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Germination of weed species (*Avena fatua*, *Bromus catharticus*, *Chenopodium album* and *Phalaris minor*) with implications for their dispersal and control

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ABSTRACT

Climatic conditions for seed germination of four weed species, *Avena fatua*, *Bromus catharticus*, *Chenopodium album* and *Phalaris minor*, which occur commonly in cereal fields in the north of Saudi Arabia, were compared. Proportionately, most seeds of the two collected seed lots germinated during the first three weeks of the experiment, confirming an early response pattern. Overall, germination was higher in *Bromus catharticus, Avena fatua* and *Phalaris minor* than *Chenopodium album.* Compared to the other species, proportionately more *Phalaris minor* seeds germinated in the second period, indicating a higher propensity for slow germination. Germination in all species favoured alternating temperatures (10/20 °C or 5/25 °C) over a constant (15 °C), in a light/dark (16/8 h) regime. However, *Avena fatua* and *Bromus catharticus* seeds also showed significant germination in a dark only (24 h) regime, indicating light has less influence on their germination. Variation in germination between geographically separate seed collections of all four species was significant in some conditions, however, the general pattern was of similar responses between the two seed lots. Results determined that, in respect of interactions between temperature and light, the most important climatic condition for maximum seed germination, in all four weed species, is alternating temperatures. The outcomes of this study can lead to the expected timings of weed species' germination and dispersal in field conditions, and are used to make recommendations for practical weed control measures.

1. Introduction

Avena fatua L. (Poaceae) is a narrow-leaved, annual grass known in English as wild oat, and in Arabic as *Shoofan*. It has been found to cause mild to very serious infestations in cool season crops throughout Saudi Arabia (Chaudhary and Akram, 1987; Gomaa, 2012) and occurs rarely in Date Palm orchards in eastern Saudi Arabia (El-Halawany and Shaltout, 1992). It has been recorded worldwide in more than fifty countries, and is often a serious weed of crops (Holm et al., 1977; Simpson, 1990) including wheat, barley and other field crops (Scursoni and Satorre, 2005). In western Canada, yield losses due to its infestation were reported to be more than USD 280 million (O'Donovan, 1988). In the United States, where it is introduced, it has invaded an area reported to be more than 11 million ha in extent, resulting in financial losses of more than USD 1 billion (Morishita and Thill, 1988). *Avena fatua* seeds are reported to germinate in different type of soils and from a soil depth of 20 cm. Once mature, *Avena fatua* seeds fall off into the soil and may germinate immediately (Dostatny et al., 2015), or persist, remaining dormant but highly viable for a long time, hence this species is considered a persistent weed (Kepezynski et al., 2010). Seeds of temperate origin showed maximum germination at temperatures between 4 and 24 °C (Naylor and Fedec, 1978). Light was reported to enhance germination of non-dormant seeds, but did not show any impact on seeds in a dormant state (Hilton and Bitterli, 1983).

Bromus catharticus Vahl (Poaceae), in the United States known as prairie grass or rescue grass, is a narrow-leaved, annual, or short-lived perennial, grass. It is called *Zarreaa* in Arabic, and is reported to be a weed in wheat and barley fields in the north of Saudi Arabia (Chaudhary and Akram, 1987). It is widely reported as widespread in South America, and, for example, in Argentina, where *Bromus catharticus* is native, and widely distributed, it grows spontaneously in both natural and disturbed habitats (Aulicino and Arturi, 2008). It is cultivated as a winter forage crop in the south east of the United States and occurs as a grass weed in fields of *Medicago sativa* (Green et al., 2001). In temperate regions it occurs widely as an introduction, however, published agronomic information about its growth and reproductivity is scanty, compared to what is known about other weed grasses of temperate regions (Belesky et al., 2007).

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Chenopodium album L. (Amaranthaceae) is a broad-leaved, annual herb, known in English as fat hen. It is known among local farmers in Saudi Arabia by the name *Aldhorbaih* and has been described as one of the worst weeds in many places in Saudi Arabia and elsewhere (Chaudhary and Akram, 1987; Gomaa, 2012; El-ghazali and Al-soqeer, 2013). It is listed as the world's 10th most serious weed and is found in Asia, Europe and North America; it is adapted to grow vigorously in many different climates and soils (Holm et al., 1977). Its presence has also been recorded in Denmark, as a summer, annual weed, usually growing on wasteland and in cultivated areas (Eslami, 2011). Seeds of *Chenopodium album* collected from Iowa state farms were found to germinate readily in light at warm temperatures between 15 and 25 °C and at even warmer ones at 25–35 °C (Altenhofen, 2009).

Phalaris minor Retz. (Poaceae) is a narrow-leaved, annual grass. Known in English by several names including small canary grass and throughout Saudi Arabia as *Zail-al-Qat.* In Saudi it is a common weed of cultivation, causing light to severe infestation during the cool season. It has been also reported as a serious weed in more than 60 countries and described as a widespread and problematic weed in the winter season in many crops in many countries (Chaudhary and Akram, 1987). *Phalaris minor* causes significant yield reduction by its competitive effects. For example, in India, as a weed, it was reported to have invaded over 16 million ha of wheat fields (Singh et al., 1999). It is characterised by its rapid dispersal of mature seeds, long persistence in the soil and long dormancy leading to emergence over an extended period (Ohadi et al., 2010). Its seed germination was reported to be adapted to low temperatures and inhibited significantly by the absence of light (Ohadi et al., 2009).

