



Seedling Emergence Comparison of Several Romanian Tomato and Pepper Varieties

Mihaela IORDĂCHESCU, Anca Amalia UDRIȘTE*, Ovidiu JERCA, Liliana BĂDULESCU

Research Center for Studies of Food Quality and Agricultural Products, University of Agronomic Sciences and Veterinary Medicine, Bucharest, Romania

*Corresponding author: Anca Amalia UDRIȘTE e-mail: amalia.udriste@qlab.usamv.ro

RESEARCH ARTICLE

Abstract

Nowadays people are turning to sustainable/ecological agriculture. Romanian local varieties with valuable traits can be used to develop novel organic varieties. Nine Romanian tomato (*Solanum lycopersicum* L.) and seven pepper (*Capsicum annuum* L.) varieties were compared during seedling emergence in growth chamber and greenhouse conditions. The aim of this study was to observe the variation of several emergence indicators among the varieties of the same species under the same growing conditions, differences that can be correlated with genotype variation in further genotyping research, with the final goal of using these results as a basis for genotype-assisted breeding programs. The present survey demonstrated significant differences in the emergence indicators among the varieties studied, both in the growth chamber and in the greenhouse growing conditions. Ștefănești 24 tomato variety stood out with the longest mean emergence time, mean emergence rate, synchrony and highest uncertainty of emergence, whereas Vladimir pepper variety had the lowest values for percentage of emergence, homogeneity and uncertainty of emergence.

Keywords: *Capsicum*; genotypes; emergence time; synchrony; *Solanum*.

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INTRODUCTION

Seed germination is an important plant physiological process that incorporates seed imbibition, activation, intra-seminal growth and embryo protrusion (Delian et al., 2010). Following seed germination, the seedlings have to penetrate the soil in order to reach light and be able to start photosynthesis (Briggs, 2016). Emergence is defined as the moment in time when the seedlings stop to rely on the seed parental reserves and start autotrophic nutrition by photosynthesis (Forcella et al., 2000). Seedling emergence can be characterized using several indicators: percentage of emergence, mean emergence time, homogeneity, mean emergence rate, uncertainty and synchrony of emergence (Ranal et al., 2009). All these indicators can be correlated with seed quality/seed vigor. The genetic make-up of the seed, together with the environmental conditions present during emergence have been proven to influence the percentage of emergence, timing and uniformity of seedling emergence, and to further influence the crop yield and marketing quality (Khan et al., 2012).

Healthy food is one of the main concerns of today's society (Coe et al., 2019), so people are turning to ecological labeled products for consume (Tobler et al., 2011). Therefore, researchers are looking to develop novel organic varieties with superior traits, based on consumer preferences (Rocha et al., 2013). In Romania, tomato is the most cultivated vegetable species (Zamfir et al., 2017). Organic tomatoes have a high content of bioactive compounds, such as carotenoid and lycopene (Bujor et al., 2019; Dobrin et al., 2019). The breeders are constantly reporting

the creation of new pepper and tomato varieties that are in accordance with consumers' demands (Vînătoru and Neicu, 2010; Vînătoru et al., 2016; Barcanu-Tudor et al., 2018). A study for checking the suitability of local tomato landraces for organic crop production in plastic tunnels identified three landraces that are suitable (Maxim et al., 2013).

In present varieties, many times desirable traits come at the cost of less desirable traits such as low percentage of emergence (Foolad and Panthee, 2012). Khan et al. (2012) have identified 62 major Quantitative Trait Loci (QTLs) on 21 different positions for seed, seedlings and root system architecture traits in tomato. By correlating the differences in emergence indicators with the results of genotyping studies, breeders can select plants with multiple desirable traits in genotype-assisted breeding programs (Santos et al., 2015; Kim et al., 2016).

The aim of the present study was to compare nine tomato varieties and seven pepper varieties during seedling emergence process in the growth chamber and in the greenhouse, based on six indicators of seedling emergence: percentage of emergence, mean emergence time, homogeneity, mean emergence rate, uncertainty and synchrony of emergence.

