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ADDITIONAL NOTE ON INHERITANCE OF FE-DEFICIENCY CHLOROSIS IN CHICKPEA (*Cicer arietinum* L.)

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ABSTRACT

When susceptible cultivars are grown in calcareous soils with high pH, significant yield loss due to iron (Fe) deficiency chlorosis is brought about in chickpea (*Cicer arietinum* L.). One of the most efficient ways for solve this problem is improved of Fe-deficiency chlorosis via conventional breeding methods. In the study, genotypes ICC 4851 and ICC 4858, which are resistant to Fe-deficiency chlorosis, were crossed with genotype ICC 6119, which is susceptible to Fe-deficiency chlorosis, and studied genetics of Fe-deficiency chlorosis in F_1 and F_2 segregating generations. Fe-deficiency chlorosis was governed by a major recessive gene and affected by environment factors like high temperature. A negative selection seems to be an effective approach after segregation in F_2 or later generations.

Key words: Chickpea; chlorosis; genetics; iron deficiency; resistance

INTRODUCTION

The cultivated chickpea (*Cicer arietinum* L.) is the first rank among cool season food legumes on the basis of harvested area with 12.3 million ha, and it is produced 11.6 million ton. Its globally average seed yield has been increased 318 kg per ha from 649 kg (in 1961) to 967 kg in 2013 (FAOSTAT 2013). However, its seed yield is still too low when compared to its potential seed yield because it is mainly grown in rainfed conditions. In some gates of these areas, it faces some nutrient deficiencies resulting in seed yield losses. One of the most important problems is iron (Fe) deficiency when the susceptible cultivars are grown in the problematic conditions such as in calcareous soil (Gowda and Smithson, 1980; Singh et al., 1986; Ali et al., 1988; Ali et al., 2000; Ohwaki and Sugahara, 1993; Zaiter and Ghalayini, 1994). Seed yield in the cultivated chickpea can reduce by 50% in Lebanon, Syria and India due to Fe-deficiency (Sakal et al., 1987; Ali et al., 2002). Although Fe-deficiency chlorosis in chickpea can be overcome with application of 10-20 kg Fe granular fertilizers per ha (Srinivasarao et al., 2003), high pH in the calcareous soil may be limited the benefits provided by the application (Ahlawat et al., 2007). The alternative approaches to overcome Fe-deficiency chlorosis is a foliar spray of 250 L per ha of 1% $FeSO_4$ (Ahlawat et al., 2007). Both of the applications can mostly be uneconomical and inconvenient since they need additional labor, time and inputs. Thus, one of the most economical and permanent approaches is grown suitable cultivars, which can efficiently obtain Fe from calcareous soil with high pH (Coyne et al., 1982; Fehr, 1984; Fairbanks, 2000). Selection of Fe-efficient chickpea genotypes depends on knowledge about its inheritance and genetics is of critical importance. In chickpea, genetics and inheritance of Fe-deficiency chlorosis were studied by Ali et al. (1988), Gowda and Smithson (1980), Halila (1983) and Saxena et al. (1990) but environmental factors have been ignored in these studies made on Fe-deficiency chlorosis. In the present study, it was evaluated inheritance of Fe-deficiency chlorosis in chickpea considering environmental factors viz. temperature.

MATERIALS AND METHODS

Crosses

ICC 6119 (♀), Fe-deficiency chlorosis susceptible genotype (Toker et al., 2010), was crossed with ICC 4951 and ICC 4958 (♂), Fe-efficient genotype and resistant to drought (Saxena et al., 1993; Canci and Toker, 2009) at Antalya location (approximately 30^o 44’ E, 36^0 52’ N, 51 m from sea level) under field conditions. Sowing of the materials was done by hand in autumn (November and December) and harvest was done by hand in beginning of the summer.

Agronomic practices

F_1 and F_2 plants were sown and grown at Antalya location in 2005-2006 and 2006-2007 growing seasons under rainfed conditions. Row and plant spacing were adjusted as 45 cm and 5 cm, respectively. Prior to sowing, fertilization was applied with N, P and K at rate of 20 kg per ha. Weed control was made by hand. Additional irrigation was not applied.

Screening for Fe-deficiency chlorosis

Materials were screened for Fe-deficiency chlorosis using some modifications of (Table 1) a visual 1-9 scale (Saxena et al., 1990) before flowering stage because Fe-deficiency chlorosis in ICC 6119 was transient.

