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Association between biometric characteristics of tomato seeds and seedling growth and development

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ABSTRACT

Background: The size and weight of tomato seeds depend on genetics and can be modified by environment and management. In some species, a strong relation has been described between physical aspects of the seeds and the quality of the corresponding seedlings, but this cannot be considered a general rule. The objective of this research was to identify any association between the biometric characteristics of tomato seeds and the growth and development of their seedlings.
Results: A total of 18 lots of hybrid tomato seeds were used (from indeterminate plants with round fruits), belonging to six varieties from two reproduction seasons. Each lot was evaluated for seed size and weight, and seed quality, in terms of the germination test (5 and 14 d after sowing). The number of normal roots emerged with a length above 2 mm was also evaluated at d 3, 4 and 5 after sowing. The length of the seedlings and their total and partial dry weight were measured 5 d after sowing. The results indicate that there was no association between seed size and weight and subsequent seedling emergence, and only weak correlations were found between the dry weight of the radicle and cotyledon and seed size.
Conclusion: There is little association between the physical characteristics of the seeds and the subsequent seedlings, making it impossible to propose the use of seed weight or size as a compliment to quality evaluation tests.

1. Introduction

The current definition of seed quality includes physical aspects such as size and weight [1] because there is often an association between size and quality in agricultural species [2]. However, this statement depends on the type of seed in question and cannot be used as a general rule for all different groups of vegetables that are sold by the global seed industry. Most information has been gathered in regard to monocots, but their particular nature, especially in terms of anatomy, composition and metabolism, can be very different to other seeds [3].

Though most information that is available is in regard to cereals and other agriculture seeds, it can be noted that for tomato, Nieuwhof et al. [4] found that heavier seeds produced heavier plants, while Khan et al. [5] demonstrated a high level of association between seed weight and seedling dry weight. Van der Merwe et al. [6] included biomass, particularly of the radicle, as an indicator of seed quality.

In the field of seed quality evaluation, there is agreement that standard germination does not provide sufficient information, and as such the parameter vigour has been considered [7]. Though this variable is complex, it has been defined by analysts [8] as the sum of seed properties that lead to the rapid production of uniform seedlings under a wide range of field conditions. Upon further analysis of this definition, it can be seen that it includes early growth and development stages, firstly in association with germination and later with emergence. This type of evaluation coincides with the current trends in growth tests and seedling evaluation [1]. This definition makes no association between the physical aspects of the seeds and the behaviour of the seedlings.

Several authors have evaluated the connection between seeds and seedling quality over short periods, without looking beyond 14 d after sowing [9,10]. For tomato, Akbudak and Bolkan [11] evaluated the quality of seedlings after 3 and 7 d while Khan et al. [5] conducted evaluations at d 5, and 10. One objective of the current analysis is to reduce analysis time. As such, in order to support some seedling evaluation methods, the analysis of digital images has been used to improve objectivity [12,13,14,15].

Other authors have evaluated seedling length, without making any connection with the physical characteristics of the seeds, *e.g.* Sako et al. [12] and Kikuti and Marcos-Filho [16] respectively implemented and used total, hypocotyl and radicle length as the basis for estimating

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a vigour index to facilitate comparison of lettuce seed quality (Seed Vigour Imaging System®). For tomato, it has been found that radicle length at d 3 and d 4 is significantly correlated with seed quality [11]. Van der Merwe et al. [6] also found that the root is a good estimation of the process of germination and the metabolic changes that occur. For bell peppers, Hacisalihoglu and White [17] found that the area of the radicle and the weight was strongly associated with germination. In flower seeds, Oakley et al. [14] used seedling length to categorise the quality of different seed lots.

Early evaluations comprise radicle protrusion, which though it is specific to each set of research conditions, for tomato it has been reported that it begins from 40 h after imbibition onwards [18]. Other key events also occur during this period, such as enzyme action [18], reserve protein mobilisation [19] and hormone participation [20]. It is, therefore, justifiable to use the radicle analytically because its early protrusion is associated with energy availability [21], and it grows more than the hypocotyl under conditions of stress [22]. Another important consideration is that abnormal seedlings germinate later [23].

Matthews et al. [23] use periodical protruding radicle count to generate a value for seed vigour, information that cannot be obtained from the standard d 14. In addition, during germination and seedling emergence the accumulation of dry weight in the seedling increases [9]. Studying bell peppers, Demir et al. [24] also state that the lots seen to germinate early produce longer seedlings that are more uniform in comparison to those that germinate later.

The objective of the present research is to associate tomato seed size and weight with seedling growth and development, in order to propose their use as early quality estimates.