MATERIALS AND METHODS

Tomato seeds from 'Argeş 11', 'Argeş 20', 'Ştefăneşti 24' and 'Ştefăneşti 22' Romanian varieties were received from I.N.C.D.B.H. Ştefăneşti-Argeş and tomato seeds from 'Kristinica', 'Florina 44', 'Andrada', 'Buzău 1600' and 'Buzău 47' varieties as well as pepper seeds from 'Decebal', 'Vladimir', 'Galben Superior', 'Splendens', 'Cosmin', 'Roial' and 'Cantemir' Romanian varieties were received from S.C.D.L. Buzău. All experiments and measurements were performed in the laboratories and the greenhouse of Research Center for Studies of Food Quality and Agricultural Products (<https://erris.gov.ro/RESEARCH-CENTER-FOR-STUDIES--1>).

Seeds were sown on Kekkila brown OPM 0.25W substrate in trays with 7×10 cells. Sowing was done using a wooden stick to make 1.5 cm holes in the soil, then placing one seed in each hole and covering it with the soil. Seedlings were considered emerged when the seedling's apical hook was visible above the soil, basically when the seedling reached light and could start photosynthesis. Seedling emergence was counted once a day and the process was considered finished when no new seedlings emerged for three days consecutively. Several emergence indicators were monitored during seedling emergence: percentage of emergence (%), mean emergence time (day), homogeneity (%), mean emergence rate (day⁻¹), uncertainty (bit) and synchrony of emergence (unitless).

In the Memmert HPP 750 growth chamber (Memmert GmbH + Co. KG, Schwabach, Germany), the experiment was carried out at 80% air relative humidity, constant temperature of 22°C, and 14 hours day/10 hours night conditions. In the greenhouse, the experiment was carried out at natural light conditions, a temperature of 23-27°C daytime/17-18°C nighttime, and an average of 55% air relative humidity. For each variety were used three replications, with 23 seeds in each replication. Physiological indicators associated with seedling emergence were calculated following the procedure described by Ranal et al. (2009). Data was statistically analyzed by ANOVA and Duncan's multiple range test (DMRT) using Microsoft Excel 2016 and IBM SPSS Statistics (version 27) software.

RESULTS AND DISCUSSIONS

Tomato seedling emergence

Nine Romanian tomato varieties were compared for several physiological indicators of seedling emergence: percentage of emergence, mean emergence time, homogeneity, mean emergence rate, uncertainty of emergence and emergence synchrony.

In the growth chamber (Figure 1), in the case of emergence percentage, over 80% emergence was observed for the 'Florina 44', 'Andrada' and 'Buzău 47' varieties, whereas the 'Argeş 11' variety displayed the lowest percentage of emergence (22.9%). The longest mean emergence time was observed for the 'Ştefăneşti 24' variety (~13 days). All the other varieties emerged between 5 and 7 days. In the case of homogeneity, expressed by the coefficient of variation of the emergence, there were no significant differences among the varieties studied at P<0.05, except for 'Florina 44', which had a value significantly higher than 'Andrada' and 'Argeş 11' at P<0.05. Mean emergence rate varied significantly among the tomato varieties. The highest value for the emergence rate was observed for the 'Florina 44' (0.21 day⁻¹), whereas the lowest emergence rate was observed for Ştefăneşti 24 (0.07 day⁻¹). In the case of uncertainty of emergence, the highest value was observed for 'Ştefăneşti 24' variety (2.64 bit) and the lowest value for the 'Buzău 47' variety (1.11 bit). The highest synchrony value was detected for the 'Buzău 47' variety (0.58) whereas the lowest value was detected for the 'Ştefăneşti 24' variety (0.09).

In the greenhouse (Figure 2), over 80% emergence was observed for the 'Florina 44', 'Andrada', 'Buzău 47' and 'Ştefăneşti 22' varieties, whereas the 'Ştefăneşti 24' variety displayed the lowest percentage of emergence (34.4%). The longest mean emergence time was observed for the 'Ştefăneşti 24' variety (~17 days). All the other varieties emerged between 8 and 10 days. In the case of homogeneity, expressed by the coefficient of variation of the emergence, there were no significant differences among the varieties studied at P<0.05. Mean emergence rate varied significantly among the tomato varieties. In the case of uncertainty of emergence, the highest value was