Seed germination is an important event in the plant life-cycle. It determines when plants will emerge and begin to grow and become evident in fields and other habitats (Gardarin et al., 2011). Germination is a physiological process usually initiated by water imbibition followed by embryo growth resulting in the emergence of the radical through its coating tissues. It is influenced by dormancy and a variety of edaphic, climatic and environmental factors. However, temperature is the most significant factor regulating seed germination in non-dormant seeds, especially in irrigated agricultural ecosystems, it plays a very important role in the seed germination process, especially at the beginning of a cultivation season, when crop and weed plants are not in competition for other inputs such as light, nutrients or moisture (Derakhshan et al., 2014). Seed germination of most weed species requires sufficient light (Pons, 1992; Noronha et al., 1997). Light has been described as acting as a climatic indicator to seeds, by which they recognise soil disturbance which exposes them to enough light to germinate (Benech-Arnold et al., 2000; Scopel et al., 1994). Global variation in climate, many aspects of which are seed germination requirements, has led to geographical variation in seed germination and emergence in various species (Eslami, 2011).

This study is aimed to verify the appropriate climatic conditions for seed germination of four common weed species (*Avena fatua, Bromus catharticus, Chenopodium album* and *Phalaris minor*) of cereal fields in the north of Saudi Arabia. Seeds were collected from two sites in the northern Saudi Arabia; Aljouf region, which is considered to be one of the most important agricultural areas in Saudi Arabia, with nearly 1.1 million ha under cereal cultivation (Ministry of Agriculture, 2011). Furthermore, the study investigates whether germination responses of weed seeds have been affected by their occurrence in a warm environment, in comparison with seed from places with cooler climates. The suitable requirements for seed germination, especially temperature and light regimes, which determine seed dispersal timings, and which are important for control practices are also considered.

2. Materials and methods

2.1. Preliminary germination tests

To ensure high seed viability before carrying out the principal experiment, two seed germination tests were applied to fresh seed samples of the weed species. According to Alshallash (2016), seeds of sterile oats (*Avena sterilis*) and rigid ryegrass (*Lolium rigidum*) from the same origin displayed the highest germination at alternating temperatures of 10/20 °C in a dark/light regime of 8/16 h respectively. Accordingly, seed samples of the four species under investigation were tested for germination in the same experimental conditions. First test comprised 12 petri dishes of standard size (100 × 15 mm), 25 seeds of each species were scattered in each petri dish on double filter papers and moistened with 2 ml sterilised water. Petri dishes were stacked inside polythene bags and incubated. The test was carried out for 21 days at alternating temperatures of 10/20 °C in the 8/16 h dark/light regime. Second test was carried out with the same procedure and conditions, except that seeds were moistened in 2 ml of potassium nitrate solution (KNO_3) at 0.02 M concentration, to act as a dormancy breaking agent.

2.2. Principal germination tests

Seeds of the four investigated species (*Avena fatua, Bromus catharticus, Chenopodium album, Phalaris minor*) were collected at the end of the cereal season in April/May 2015 from two locations, 120 km apart, on cereal farms in the north and south of Aljouf region in the north of Saudi Arabia. Seed collection was carried out by specialists from the Range and Animal Wealth Research and Development Centre in Aljouf Region, Saudi Arabia. The two geographically distinct seed lots of each species were kept separate and immediately after collection placed in glass jars and stored in cold storage at 4 °C. At the beginning of June 2015, seeds samples were brought to the UK and maintained at 4 °C in preparation for the experiments.

A randomised complete block design was used, two seed samples (lots) of each of the four investigated species were tested for germination in all combinations of three temperature and two light regimes. The temperature regimes were: 15 °C constant temperature and alternating temperatures of either 10/20 °C or 5/25 °C. The light regimes were: exposure to light for 16 h followed by 8 h darkness (light/dark, 16/8h), and exposure to complete darkness for 24 h (dark only). The 48 treatments were replicated four times. For each treatment, a sample of 25 seeds was scattered over two filter papers in a petri dish moistened with 2 ml of sterilised water. Each petri dish was labelled with treatment information and replicate number. Each block of 12 petri dishes was then stacked in a polythene bag. A petri dish containing two filter papers moistened with 7 ml water was placed beneath the stack of petri dishes and another similarly prepared placed on top of them, to ensure enough moisture inside the polythene bag to prevent the seeds from drying out. The polythene bags containing the petri dishes were then sealed and placed randomly inside incubators. Petri dishes in the dark only treatment were totally covered by two layers of aluminium foil, instead of polythene bags. Early seed germination counts were recorded after 21 days, only for petri dishes in the light/dark regime treatment; germinated seeds were counted and removed. Petri dishes containing non-germinated seeds were placed back inside the polythene bags and returned to the incubators. 21 days later, final germination counts were recorded for all the petri dishes. True germination of each seed was ensured by counting only seeds with 2 mm or longer of radical root penetration.

2.3. Statistical analysis

Data were organised in a Microsoft Excel spreadsheet and transformed to percentages (%) by multiplying each observation by four. Three-way balanced ANOVA was undertaken in GenStat (VSN

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