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INFLUENCES OF PLANT DENSITY AND SEEDLING PLANTING DATES ON CABBAGE (*BRASSICA OLERACEA* VAR. *CAPITATA*) SEED PRODUCTION EFFICIENCY

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Abstract

Cabbage (Brassica oleracea var. capitata) is a prevalent vegetable crop cultivated for its nutritious leaves, which have a variety of culinary and medicinal use. As a consequence, vegetables such as cabbage are extremely popular among consumer demands. Constraints in the seed production chain highlight the significance of seed germination and crop`s growth at the farm level. The production of high-quality seeds is a crucial step in this crop`s cultivation since it impacts the success of germination and plant growth. In this study, we aimed to investigate the influence of plant density and seedling planting dates on cabbage seed process performance. This research is a component of a larger project aimed to devise a comprehensive and new modernized strategy for cabbage seed production. The experiment was carried out on `Silviana` autumn cabbage variety during two growing seasons, a field trial was undertaken to assess three plant densities (low, medium and high) and three seedling planting dates (early, mid-season and late). Cabbage seeds were also subjected to a range of seed viability and vigour tests.

Key words*: seed yield, germination, Brassicaceae, cabbage crops, plant spacing.*

INTRODUCTION

Cabbage is a biennial cruciferous plant that produces a terminal head in the first season of growth and reproductive structures in the second season of growth.
Cabbage *(Brassica oleracea* var. *capitata*) is a leafy vegetable known for its high content of health-promoting bioactive compounds, including fiber, vitamins, glucosinolates, polyphenols, and flavonoids (Nawaz et al., 2018; Novotny et al., 2018; Haghighi et al., 2020). Flavonoids possess various beneficial properties, including anti-tumor, anti-aging, and anti-inflammatory effects, and can protect against diseases caused by free radicals generated by oxidative stress (Xiao et al., 2016). Vitamin C and polyphenols are the primary antioxidants that protect cells from oxidative damage by scavenging free radicals (Podsędek, 2007).
Sprouts represent the initial stage of seed germination and contain high levels of bioactive compounds, such as minerals, amino acids, vitamins, and flavonoids, compared to mature plants (Kim et al., 2004; Xu et al., 2020). Sprouts are also a rich source of dietary antioxidants (Bendary et al., 2013), and the bioactive compound content in sprouts is influenced by seed quality and developmental stage (Nam et al., 2018).
Seeds store all the nutrients required for plant growth, including vitamins, minerals, proteins, fats, and carbohydrates. Similar to other cruciferous crops, cabbage undergoes vernalization, which triggers flowering after exposure to cold temperatures (Miller, 1929). Due to a prolonged juvenile phase and strong vernalization dependence for flowering (Ito and Saito, 1961; Miller, 1929), cabbage requires at least six months, even under optimal conditions in a climate-controlled environment, to complete one generation. In extreme cases, some cabbage accessions may not flower even after overwintering (Kinoshita et al., 2021).
Various studies have identified genes that regulate the vernalization process in *B. oleracea*, with the major ones being homologs of *FLOWERING LOCUS C*, a master regulator of the vernalization floral pathway in *Arabidopsis thaliana* (Abuyusuf et al., 2019; Irwin et al., 2016; Lin et al., 2018; Michaels & Amasino, 1999; Okazaki et al., 2007). The strong vernalization requirement of cabbage

offers a benefit in agricultural production as it can effectively suppress the incidence of bolting, a process marked by the elongation of stems followed by flowering, causing damage to the harvesting sites (Jung and Müller, 2009).

The planting date and the plant density are critical factors in the seed production practices of cabbage. Appropriate planting dates and optimal plant spacing play a significant role in determining yield-contributing characteristics and overall seed yield. Furthermore, these factors have a pronounced impact on the quality attributes of the harvested seeds. Therefore, selecting appropriate planting dates and optimal plant spacing can significantly improve the yield and quality of cabbage seed production.