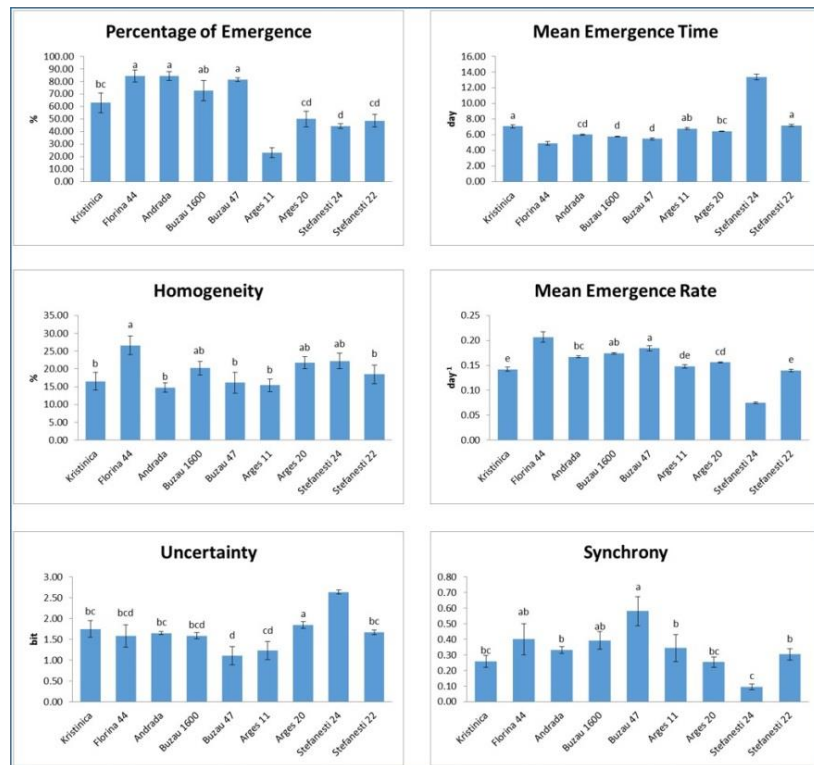


Figure 1. Seedling emergence indicators for the nine tomato varieties grown under growth chamber conditions. Error bars represent standard error of the mean. Bars with the same letters are not significantly different at $P < 0.05$ according to Duncan's multiple range test.

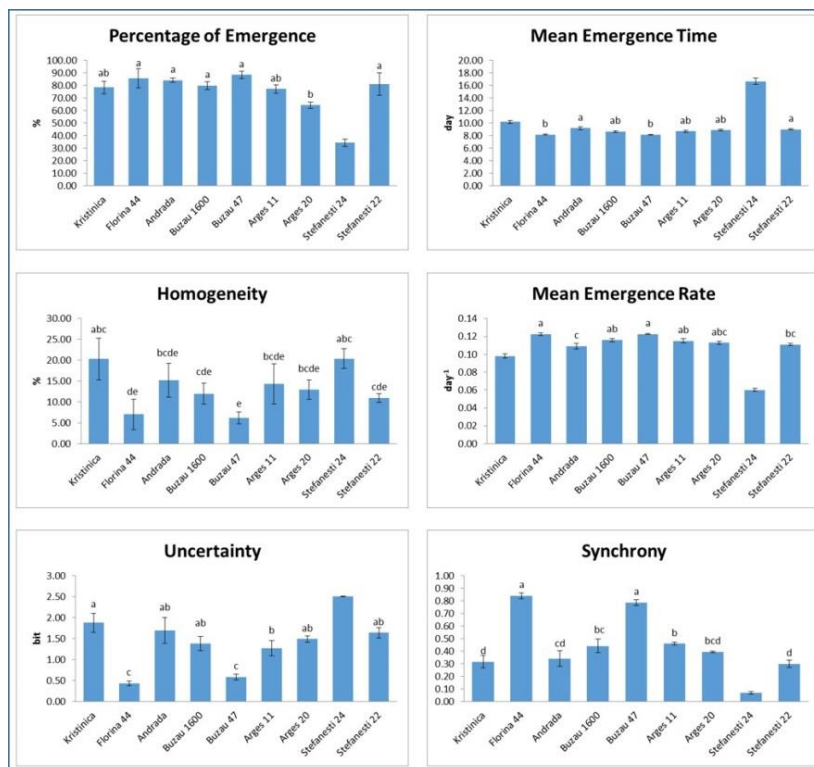


Figure 2. Seedling emergence indicators for the nine tomato varieties grown under greenhouse conditions. Error bars represent standard error of the mean. Bars with the same letters are not significantly different at $P < 0.05$ according to Duncan's multiple range test.

