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Effect of light and temperature on seed germination of selected African leafy vegetables

M.M. Motsa [a,*], M.M. Slabbert [b], W. van Averbeke [a], L. Morey [a,c]

[a] Centre for Organic and Smallholder Agriculture, Department of Crop Sciences, Tshwane University of Technology, Private bag X680, Pretoria 0001, South Africa
[b] Department of Horticulture, Tshwane University of Technology, Private bag X680, Pretoria 0001, South Africa
[c] Agricultural Research Council, Central Office (ARC-CO), PO Box 8783, Pretoria 0001, South Africa

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ABSTRACT

Using laboratory incubation, the response of seed germination and emergence to variability in temperature and light was examined for spider flower (*Cleome gynandra* L.), amaranth (*Amaranthus cruentus* L.), non-heading Chinese cabbage (*Brassica rapa* L. subsp. *chinensis*), nightshade (*Solanum retroflexum* Dun.), pumpkin (*Cucurbita maxima* Duchesne), tsamma melon (*Citrullus lanatus* Thunb.), Jew's mallow (*Corchorus olitorius* L.) and cowpea (*Vigna unguiculata* (L.) Walp.). Effect of temperature on seed germination and emergence was monitored under continuous darkness and at constant temperatures that ranged from 4 °C to 44 °C with 4 °C increments. The effect of light on seed germination was measured at 25 °C. Temperature affected germination rate and final germination percentage of all species tested in ways that were characteristic for each of the species tested. Generally, optimum germination occurred at temperatures ranging between 29 °C and 32 °C but at higher temperatures for *V. unguiculata* (36 °C) and *C. olitorius* (35 °C). The minimum temperature for germination ranged between 8 °C and 15 °C, and the maximum between 36 °C and 44 °C. Optimum temperatures for seedling emergence ranged from 25 °C to 31 °C, the maximum between 32 °C and 40 °C and minimum between 2 °C and 13 °C. Light positively ($p < 0.01$) affected onset of germination in *A. cruentus*, *B. rapa* subsp. *chinensis* and *C. olitorius*, and final germination percentage of *B. rapa* subsp. *chinensis*, *C. lanatus* and *S. retroflexum*. The results suggested that under South African conditions, seeds of the eight species will typically germinate optimally as temperatures rise during spring before the occurrence of very hot temperatures in summer. Due to their positive response to light, germination of *B. rapa* subsp. *chinensis*, *C. lanatus* and *S. retroflexum* seeds is expected to be optimal when sown at or close to the soil surface.

1. Introduction

Leafy vegetables are plant species of which the leafy parts, which may include young succulent stems, flowers and fruits, are used as vegetables (Jansen van Rensburg et al., 2007). African leafy vegetables (ALVs), also called 'traditional leafy vegetables', comprise "the collective of leafy vegetable species that form part of the culinary repertoire of particular contemporary African communities" (Jansen van Rensburg et al., 2007; Van Averbeke et al., 2012). Consumption of leafy vegetables is traditional practice in many African communities (Abukutsa-Onyango, 2007; Odhav et al., 2007; Faber et al., 2010). Dark-green leafy vegetables are high in micronutrients (Schönfeldt and Pretorius, 2011; van Jaarsveld et al., 2014), and their consumption can improve the nutritional balance of cereal-based, nutrient-poor human diets, which are characteristic of many poor rural communities across the globe (Faber et al., 2010; Uusiku et al., 2010). The leafy vegetables that are consumed by rural African people in South Africa consist primarily of weedy species, which grow as wild plants, or as weeds in fields planted to other crops. They are usually obtained locally by gathering, and availability tends to be limited quantitatively and temporally (Abukutsa-Onyango, 2007; Faber et al., 2010). Cultivation and commercialisation of African leafy vegetables increase their consumption by broadening and prolonging access (Diouf et al., 2007; van Averbeke et al., 2007). Cultivation of a wider range of species than is the case at present could make a significant contribution to nutritional security in the rural areas of South Africa, but information on the agronomic requirements of many of these potential crops is scant (Oelofse and van Averbeke, 2012). Such knowledge is needed to guide their effective cultivation. The current study is concerned with the process of germination and emergence of a selection of these traditional leafy vegetable species, and in particular the effect of temperature and light on the germination and emergence process.

