Table 2. Results showed that maximum number of pods per plant (34.20), the maximum numbers of seeds per pod (12.80) and maximum 1000-seed weight (68.00 g) were found under the highest level of Fe (1.5% $FeSO_4$) at both branching and flowering stages. It has been found that application of Fe increased the number of pods per plant in mothbean (Sachendra et al., 2006) and mungbean (Panpruick et al., 2002), because Fe involves in the chlorophyll synthesis process. Moreover, it was found that foliar Fe application under different irrigation regimes increased the 1000-seed weight in sunflower (Ebrahimian and Bybordi, 2011). The 1000-seeds weight was also increased because of Fe concentration (Table 2). These results regarding seed weight are in agreement with Malakoti and Tehrani (1999) who reported that micronutrients increased the yield of agriculture products.

Table 1: Effects of different treatments of foliar application of iron sulfate on plant population, plant height, number of pod bearing branches per plant and number of nodules per plant of mungbean

Treatments	Plant Population /m^2	Plant height (cm)	Pod-bearing branches/ plant	Number of nodules/ plant
T_1	32.66	45.00 g	4.13 e	6.00 e
T_2	33.33	50.80 f	5.50 d	9.00 d
T_3	33.33	50.20 f	5.40 d	8.40 d
T_4	33.33	54.80 d	6.10 c	12.27 c
T_5	32.00	53.90 e	5.60 d	11.90 c
T_6	32.66	53.43 e	5.57 d	11.80 c
T_7	33.33	57.40 b	6.70 b	14.60 b
T_8	32.00	56.00 c	6.30 c	13.07 c
T_9	32.66	55.83 c	6.20 c	13.00 c
T_{10}	33.33	59.07 a	7.27 a	16.07 a

The same letters after the data within a column mean no significant difference at 95% probability level; T_1= Control; T_2= 0.5% $FeSO_4$ at branching; T_3= 0.5 % $FeSO_4$ at flowering; T_4= 0.5% $FeSO_4$ at branching + 0.5% $FeSO_4$ at flowering; T_5= 1% $FeSO_4$ at branching; T_6= 1% $FeSO_4$ at flowering; T_7= 1% $FeSO_4$ at branching + 1% $FeSO_4$ at flowering; T_8= 1.5% $FeSO_4$ at branching; T_9= 1.5% $FeSO_4$ at flowering; and T_{10} =1.5% $FeSO_4$ at branching + 1.5% $FeSO_4$ at flowering

Table 2: Effects of different treatments of foliar application of iron sulfate on number of pods per plant, number of seeds per pod and 1000-seed weight (g) of mungbean

Treatments	Number of pods/plant	Number of seeds/pod	1000-seed Weight
T_1	18.93 f	7.00 e	55.10 g
T_2	24.67 e	9.00 d	58.03 f
T_3	24.37 e	8.67 d	57.93 f
T_4	27.20 d	10.33 bcd	62.70 cde
T_5	26.90 d	9.93 cd	62.43 de
T_6	26.73 d	9.67 cd	62.13 e
T_7	30.20 b	11.83 ab	66.00 b
T_8	28.83 c	11.00 bc	63.93 c
T_9	28.43 c	10.90 bc	63.80 cd
T_{10}	34.20 a	12.80 a	68.00 a

The same letters after the data within a column mean no significant difference at 95% probability level; T_1= Control; T_2= 0.5% $FeSO_4$ at branching; T_3= 0.5% $FeSO_4$ at flowering; T_4= 0.5% $FeSO_4$ at branching + 0.5% $FeSO_4$ at flowering; T_5= 1% $FeSO_4$ at branching; T_6= 1% $FeSO_4$ at flowering; T_7= 1% $FeSO_4$ at branching + 1% $FeSO_4$ at flowering; T_8= 1.5% $FeSO_4$ at branching; T_9= 1.5% $FeSO_4$ at flowering; and T_{10} =1.5% $FeSO_4$ at branching + 1.5% $FeSO_4$ at flowering

The data regarding biological yield, seed yield and protein contents in the grains of mungbean under different treatments of foliar $FeSO_4$ is shown in Table 3. It was observed that application of $FeSO_4$ significantly increased biological yield, seed yield and the protein contents in the grains of mungbean. The

Table 3: Effects of different treatments of foliar application of iron sulfate on biological yield (Kg ha^{-1}), seed yield (Kg ha^{-1}) and protein contents (mg g^{-1}) in grains of mungbean

Treatments	Biological yield	Seed yield	Protein contents in grains
T_1	4300.0 e	1533.3 f	256.43 f
T_2	4800.0 d	1900.0 de	257.23 f
T_3	4700.0 d	1833.3 e	259.60 ef
T_4	5200.0 c	2000.0 cde	263.1 cde
T_5	5166.7 c	2066.0 bcde	260.0 ef
T_6	5133.3 c	2033.0 bcde	261.4 def
T_7	5600.0 ab	2300.0 ab	270.4 ab
T_8	5400.0 bc	2200.0 bc	266.2 bcd
T_9	5366.7 bc	2133.0 bcd	268.1 bc
T_{10}	5900.0 a	2500.0 a	274.6 a

