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Relationships between seedling establishment and soil moisture content for winter and spring rapeseed genotypes

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ABSTRACT

Rapeseed cultivars are important for edible oil production under semiarid area regions in Iran. However, germination and seedling establishment of rapeseed cultivars are the critical steps in successful production of this oil crop plant that are not well understood. The objective of this study was to evaluate the effect of low soil moisture on emergence and seedling establishment of 24 rapeseed genotypes including 13 cultivars and 11 doubled haploid lines. A pot experiment was conducted in a greenhouse using a factorial experiment based on a completely randomized design with three replications. The genotypes were evaluated under different soil field capacity (FC) levels (80%, 50%, 30% and 20% FC). Decreasing the soil moisture content from 50% to 20% FC resulted in reduced overall final emergence from 94.3% to 82.7%. Significant differences were observed among genotypes under different soil moisture levels for all studied characters. Seedling vigor index and shoot growth of the tolerant genotypes were significantly higher under lower soil moistures levels. Studies on identification indices of drought resistance by principal component analysis (PCA) indicated that germination rate and final emergence were most important and better indicators of establishment in rapeseed. Cluster analysis and PCA method separated the genotypes into four groups. Genotypes in group I had the greatest tolerance, cluster II the intermediate tolerance, and clusters III and IV had the least tolerance to low soil moisture. In response to low soil moisture, cluster I (included GKH2005, Opera and Okapi) showed higher final emergence, rapid emergence, strong seedling vigor, and maximum shoot growth. On the other hand, cluster II (included DH1, DH3, DH4, DH5, DH7, DH8, DH9, DH10, DH11 and DH13) showed high coefficient of germination rate. Cluster III (included Cooper, SLM046, Lilian, Billy and Karun) had greater root length, cotyledon length and width, and root-to-shoot length with high mean time to germination whereas decreasing soil moisture resulted in severe reductions of final emergence and germination rate compared with those observed for 80% and 50% FC. Also, cluster IV (Included Adriana, Oase, Savanah, Triangle, Tasilo and DH6) had lower final emergence, delayed emergence, low growth potential, and high sensitivity for shoot and root growth. The results suggest that the genetic diversity within cluster I could be used for crop breeding programs and increasing the cultivation area in arid and semiarid regions of Iran.

1. Introduction

Drought is one of the major abiotic stresses, which adversely affects crop growth and is a global issue to ensure survival of agricultural crops and sustainable food production (Jaleel et al., 2007). Iran contains both arid and semiarid regions and drought stress is one of the major environmental stresses restricting crop production in the country.

Water stress is considered as important limiting factor at the initial phase of plant growth and seedling establishment (Devane, 2009). Drought may delay the onset, reduce the rate, and increase the dispersion of germination events; leading to reductions in plant growth and final crop yield (Omidi et al., 2009).

Rapeseed (*Brassica napus* L.) is one of the most important industrial crops in Iran. One of the major challenges for the production of rapeseed in Iran is the lack of uniform stand establishment of the plants due to poor weather and dry soil conditions (Mwale et al., 2003). Worldwide rapeseed production is approximately 62.4 million tons and covers a total area of 33.6 million hectares (FAOSTAT,

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2011). The seeds are occasionally sown in seed-beds having unfavorable moisture because of the lack of rainfall at sowing time (Angadi and Entz, 2002), which results in poor and non-uniform seedling emergence (Mwale et al., 2003). Under the conditions of the major rapeseed production areas in Iran, soil moisture content at sowing time (from October until mid-November) is most often inadequate. This results in irregular seed germination and crop establishment (Omidi et al., 2009). Selecting tolerant cultivars, under drought conditions and using these improved cultivars can contribute to higher performance and stability of yield in arid and semi-arid regions.

Almost all crop plants face varying levels of drought stress, but the extent they are affected from this stress varies from species to species and even different varieties within species. Moreover, tolerance to drought stress is very complex, due to the intricate interactions between stress factors and various molecular, biochemical and physiological phenomena affecting plant growth and development (Razmjoo et al., 2008). Germination and seedling characteristics such as germination percentage, germination rate, and seedling growth are the most viable criteria used for selecting drought tolerance in crops, at the seedling stage. Moreover, studies have shown that a positive relationship exists between drought tolerance in germination and subsequent growth of *Salvadora persica* (Ramolya et al., 2004). One of the methods for evaluation of drought tolerance at germination and the seedling stage is lowering osmotic potential using materials such as manitol or polyethylene glycol (PEGs). Osmotic potential created by such material is similar to the osmotic potential in relatively dry soil. The method of seed germination testing under water stress conditions, using polyethylene glycol is fast and easy, but can never replace the real field condition. Pot experiments are considered as other simple method for screening drought tolerant genotypes at germination and seedling stages (Gazanchian et al., 2006). Sangtarash et al. (2009) studied the sensitivity of rapeseed seedlings to water stress and their results indicated that even mild water stresses negatively affect seedling growth (stem height, leaf area, and seedling dry matter accumulation). Drought stress decreased the shoot and root length in *B. napus* genotypes (Omidi et al., 2009; Jamaati-e-Somarin et al., 2010). Similar results were observed in cowpea (*Vigna unguiculata* L.) seedling (Agbicodo et al., 2009) and sunflower (*Helianthus annuus* L.) seedling (Ahmad et al., 2009). Andalibi et al. (2005) reported that germination rate in rapeseed genotypes was the most sensitive trait to drought stress. Drought stress is responsible for both inhibition or delayed seed germination and seedling establishment of durum wheat (*Triticum turgidum* L.) (Almansouri et al., 2001). On the other hand, the most tolerant rapeseed cultivars exhibited the highest germination percentage at water deficit stress (Jamaati-e-Somarin et al., 2010).