Our study will contribute to the understanding of the factors that influence cabbage seed production efficiency and provide insights into optimal plant density and seedling planting dates for cabbage seed production. These findings will be valuable to farmers and seed companies seeking to produce high-quality cabbage seeds and meet the increasing demand for this nutritious vegetable crop.

Previous investigations, such as those conducted by Singh et al. (2010), Thirupal et al. (2014), and Jayamanne et al. (2015), have indicated that planting date has a significant impact on the vegetative and generative characteristics, head attributes, and seed yield of cabbage plants. This is due to the direct relationship between planting date, planting space and the maturity and harvesting time of cabbage, which is influenced by environmental factors such as temperature, day length, and light intensity. Choosing a suitable planting date is crucial for ensuring optimal growth conditions for cabbage plants and maximizing total and marketable yield, as observed in studies by Wszelaki & Kleinhenz (2003) and Tendaj and Sawicki (2012). These studies have demonstrated that earlier planting dates result in higher yields, while delayed planting leads to a decrease in both total and marketable yield.

Additionally, planting date affects the traits of the cabbage head and core traits, as evidenced by research conducted by Greenland et al. (2000), Orzolek et al. (2000), Kleinhenz and Wszelaki (2003), and Faizullah et al. (2015). Late planting dates were found to result in denser cabbage heads and head volume, while earlier planting dates produced heavier heads with larger diameters and wider core widths compared to late planting. Moreover, Faizullah et al. (2015) reported a reduction in head diameter and head weight with delayed planting dates.

In this study, we aim to investigate the influence of plant density and seedling planting dates on cabbage seed process performance. This research is part of a larger project aimed at developing a modernized strategy for cabbage seed production.

We conducted a field trial on the 'Silviana' late cabbage variety during two growing seasons to assess the impact of three plant densities (low, medium, and high) and three seedling planting dates (early, mid-season, and late) on cabbage seed production. We also evaluated the viability and vigor of cabbage seeds using established methods (ISTA, 2020).

The success of seed production in autumn cabbage is largely dependent on the crop's generative phase, which is a critical link in the seed production chain. It is well-established that the primary biological and physical characteristics of seeds are directly and significantly influenced by harvesting and conditioning operations, as well as by crop establishment techniques. These seed traits are the phenotypic expression of the cultivar, influenced by planting densities and the establishment period of the seed-producing crop. In this context, the research objective is to determine the extent to which planting date and density affect the quantity and quality of obtained seeds, and to identify the most efficient methods and techniques for maximizing the production of superior-quality seeds.

The overarching aim is to elucidate the interplay between crop establishment techniques and seed characteristics, and to optimize seed production through a comprehensive understanding of the underlying biological and environmental factors.

MATERIALS AND METHODS

Plant material

The experiment focused on the evaluation of the seed yield production of the late-season white cabbage cultivar, 'Silviana', which was patented at the Vegetable Research and Development Station Bacau in 2014. 'Silviana' is a robust and crack-resistant cabbage type with superior yield potential. The cabbage head is uniform and ranges from round to elliptical in longitudinal section, with a height ranging from 19-22 cm and a diameter of 22-25 cm. The calculated shape index falls within the range of 0.8-0.95, and the average weight ranges from 1.7-3.3 kg. The leaves exhibit a delicate texture, and the head form in longitudinal section ranges from round to elliptical, with leaves varying in color from raw green to medium intensity green. Furthermore, 'Silviana' has a high vitamin C concentration (44.50 mg per 100 g) and a cellulose level of up to 1.15%, contributing to its nutritional value. 'Silviana' has the potential to achieve high seed yields of 100 to 120 tons ha^{-1}.