2. Materials and methods

2.1. Seed material

A total of 18 seed lots were used. They belong to six hybrid tomato varieties obtained by manual crossing and were studied over two seasons (2005–2006 and 2006–2007). The varieties denominated F, G, H and I were obtained in the first season while varieties J and K were from the second season. All seeds were produced in Chile, within the area located between latitudes 32°54′ and 34°21′ S and longitude 70°50′ and at an altitude of 120 m to 146 m above sea level.

All lots have different harvest dates for each variety. The genetic lines from which the seeds in question were derived were the property of private transnational companies. The multipliers were not made aware of the attributes or characteristics of the seeds, though they were known to be of indeterminate growth habits, simple racemes, and round multilocular fruit, and were grown under greenhouse conditions.

2.2. Seed characterisation

The physical characteristics of the seeds from each lot were determined using four repetitions of 100 seeds. The weight (SW) was recorded individually using an analytic scale. Seed size was characterised as seed length (SL), seed width (SWi) and seed area (SAr), and was obtained from digital images acquired with a Hewlett Packard model Precision Scan Pro 3.02 flatbed scanner, with a resolution of 300 dpi; the images were stored in jpeg format.

2.3. Germination test

The germination test was conducted by sowing four repetitions of 100 units each for each lot onto filter paper substrate saturated with distilled water. The procedure is based on ISTA standards [25]. The count was carried out on normal seedlings on two occasions: at 5 d after planting (G1) and at 14 d after planting (G).

2.4. Seedling emergence

The methodology is based on that described by Sako et al. [12] without calculating the vigour index developed by the author. Seeds from each lot were sown in four repetitions of 25 seeds on a double-layer of blue filter paper (Anchor Paper Co.) saturated with distilled water. The substrates were stored in transparent plastic boxes measuring $15 \times 23 \times 4$ cm. The boxes were placed in a germination chamber at 25°C $\pm$ 0.1, without light. The boxes were placed vertically at 85°C. Digital images were taken of each repetition on a daily basis using a Hewlett Packard model 4670 vertical scanner with a resolution of 200 dpi. The evaluations were conduction only with germinated seedlings with a radicle length of ≥2 mm. Counts were made of the number of seedlings germinated 3, 4 and 5 d after sowing (S3d, S4d and S5d respectively) and then were converted to be expressed as percentages. Germinated seedling length was measured 5 d after sowing and was broken down into radical length (RL), hypocotyl length (HL) and total length (TL). The dry weight of the germinated seedlings was taken 5 d after sowing and was broken down into radical dry weight (DWR), hypocotyl dry weight (DWH), cotyledon dry weight (DWC) and total dry weight (DWT). The dry weight was calculated by maintaining the seedling at a temperature of 70°C for 48 h.

2.5. Data extraction and digital image processing

The seed characterisation images were used to obtain data on the area, length and width of the seeds. The sprouted seedling images were used to obtain data on the lengths of the radicle and the hypocotyl. In both cases, this was done using the programme Sigma Scan Pro 5. Prior to this, all images were processed with calibration functions, intensity threshold, filter and number of objects.

2.6. Experimental design and data analysis

A fully randomised experimental design was used. The quantitative variables of the seed lots representing each variety were subjected to variance analysis and the means were compared using the Tukey or student's t-test, with a level of significance of 0.05. Values expressed in percentages were transformed using the arcsine function $\sqrt{x}/100$.

The association between two variables was determined *via* Pearson correlations with a level of significance of 0.05.

The variables of seed size and weight and their correlation to the dry weight of the sprouted seedlings were analysed using multiple regressions with a level of significance of 0.05.

Minitab 16, by Minitab Inc., was used for the statistical analysis.

3. Results and discussion

3.1. Seedling emergence

The emerged plants and their growth and development characteristics are presented as an alternative for evaluating quality through new vigour tests, as they satisfy the needs established by several authors for quick low cost analysis methods that are non-destructive and easy to implement within the seed industry [26].

As can be seen in Table 1, the emerged seedling showed significant differences between lots in three of the six varieties evaluated in the study; these were varieties H, I and J. This was the case for the different d after sowing, though it was more frequent on d 4 (S4d) and 5 (S5d). These results partially complement the information from the germination test (G), which is insufficiently sensitive to distinguish the quality of lots according to several authors [7,23]. Akbudak and Bolkan [11], identified the importance of seedlings at d 3 or 4 for differentiating the quality of tomato seed lots. In addition, the values from d 4 (S4d) onwards were higher than those obtained in