One main limitation for introduction of winter and spring rapeseed genotypes in Iran is the lack of knowledge about their water requirements for germination and subsequent establishment. Our objectives in this study were: (i) develop simple, reproducible and reliable techniques for screening winter and spring rapeseed genotypes for low soil moisture tolerance at emergence and seedling establishment, (ii) evaluation of 24 rapeseed genotypes on the basis of their tolerance value to low soil moisture, and (iii) identification of drought tolerance indexes and good indicators using principal component analysis during rapeseed seed germination.

2. Materials and methods

2.1. Plant materials and treatments

Seeds of 24 genotypes of rapeseed (13 cultivars and 11 doubled haploid lines) were collected from Seed and Plant Improvement Institute (SPII) and Agricultural Biotechnology Research Institute of Iran (ABRII) (Table 1).

Table 1
Descriptions and origin of 24 rapeseed genotypes evaluated for determining the relationships between seedling emergence and soil moisture.

Number	Genotypes name	Cultivars	Lines	Open pollinated	Hybrids	Origin
1	Cooper	×		×		France
2	SLM046	×		×		Germany
3	Karun	×		×		France
4	Lilian	×		×		France
5	Billy	×		×		France
6	Tassilo	×		×		Germany
7	Adriana	×		×		France
8	Savanah	×		×		France
9	Oase	×		×		France
10	Triangle	×		×		Germany
11	Okapi	×		×		France
12	Opera	×		×		Sweden
13	GKH2005	×		×		Hungary
14	DH 1[a]		×	×		Iran
15	DH 3		×	×		Iran
16	DH 4		×	×		Iran
17	DH 5		×	×		Iran
18	DH 6		×	×		Iran
19	DH 7		×	×		Iran
20	DH 8		×	×		Iran
21	DH 9		×	×		Iran
22	DH 10		×	×		Iran
23	DH 11		×	×		Iran
24	DH 13		×	×		Iran

[a]DH, doubled haploid (inbred lines).

A pot experiment was carried out in a greenhouse at ABRII, Karaj, Iran. Each genotype was grown under four soil moisture levels Field capacity (80%, 50%, 30% and 20% FC, respectively). Seedling emergence, root and shoot length, cotyledon length and width, and root to shoot ratio were recorded after 12 days of sowing. Each pot (9-cm diameter by 10-cm depth) was filled with 300 g of sifted dry loamy sand soil (722 g kg^{-1} sand, 147 g kg^{-1} silt, and 131 g kg^{-1} clay) which was oven dried at 180 °C for 6 h. Fifteen intact seeds of each genotype were covered with a 5-mm layer of the soil. Immediately after planting, water was added to the dry soil to reach 80%, 50%, 30% or 20% FC corresponding to 12, 9, 6, and 3 mL water/100 g dry soil, respectively. After watering, the pots were sealed with transparent nylon bags for the duration of the study to prevent evaporation. Greenhouse conditions were maintained at 17/27 °C (night/day) under natural day light and 40–50% relative humidity. Soil volumetric water content was determined by weighing the pots during the experimental period for each treatment.

2.2. Measurements

Germination and seedling establishment was monitored daily for 12 days and seeds emergence percentages were counted every day. Seedling emergence was recorded at the cotyledon leaf appearance from the soil surface for 80%, 50%, 30% and 20% FC. The shoot length and the maximum root length for each emerged seedling were measured for each pot at the end of experiment (12 days). In this study, mean time to germination (MTG), mean daily germination (MDG), daily germination speed (DGS), germination rate (GR) and coefficient of germination rate (CGR) were determined according to Ellis and Roberts (1980), Jajarmi (2008), Maguire (1962) and Scott et al. (1984), respectively. Also, seedling vigor index (SVI) was determined according to Abdul-Baki and Anderson (1973) with some modifications and was calculated by multiplying percent