observed for the 'Ştefăneşti 24' variety (2.51 bit) and the lowest value for the 'Florina 44' variety (0.23 bit). The highest synchrony value was detected for the 'Florina 44' variety (0.84) whereas the lowest value was detected for the 'Ştefăneşti 24' variety (0.07). 'Ştefăneşti 24' displayed the longest mean emergence time and lowest mean emergence rate, lowest synchrony and highest uncertainty of emergence.

Pepper seedling emergence

Seven pepper varieties were compared for the same physiological indicators of seedling emergence. In the growth chamber (Figure 3), the highest percentage of emergence was observed for the varieties 'Galben Superior' (89.9%), 'Splendens' (78.8%) and 'Cosmin' (92,8%), whereas the lowest percentage of emergence was observed for the 'Vladimir' variety (10.00%). The shortest mean emergence time was noted for the 'Roial' variety (~9 days), and the longest emergence time was noted for 'Decebal' variety (~22 days). For the rest of the varieties, the mean emergence time values were between 12-17 days. The highest values for homogeneity were noted for 'Splendes' (36.6) and 'Cantemir' (36.9) varieties, whereas the lowest value was noted for the 'Vladimir' variety (6.5). The highest mean emergence rate was observed for the 'Roial' variety (0.11 day⁻¹), and the lowest emergence rate was observed for the 'Decebal' variety (0.08 day⁻¹). The highest value for the uncertainty was observed for 'Cosmin' variety (3.20 bit) and the lowest value for the 'Vladimir' variety (0.92 bit). The highest synchrony value was detected for the 'Vladimir' variety (0.33) whereas the lowest value was detected for the 'Deceba'l and 'Cosmin' varieties (0.08).

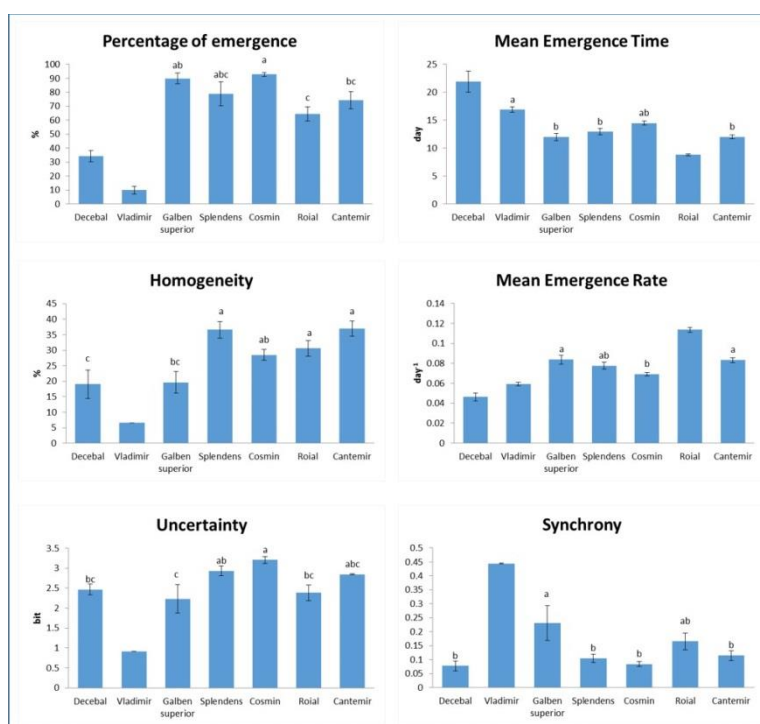


Figure 3. Seedling emergence indicators for the seven pepper varieties grown under growth chamber conditions. Error bars represent standard error of the mean. Bars with the same letters are not significantly different at $P < 0.05$ according to Duncan's multiple range test