The same letters after the data within a column mean no significant difference at 95% probability level; T_1= Control; T_2= 0.5% $FeSO_4$ at branching; T_3= 0.5% $FeSO_4$ at flowering; T_4= 0.5% $FeSO_4$ at branching + 0.5% $FeSO_4$ at flowering; T_5= 1% $FeSO_4$ at branching; T_6= 1% $FeSO_4$ at flowering; T_7= 1% $FeSO_4$ at branching + 1% $FeSO_4$ at flowering; T_8= 1.5% $FeSO_4$ at branching; T_9= 1.5% $FeSO_4$ at flowering; and T_{10} =1.5% $FeSO_4$ at branching + 1.5% $FeSO_4$ at flowering

Table 4: Effects of different treatments of foliar application of iron sulfate on iron contents (µg^{-1}) in leaves, stems and grains of mungbean

Treatments	Iron content in leaves	Iron content in stems	Iron content in grains
T_1	511.37 h	380.07 g	78.50 g
T_2	601.73 g	470.42 f	90.43 f
T_3	623.70 f	488.17 e	96.10 e
T_4	675.43 d	520.24 d	101.50 e
T_5	654.07 e	515.22 d	96.83 e
T_6	668.37 de	505.16 de	99.60 e
T_7	717.17 b	585.54 b	127.80 b
T_8	672.60 d	550.33 c	115.73 d
T_9	698.70 c	559.51 c	121.43 c
T_{10}	794.90 a	634.27 a	146.43 a

The same letters after the data within a column mean no significant difference at 95% probability level; T_1= Control; T_2= 0.5% $FeSO_4$ at branching; T_3= 0.5% $FeSO_4$ at flowering; T_4= 0.5% $FeSO_4$ at branching + 0.5% $FeSO_4$ at flowering; T_5= 1% $FeSO_4$ at branching; T_6= 1% $FeSO_4$ at flowering; T_7= 1% $FeSO_4$ at branching + 1% $FeSO_4$ at flowering; T_8= 1.5% $FeSO_4$ at branching; T_9= 1.5% $FeSO_4$ at flowering; and T_{10} =1.5% $FeSO_4$ at branching + 1.5% $FeSO_4$ at flowering

maximum biological yields (5900.0 kg ha^{-1}), maximum seed yield (2500.0 kg ha^{-1}) and maximum protein contents in grains (274.6 µg g^{-1}) were observed in T_{10} treatment; which is statistically at par with T_7 treatment. Previously, it was stated that application of Fe improved the biological yield in groundnut (Singh and Chaudhary, 1999 or 1997). It has been well documented in the literature that foliar application of Fe plays an important role in increasing the yield of mungbean (Kumawat et al., 2006). It was concluded that application of nutrients through foliar sprays increased the seed yield of soybean (Haq and Mallarino, 2000). Recently, Habib (2009) confirmed that foliar application of Fe and Zn increased the seed yield in wheat. Moreover, they concluded that protein contents increased with increasing the Fe levels in the treatments. It has been documented that Fe plays an important role in synthesis of chlorophyll and plant growth regulators (Jin et al., 2008). Fe improves photosynthesis and assimilates transportation to sinks and finally increased seed yield. The increase in biological and seed yield might be due to increase of carbohydrate synthesis as previously described (Hemantaranjan and Gray, 1988).

The data regarding Fe contents in leaves, stems and roots under different concentration of foliar iron sulfate have been shown in the Table 4. Results stated that maximum Fe contents in leaves (794.60 µg g^{-1}), in stems (634.27 µg g^{-1}) and in grains (146.43 µg g^{-1}) were observed under T_{10} treatments. As like present findings, previously it was also found that when Fe–EDTA was applied as a foliar fertilizer to soil-grown plants, the growth and Fe contents were significantly enhanced in red clover (Jin et al., 2006). Moreover, it was stated that Fe contents increased in beans with the application of Fe (Karaman et al., 1997). It was observed that Fe contents increased by 21% as compared to control in wheat grains under the foliar application of iron (Pahlavan-Rad and Pessarakali, 2009). The results stated that foliar application of $FeSO_4$ enhanced the Fe contents in mungbean grains, which significantly increased the seed quality. The same results also observed earlier by Patel et al. (1993) with the application of iron sulfate on the groundnut plants.

Conclusion

From the findings of present study, it can be concluded that application of iron sulfate ($FeSO_4$) improved plant growth, yield and increased the quality of mungbean (*Vigna radiata* L.) in terms of improving Fe contents in the grains. The $FeSO_4$ as 1.5% foliar spray both at branching and flowering stages, was suitable to gain better yield and quality of mungbean, because at this level, we found better plant growth, yield and protein contents in grains as compared to control. Based on these findings, we concluded that $FeSO_4$ could be used for sustainable production of this important leguminous crop.

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