Table 1. A visual 1- 9 scale and reaction category of plants.

Scale	Reaction category	Visual reaction of plants
1	Very highly resistant	Plants free from any Fe-deficiency symptoms
2	Highly resistant	1% leaflets yellow
3	Resistant	2-5% leaflets yellow
4	Moderately resistant	6-10% leaflets yellow
5	Intermediate	11-50% leaflets and some plants yellow
6	Moderately susceptible	51-75% leaflets and about 25% plants show yellowing
7	Susceptible	76-80% leaflets and about 26-50% plants show yellowing
8	Highly susceptible	81-99% leaflets and about 51-75% plants show yellowing
9	Very highly susceptible	All plants show yellowing color and stopped

Characteristics of experimental soil

Soil sample was taken once before sowing in the first year. Therefore, results of soil analyses were given for one year in Table 2. Soil was high calcareous and moderately alkaline. Available Fe concentration was very low with high pH in experimental soil.

Table 2. Soil analyses results.

Soil Parameters	Results	Interpretation
pH	7.96	Moderately alkaline
E.C (mS/cm)	0.93	No salinity effects
$CaCO_3$ (%)	26.5	High calcareous
Sandy (%)	45.08	-
Clay (%)	31.28	-
Silt (%)	23.64	-
Texture		Candy clay loam
Organic matter (%)	1.87	Low
Total N (%)	0.106	Medium
Available P (ppm)	9.37	Medium
Exchangeable K (meq / 100 g)	0.61	Optimum
Exchangeable Na (meq / 100 g)	0.15	Low
Exchangeable Ca (meq / 100 g)	37.71	Optimum
Exchangeable Mg (meq / 100 g)	7.12	Optimum
Available Fe (ppm)	3.56	Very low
Available Zn (ppm)	0.746	Low
Available Mn (ppm)	23.156	Optimum
Available Cu (ppm)	1.368	High

Records for climatic conditions

Data for weather condition at Antalya location were presented in Table 3. Maximum temperatures reached up to 43.5ºC during the growing period.

Statistical analyses

Chi-squares ($\chi 2$) test was performed in F_2 plants with the following formula: $\chi 2 = \Sigma(O-E)^2/E$, where E and O are expected and observed values, respectively (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Records for Fe-deficiency chlorosis

The soil was considered an ideal chose to differentiate of Fe-deficiency and Fe-efficiency in chickpea since Fe content of the soil was found to be low with high pH (Table 1).

As seen in Table 4, six hybrids were obtained from the cross between ICC 6119 and ICC 4951, while the cross between ICC 6119 and ICC 4958 produced 11 hybrids.

All F_1 plants were found as Fe-efficient, while F_2 plants were segregated in point of Fe-deficiency chlorosis. In F_2 observation, 88 plants were recorded as resistant, while 30 plants were recorded as susceptible in cross ICC 6119 x ICC 4958. In the cross ICC 6119 x ICC 4958, 108 plants were found as resistant, while 38 plants were found as susceptible.

Table 3. Weather conditions during 2005-2006 and 2006-2007 growing seasons.

Months	**Temperature (°C)**								**Rainfall (mm)**	
	Average maximum		**Average minimum**		**Extreme maximum**		**Extreme minimum**			
	2005-2006	2006-2007	2005-2006	2006-2007	2005-2006	2006-2007	2005-2006	2006-2007	2005-2006	2006-2007
October	25.7	25.9	14.5	15.5	31.4	33.4	9.0	12.2	17.2	494.7
November	19.9	20.2	9.7	8.7	24.4	26.0	4.8	3.8	142.2	126.4
December	17.4	17.6	7.8	8.3	25.4	21.8	2.6	1.8	129.6	66.4
January	14.2	16.2	5.4	8.3	18.4	21.1	1.0	4.3	319.0	136.8
February	15.9	16.0	6.9	9.0	21.4	20.7	0.2	2.4	84.5	182.6
March	18.2	18.7	9.1	11.1	21.7	22.3	4.1	8.4	78.2	10.2
April	22.4	22.2	12.6	13.8	29.4	27.3	9.2	10.5	87.3	1.6
May	26.9	25.6	15.4	18.9	40.2	35.0	10.8	14.0	12.3	5.2
June	31.5	31.7	20.4	23.8	38.2	43.5	16.0	17.8	21.9	1.4

Table 4. Segregation for Fe-deficiency chlorosis in F_2 progeny.

