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INHERITANCE OF RESISTANCE TO IRON DEFICIENCY CHLOROSIS IN CHICKPEA (*CICER ARIETINUM* L.)

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□ *Iron (Fe)-deficiency chlorosis causes considerable yield losses in chickpea (*Cicer arietinum *L.) when susceptible genotypes are grown in calcareous soils with high pH. The most feasible method for alleviating Fe deficiency is the selection of suitable cultivars resistant to Fe deficiency chlorosis. ICC 6119 (desi type), which is Fe-deficient chlorosis, was crossed with CA 2969 and Sierra (kabuli types), resistant to Fe deficiency chlorosis. Inheritance of resistance to Fe deficiency in chickpea revealed that the resistance was controlled by a single dominant gene in these genotypes crossed. A negative selection for resistance to Fe deficiency chlorosis will be effective after segregating generations.*

Keywords: chickpea, chlorosis, inheritance, iron deficiency, resistance

INTRODUCTION

Based on the World Reference Base Soil Classification System (FAO, 2006), calcareous soil is classified under the reference soil group of Calcisols covering 800 million hectares worldwide, mainly found in South Asia, (Gowda and Smithson, 1980; Saxena and Sheldrake, 1980; Singh et al., 1986; Ali et al., 1988, 2000; Ohwaki and Sugahara, 1993; Srinivasarao et al., 2006), Australia (Siddique et al., 2000) and West Asia and North Africa under arid and semi-arid climates or Mediterranean climates (Halila, 1983; Erskine et al., 1993; Zaiter and Ghalayini, 1994; Sonmez and Kaplan, 2004; Mahmoudi et al., 2005, 2007; Toker et al., 2007).

Although iron (Fe) is absorbed from soil in both $Fe^{2+}$and Fe^{3+}forms (Gupta and Gupta, 2005), the availability of Fe^{3+} in calcareous soil decreases markedly when the pH of the soil is high (Lucena, 2003; Rashid and Ryan,

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2004). Therefore, Fe deficiency in this type of soils is an important problem limiting the growth and production of many crop plants cultivated (Singh et al., 1986; Alloush et al., 1990; Jolley and Brown, 1991; Chaney et al., 1992; Ellsworth et al., 1997; Ashraf and Zafar, 1998; Li et al., 2000; Krouma et al., 2003; Rashid and Ryan, 2004).

Yield reduction in chickpea due to Fe deficiency was estimated up to 44% in Syria and Lebanon and about 24–50% in India (Saxena and Sheldrake, 1980; Sakal et al., 1987; Ali et al., 2002). Although promising results of soil application of 10–20 kg Fe per ha was reported (Srinivasarao et al., 2003), the high pH of calcareous soil usually hinders the benefits in the long run (Ahlawat et al., 2007). Instead of soil application, a foliar spray of 250 L per ha of 1% iron sulfate ($FeSO_4$) solution was found to improve chickpea yield (Ahlawat et al., 2007). Chickpea is generally grown in marginal areas with low yield (Toker et al., 2007), which makes both approaches above uneconomical due to additional labor and inputs. Also, foliar application of Fe-chelate reduces availability of manganese (Ghasemi-Fasaei et al., 2005). Therefore, the most feasible method for alleviating Fe deficiency seems to be the selection of suitable cultivars, which can acquire Fe-efficiently from calcareous soil with high pH (Coyne et al., 1982; Fehr, 1984; De Cianzio, 1991; Fairbanks, 2000). This study was aimed to study the inheritance of Fe deficiency chlorosis and resistance in chickpea.

MATERIAL AND METHODS

Crosses

In 2004–2005 growing season, the Fe deficiency chlorosis susceptible genotype ICC 6119 (♀) (Toker et al., 2010) was crossed with CA 2969 (♂) (Rubio et al., 2003) and Sierra (♂) separately (Muehlbauer et al., 2004), which are resistant to Fe deficiency chlorosis and kabuli types, at Antalya location (approximately 30° 44′ E, 36° 52′ N, 51 m from sea level) under field conditions. F_1 and F_2 generations were grown at the same location in 2005–2006 and 2006–2007 growing seasons, respectively.

Agronomic Practices

All mentioned materials and generations were grown with 45 cm row and 5 cm plant spacing. Materials were fertilized with nitrogen (N), phosphorus (P), and potassium (K) at rate of 20 kg per ha prior to sowing. Weed control was done by hand prior to flowering stage.

Screening for Resistance to Fe Deficiency Chlorosis

Filials and parents as well were screened for Fe deficiency chlorosis before flowering stage. Green parts of plants free from any symptoms of chlorosis, and the youngest yellow leaflets of plants were accepted as Fe-resistant and Fe-susceptible, respectively.

Statistical Analyses

Chi-squares (χ^2) test was performed for goodness of fit of three Fe-resistant to one Fe-susceptible chlorosis ratio in F_2 according to the formula: $\chi^2 = \Sigma\,(O\text{-}E)^2/E$, where O and E are observed and expected values, respectively (Steel and Torrie, 1980).