In the greenhouse (Figure 4), four varieties displayed over 90% percentage of emergence: 'Galben Superior' (97.2%), 'Cosmin' (94.3%), 'Roial' (91.5%) and 'Cantemir' (92.9%). The lowest percentage of emergence was observed for 'Vladimir' (12.9%). The shortest mean emergence was noted for the 'Roial' variety (~10 days), and the longest emergence time was noted for Vladimir variety (~18 days). For the rest of the varieties, the mean emergence time values were between 12-16 days. The highest homogeneity value was noted for 'Decebal' variety (15.9) whereas the lowest value was noted for 'Galben Superior' variety (7.6). The highest mean emergence rate was observed for 'Roial' variety (0.10 day⁻¹), and the lowest emergence rate was observed for 'Vladimir' variety (0.05 day⁻¹). The highest uncertainty value was observed for 'Decebal' variety (2.66 bit) and the lowest value for 'Vladimir' variety (1.14 bit). The highest synchrony value was observed for 'Galben Superior' variety (0.29) whereas the lowest value was detected for 'Decebal' variety (0.11). Most published studies regarding seedling emergence involve various environmental conditions, seed treatments/pretreatments, and toxic substances that may influence this physiological process.

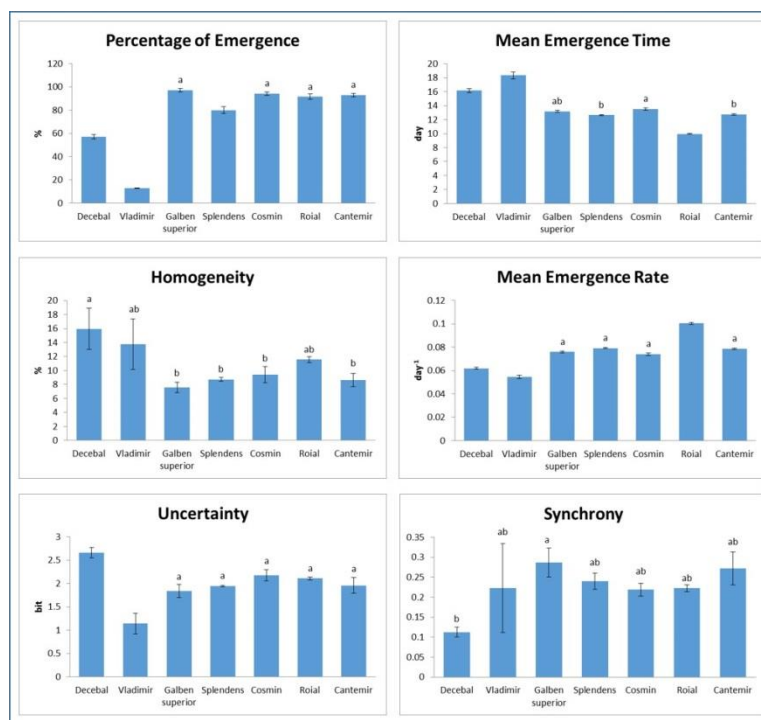


Figure 4. Seedling emergence indicators for the seven pepper varieties grown under greenhouse conditions. Error bars represent standard error of the mean. Bars with the same letters are not significantly different at $P < 0.05$ according to Duncan multiple range test.

Soil conditions may affect seedling emergence, either positively or negatively. For instance, rhizobacteria *Pseudomonas fluorescens* and *Bacillus mycoides* were shown to improve wheat seedling emergence and plant biomass (Czaban et al., 2004; Sivaramaiah et al., 2007). In addition, bacteria isolated from mud volcano and lime cave of Andaman and Nicobar Islands increased the percentage emergence for chili and tomato seedlings (Venkadesaperumal et al. 2014). Levy and Taylor (2003) published a study regarding the effects of several composts and pulp mill solids on tomato early growth. MSW (municipal solid waste) compost strongly inhibited tomato seedling emergence, whereas both race track compost and pulp mill solids showed improved emergence compared to pot soil only.