Among the various germination factors (Ghaderi et al., 2008), temperature is the most prominent environmental factor regulating

* Corresponding author. Tel.: +27 21 809 3500.
E-mail addresses: motsam@arc.agric.za (M.M. Motsa), slabbertmm@tut.ac.za (M.M. Slabbert), vanaverbekew@tut.ac.za (W. van Averbeke), moreyl@arc.agric.za (L. Morey).

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growth and development of plants (Koger et al., 2004). The temperature (optimum) at which the maximum germination and emergence percentage are recorded tends to differ among crops. Clear understanding of the germination and emergence response of crop seeds to temperature, obtained by determining cardinal temperatures, is important, because it enables identification of tolerance to low and high temperatures, and climatic conditions under which particular crops can germinate and establish successfully. It also assists in the construction of models that predict crop development processes (Ghaderi et al., 2008).

The requirement of light for the germination of seeds of certain plant species prevents germination in places and times not favourable for seedling establishment (Fenner and Thompson, 2005). The light requirement of such seed acts as a mechanism that determines where and when germination takes place, and is important for survival of the plant species concerned, as it prevents stored seed reserves from being depleted. Some seeds germinate equally well in light and darkness, whilst others germinate better under only light or darkness (Chanyenga et al., 2012).

Existing knowledge of the effects of light and temperature on seed germination and emergence of traditional South African leafy vegetables appears to be limited. Therefore, the objective of this study was to investigate the effect of temperature on the germination and emergence and the effect of light on seed germination of a selection of these vegetable species. Pigweed (*Amaranthus cruentus* L.), nightshade (*Solanum retroflexum* Dun.), non-heading Chinese cabbage (*Brassica rapa* L. subsp. *chinensis*), spider flower (*Cleome gynandra* L.), tsamma melon (*Citrullus lanatus* Thunb.), Jew's mallow (*Corchorus olitorius* L.), pumpkin (*Cucurbita maxima* Duchesne) and *Vigna unguiculata* (L.) Walp. were selected for the study, because they are already being cultivated or have considerable potential to be developed into cultivated species (Oelofse and Van Averbeke, 2012).

2. Materials and methods

2.1. Seed sources and treatment

Seeds of pigweed (*A. cruentus*), spider flower (*C. gynandra*), tsamma melon (*C. lanatus*), Jew's mallow (*C. olitorius*), pumpkin (*C. maxima*) and *V. unguiculata* Walp. were obtained from the Vegetable and Ornamental Plant Institute of the Agricultural Research Council at Roodeplaat (VOPI). Seeds of the non-heading Chinese cabbage (*B. rapa* subsp. *chinensis*) (land race *dabadaba*, van Averbeke et al., 2007) and black nightshade (*S. retroflexum*) were obtained from Mr. Mabulannga, a smallholder farmer at Dzindi Irrigation Scheme (Itsani village) in Limpopo Province of South Africa (23°01′45″S and 30°26′30″E). Seeds were surface-sterilised in a warm water bath at 50 °C for 20 min (Labcon™ shaking water bath, 5070 U, model WBM-SPL 25) to reduce the risk of fungal growth. Thereafter, seeds were chilled in cold distilled water, evenly spread on a piece of germination paper and dried overnight at 20 °C (Floyd, 2005).