RESULTS

Soil Analyses

Organic matter and total nitrogen in the experimental area were at low levels, 1.87 and 0.106%, respectively. Soil texture was loam with a pH of 8.0, 0.9 mS cm^{-1} electrical conductivity and 26.5% calcium carbonate ($CaCO_3$). Available manganese (Mn), phosphorus (P), iron (Fe), copper (Cu), and zinc (Zn) were 23.2, 9.4, 3.6, 1.4, and 0.8 ppm, respectively; whereas exchangeable calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) were 37.7, 7.1, 0.6, and 0.2 mg per 100 g, respectively. Iron and Zn were also considered to be at low levels.

Climatic Records

Rainfall was irregular and drastically decreases in spring months, while temperature increased gradually during spring months, typical Mediterranean climate. During the cropping season, the maximum temperature was recorded more than 35°C during flowering and pod filling stages (Canci and Toker, 2009a, 2009b). High temperature reduced the number of successful crosses.

Genetics of Fe Deficiency Chlorosis

In F_1 generation, all filials obtained between Fe deficiency chlorosis susceptible genotype ICC 6119 (♀) and Fe-efficient genotype CA 2969 and Sierra (♂) were resistant to Fe deficiency chlorosis (Table 1) showing dominant character of Fe-efficiency over Fe deficiency chlorosis. Moreover, all F_1 plants had normal leaf type, while ICC 6119, CA 2969 and Sierra have multipinnate or bipinnate, normal and simple leaves, respectively. This result indicated that normal leaf type was dominant over multipinnate leaf type.

In F_2 generation, the ratios of Fe-efficient to Fe-deficient progenies for crosses ICC 6119 × CA 2969, and ICC 6119 × Sierra were found as 88:30 and 83:21, respectively (Table 1). Segregating progenies of former cross

TABLE 1 Genetics of resistance to Fe-deficiency chlorosis

Parents/Crosses		F_1		F_2			
Susceptible	Resistant	No. of plants tested	No. of resistant: susceptible plants	No. of plants tested	No. of resistant: susceptible plants	Expected ratio	χ^2 (Probability)
ICC 6119 (♀)	x CA 2969 (♂)	6	6 : 0	118	88 : 30	3 : 1	0.014 (0.97–0.95)
ICC 6119 (♀)	x Sierra (♂)	6	6 : 0	104	83 : 21	3 : 1	0.009 (0.97–0.95)

produced only normal and multipinnate leaves, while the latter cross produced all three types of leaves; normal, multipinnate, and simple leaves (data not shown).

DISCUSSION

The results of this study demonstrated that Fe deficiency chlorosis in chickpea was controlled by a single dominant gene (Table 1). Gowda and Rao (1986) and Saxena et al. (1990) reported similar results previously, and our findings confirmed their results in chickpea. However, Gumber et al. (1997) found that Fe deficiency chlorosis in irrigated chickpea was governed by two homozygous recessive genes. Irrigation induced Fe deficiency in chickpea. The gene symbols *Y1* and *Y2* for resistance and *y1* and *y2* for susceptibility to Fe deficiency chlorosis in irrigated chickpea were proposed by Gumber et al (1997). Gowda and Rao (1986) proposed a symbol *fe* for susceptibility to Fe deficiency chlorosis. The gene symbols and the dominance relationship were proposed as *Fe* for resistance and *fe* for susceptibility and $Fe > fe$, respectively.

In lentil (*Lens culinaris* Medik.), it was found that resistance to Fe deficiency chlorosis was dominant and also controlled by a single gene (Ahmad et al., 1995; Ali et al., 1997). On the other hand, in common bean (*Phaseolus vulgaris* L.), Zaiter et al. (1987) found that resistance to Fe deficiency chlorosis was determined primarily by two complementary dominant genes. Dasgan et al. (2004) reported that resistance to Fe deficiency chlorosis in tomato (*Solanum lycopersicum* L.) was controlled by polygenic loci with a relatively high additive effect. Tolerance or moderate tolerance to Fe deficiency chlorosis in rice (*Oryza sativa* L.) was dominant over susceptibility and it was controlled by two sets of nonallelic genes with complementary interaction (Hoan et al., 1992). Genetics of Fe deficiency showed different reactions from genera to genera.

In F_1 generation, all filials obtained from crosses between ICC 6119 (multipinnate leaf) × CA 2969 (normal leaf) and ICC 6119 (multipinnate leaf) × Sierra (simple leaf) produced normal leaf. In F_2 generation, segregating progenies of the former cross produced only normal and multipinnate leaves, while the latter cross produced all three types of leaves. Although there is not a relationship between leaf type and Fe deficiency chlorosis in chickpea, these results indicated that normal leaf type in chickpea was dominant over multipinnate and simple leaf types (Rao et al., 1980; Muehlbauer and Singh, 1987; Pundir et al., 1990). Danehloueipour et al. (2008) have recently found similar results on inheritance of leaf type in chickpea.

Transient Fe deficiency chlorosis was observed in ICC 6119 because of Fe deficiency symptoms disappearing during reproductive growth. Erskine et al. (1993) found similar results in lentil. Bejiga et al. (1996) evaluated germplasm lines of chickpea and concluded that Fe deficiency chlorosis was more prominent in winter-sown chickpeas than spring-sown crops.

Saxena et al. (1990) recommended negative selection to discard the susceptible lines from breeding material under such this condition. Therefore, a negative selection for resistance to Fe deficiency chlorosis could be more effective after segregating generations.

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