Crosses		**F_1**	**F_2**		
Susceptible (S)	Resistant (R)	No. of R:S Plants	No. of R:S Plants	Expected	χ^2
ICC 6119 (♀)	ICC 4951 (♂)	6 Resistant	88 Resistant: 30 Susceptible	3:1	0.01
ICC 6119 (♀)	ICC 4958 (♂)	11 Resistant	108 Resistant: 38 Susceptible	3:1	0.08

Ratio for Fe-efficiency and Fe-deficiency in F_2 plants was found as fixed well for 3:1 segregating ratio (Table 4). These finding shows that Fe-deficiency chlorosis is governed by a major recessive gene with minor genes since Fe-deficiency were affected by environmental effects such as high temperature. Fe-deficiency chlorosis disappeared after air temperatures rose to 40°C in May (Table 2) indicating that it is affected by temperature. Prior to the present study, monogenic inheritance for Fe-deficiency chlorosis has been reported in chickpea (Gowda and Rao,1986; Saxena et al., 1990; Toker et al., 2010). F_2 plants show continuous distribution for Fe-deficiency and Fe-efficiency (Fig. 1). Distribution of F_2 plants (Fig 1) indicated that there were small genes effects on Fe-deficiency chlorosis. Gumber et al. (1997) reported that Fe-deficiency chlorosis was controlled by two homozygous recessive genes, and the irrigation also increases Fe-deficiency chlorosis in chickpea. Bejiga et al. (1996) found that Fe-deficiency chlorosis was more outshined problem in autumn-sown chickpeas when compared to traditional spring-sown crops. In lentil (*Lens culinaris* Medik.), Erskine et al. (1993) pointed out that Fe-deficiency chlorosis was transient since Fe-deficiency symptoms disappeared under day length and high temperature conditions. In faba bean (*Vicia faba* L.) and pea (*Pisum sativum* L.), environmental effects on Fe-deficiency chlorosis was reported by Kosagarten et al. (1988) and Kabir et al. (2013). In common bean (*Phaseolus vulgaris* L.), Fe-deficiency chlorosis is primarily governed by two complementary dominant genes (Zaiter et al., 1987).

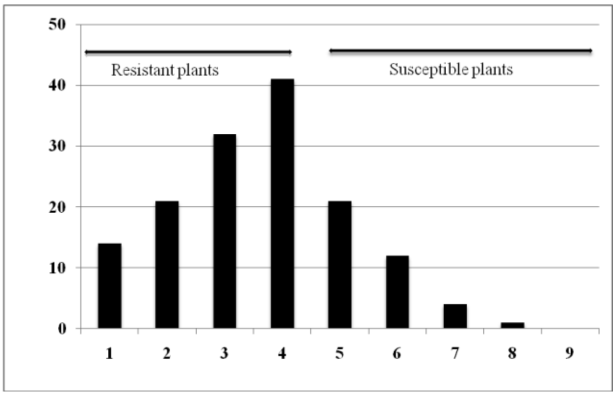

Figure 1. Visual scale (1- 9) for resistance to Fe-deficiency chlorosis in F_2.

In chickpea, the gene symbols '*fe*' for susceptibility and '*Fe*' for Fe-efficiency and Fe-deficiency chlorosiswere used by Gowda and Rao (1986) and Toker et al. (2010). In the present study, it was suggested that the gene symbols '*Fe*' and '*fe*' could be used for resistance and susceptipllity, respectively. In irrigated chickpea, *Y1* and *Y2* and *y1* and *y2* were used for Fe-efficiency and Fe-deficiency chlorosis, respectively (Gumber et al., 1997).

To breed Fe-efficient chickpea, Saxena et al. (1990) suggested that plants susceptible to Fe-deficiency chlorosis should be removed in F_2 and later generations. Similarly, Toker et al. (2010) pyramided both of genes for resistance to Fe-deficiency and leaf miner (*Liriomyza cicerina* Rond.) after M_2. In conclusion, Fe-deficiency chlorosis was governed by a single recessive gene with minor genes affected by high temperature. Also, negative selection will be effective in F_2 and later generations.

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