Pre-sowing seed treatments (priming) were reported to improve germination rate, emergence time, as well as synchrony in various crops (Parera and Cantliffe, 1994; Taylor et al., 1998; Farooq et al., 2009; Wang et al., 2016). Synchrony and fast emergence time is especially important when producing tomato rootstock seedlings, which are known to have slow and erratic emergence, reducing the efficiency of grafted seedling production. Mavi et al. (2006) reported the success of several treatments in reducing the mean emergence time and improving emergence synchrony of tomato rootstock seedlings. The seed priming treatment with 2% HNO_3 produced the best results in increasing the efficiency of grafted seedling production.

Among toxicity studies, DBDP-Ethane, a brominated flame retardant that accumulates in sewage sludge, proved to reduce significantly the emergence of cucumber seedlings (Hardy et al., 2011). In a recent study (Brain and Hoberg, 2016) performed in order to assess the effect of the herbicide atrazine on seedling emergence for several herbaceous species, including tomatoes, tomato seedlings emergence was affected negatively by the herbicide spray, however the plants were able to recover once the treatment ended.

Polyploidy can also affect seedling emergence. A study comparing diploid and tetraploid cytotypes of *Centaurea stoebe*, a herbaceous plant native in Europe, showed that the tetraploid type has an improved emergence compared to the diploid one, aiding it to become an invasive species in North America (Hahn et al., 2013).

An interesting experiment performed in the 1990s studied the effect of outer space on germination, emergence and fruit yield. Tomato seeds were exposed for 6 years to outer space (launched by the shuttle Challenger in 1984 and recovered by the crew of Columbia shuttle in 1990). No adverse effects on the emergence process were observed due to space exposure (Kahn and Stoffella, 1996). As opposed to the above mentioned studies, the present experience was performed with the purpose of comparing several varieties of the same species (tomato/pepper) during seedling emergence process. The results of this study will be correlated in future research with genotyping studies, with the ultimate goal of creating new, improved varieties in genotype-assisted breeding programs.

Romanian customers prefer to consume local tomato and pepper varieties, so breeding programs are delivering new varieties using local landraces that are well adapted to the local ecological conditions. 'Ștefănești 24' tomato

variety appears to have the lowest percentage of emergence, the lowest synchrony value, and longest time to emerge. However, this variety has been shown to have a high production, 9.8 kg/plant and ~290 t/ha (Bădulescu and Uleanu, 2017). 'Kristinica' tomato variety, besides a good percentage of seedling emergence, has been shown to be resistant/tolerant to several pathogens such as *Fusarium oxysporum* sp. *lycopersici*, *Phytophthora infestans*, *Verticillium dahliae* (Mîndru et al., 2019). This variety is also an early one, as its fruits are reaching the physiological maturity at 90 days after planting and it is preferred for industry, since the fruits have over 30 days shelf life (Vînătoru et al., 2016). One of the varieties of pepper from the present study, 'Decebal', was patented in 2015 from the 'Cornul Caprei' landrace, which has been cultivated in Buzău region for more than 200 years and shows an improved yield compared to the original landrace (Tudor et al. 2019) in spite of low percentage of emergence and low synchrony values.

Tomato germplasm collection at V.R.D.S. Buzău has over 1500 genotypes (Zamfir et al., 2017) and pepper germplasm collection over 200 lines (Lagunovschi-Luchian et al., 2016). In the future, further genotyping studies are needed to correlate the phenotyping traits studied in this survey with DNA sequence differences, in order to select plants with multiple superior traits in genotype-assisted breeding programs, and select against undesirable traits, with the final goal of creating novel valuable ecological varieties of tomato and pepper, which will appeal to the Romanian consumers.

CONCLUSIONS

Significant differences in the seedling emergence indicators were observed among the tomato and pepper varieties studied, both in growth chamber and in greenhouse.

Among the tomato varieties, 'Ștefănești 24' displayed the longest mean emergence time and lowest mean emergence rate, and the lowest synchrony and highest uncertainty of emergence values.

Among the pepper varieties studied, 'Vladimir' showed the lowest values for percentage of emergence (10.0% growth chamber/12.9% greenhouse), homogeneity (6.5%/13.7%) and uncertainty of emergence (0.9 bit /1.1 bit).

Author Contributions: M.I. and A.A.U. conceived and designed the experiment. M.I. collected the data, performed data analysis, and wrote the paper. A.A.U. and L.B supervised the project. J.O. contributed data and analysis tools.

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Conflicts of Interest

The authors declare that they do not have any conflict of interest.

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