2.2. Seed germination and temperature

Small seeds (*A. cruentus*, *B. rapa* subsp. *chinensis*, *C. gynandra*, *C. olitorius*, and *S. retroflexum*) were placed on four layers of brown anchor germination paper (115 mm × 125 mm) and moistened with 10 ml distilled water. Large seeds (*C. maxima*, *C. lanatus* and *V. unguiculata*) were placed on four layers of rolled germination paper (260 mm × 380 mm) moistened with 50 ml distilled water (ISTA, 2008). Seed weights of 100 seeds of the ALVs are shown in Table 2. Germination was monitored every 6 h during the first 10 days (240 h), and every 12 h throughout the remainder of experiments. Seeds were considered to have germinated once the radicle had protruded at least 2 mm from the testa.

2.3. Seedling emergence and temperature

Seeds were sown in containers (280 mm × 190 mm) filled with germination sand [Rolfes Silica, 0.4–0.85 grading; dry graded silica sand (SiO_2, 98% Fe_2 O_3 0.18%)] moistened with distilled water for small seeds (0.0675 l kg^{-1} sand) and large seeds (0.4675 l kg^{-1} sand). Water was allowed to redistribute in the sand before incubation for 24 h at the designated treatment temperatures to allow the sand to attain the desired temperature. Small seeds were broadcasted evenly on top of moistened sand and firmly pressed into the substratum to allow contact with sand. Large seeds were sown at a depth of 1 cm. Spacer sticks were used to separate sample containers inside the incubators to allow sufficient circulation of air around the containers. Water was replenished as needed. Emergence was recorded every 24 h. Seeds were considered to have emerged once the cotyledons were visible above the surface of the sand (Koger et al., 2004; Maraghni et al., 2010).

2.4. Seed germination and light

To investigate the effect of light on germination, seeds were incubated at a constant temperature of 25 °C, and exposed to alternating light (8 h dark and 16 h light) and continuous darkness in an environmentally controlled Labcon™ (220V, 50 Hz) low-temperature incubator and growth chamber. Light was provided by six OSRAM DULUXSTAR light bulbs (14 W/840, 220–240 V, 116 mA, 50/60 Hz). Seed germination was recorded every 24 h. In the light effect experiment, samples incubated under darkness received small quantities of light during daily evaluations, and this could have triggered germination and affected the final germination percentage. For this reason, a second experiment was undertaken to determine the effect on light on final germination percentage in which the short exposure to light of the continuous darkness treatment as part of daily germination counts was eliminated. Accordingly, seeds were kept in the respective incubators for 10 days (240 h) without daily evaluation and germination counts were done after 240 h. The reason for incubating the seeds for 240 h was that in the first light-effect experiment final germination had been reached in all treatments and for all species before 240 h had expired.

2.5. Temperature regimes

Germination and emergence experiments were conducted in incubators set at constant temperatures which ranged from 4 °C to 44 °C with 4 °C increments, under continuous darkness. All experiments were incubated over a period of 14 days (336 h). In all experiments seeds were exposed to normal light during observations. All treatments were replicated four times with 50 seeds per treatment. Replicates were arranged in a completely randomized design in controlled incubators/growth chambers. Seeds that showed signs of fungal growth were removed from the population. Germinated or emerged seeds were counted, removed and expressed as a percentage of the total number of tested seeds.

2.6. Data analysis

The non-intercept sigmoid function as described in TableCurve® 2D (2002) was fitted on the cumulative germination/emergence percentage to determine the time to 50% germination/emergence (T_{50}) (Jami Al-Ahmadi and Kafi, 2007): $y = \frac{a}{1+e^{\left(\frac{x-b}{c}\right)}}$, where a is the maximum germination/emergence percentage, b is the turning point, c is slope of the line, x is the time (h) and y is the germination/emergence %. T_{50} germination/emergence was calculated and subjected to an appropriate analysis of variance (ANOVA) using SAS® statistical software version 9.2 (SAS, 1999).

The rate of germination/emergence was defined as the reciprocal of the time taken for half the population to germinate/emerge ($1/T_{50}$). The