Site description

The present investigation was carried out at the experimental field of the Vegetable Research and Development Station Bacau, situated at geographic coordinates 46.585205 N, 26.950087 E, in Romania's north-eastern Bacau region. The study involved a fertile and well-developed soil, characterized by a loamy-sandy texture and polished cambic chernozem soil type. The soil pH was observed to be within the range of 6.2 to 6.7, while the humus content was found to be in the range of 2.5 to 3.5%, making it an ideal soil type for the cultivation of the target crop.

Experimental design

For the experimental investigations, 40-day-old cabbage seedlings of the 'Silviana' cultivar were utilized. The seedling was sown in alveolar palettes in accordance with three distinct time periods and transplanted into the experimental field according to the following periods. The first planting period occurred on July 10^{th} (early), the second on August 10^{th} (mid-season), and the third on September 10^{th} (late). Within each time period, three different planting densities were established. The lowest planting density was achieved using a spacing of 55 x 96 cm (low), resulting in an approximate yield of 18,900 plants ha^{-1}. The medium planting density was obtained with a spacing of 40 x 96 cm (medium), resulting in an average yield of approximately 26,000 plants ha^{-1}. The highest planting density was obtained with a spacing of 25 x 96 cm (high) between plants and rows, resulting in an average yield of approximately 41,600 plants ha^{-1}. The research was conducted on two distinct aspects: the investigation of the planted material and its development, specifically the phenology of the plants, and the analysis of seed germination.

Data collection

The study of the planted material involved the analysis of various morphological characters across all three sets of plants, including number of seeds per silique, seed weight per thousand seeds (TSW), total seed quantity per square meter and per hectare.

Germination

The procedures outlined by the International Seed Testing Association (ISTA) were followed when performing germination tests. For germination of cabbage seeds, a SANYO MLR - 351H germinator was utilized. The optimal temperature for germination was maintained at approximately 20 degrees Celsius, with optimal humidity levels of 80-90% and optimal light exposure of 16 hours per day. The germinator was precisely calibrated to maintain these parameters, providing optimal conditions for cabbage seed germination. Additionally, air circulation was regulated to ensure adequate levels of oxygen for germinating seeds.

Daily observations were conducted during the cabbage seed germination experiment to monitor the process evolution. This allowed for the collection of necessary data to evaluate germination percentage, germination time, germination velocity, as well as other relevant observations.

Germination percentage (G %) represents an approximation of the potential germination of the seed population. The equation to calculate germination percentage is:

$$G(\%) = \frac{\sum_{i=1}^{k} n_i}{N} \times 100$$

The germination percentage was relativized (R %) by the following equation (Fitch et al., 2007):

$$R(\%) = \frac{AP}{HP} \times 100$$

Mean germination time (MGT) is a measure of the rate and time spread of the germination. It indicates time spent to germinate or emerge. Following formula was used to calculate the mean germination time (Ellis and Roberts, 1981):

$$\bar{t} = \frac{\sum_{i=1}^{k} n_i t_i}{\sum_{i=1}^{k} n_i}$$

Mean germination rate (MGR) is the reciprocal of the mean germination time as shown below (Ranal et al., 2009):

$$\bar{v} = \frac{1}{\bar{t}}$$

The measure of uncertainty of germination process (U) represents the extent of variability associated with the distribution of the relative frequency of seed germination (Labouriau and Valadares, 1976):

$$U = \sum_{i=1}^{k} f_i \log_2 f_i$$

Synchrony of germination process (Z) evaluates the degree of overlapping among individuals of one population. Synchronization index produces a number if and only if there are two seeds finishing the germination process at the same time. It is calculated using the following formula (Labouriau, 1978):

$$Z = \frac{\sum_{i=1}^{k} C_{n_{i,}2}}{C_{\sum n_1 2}}$$

Coefficient of variation of the germination time (CV_t) is calculated by the following expression (Ranal et al., 2009):

$$CV_t = \frac{S_t}{\bar{t}} \times 100$$

Where: $S_t = \sqrt{\frac{\sum_{i=1}^{k} n_i \left(t_i - \bar{t}\right)^2}{\sum_{i=1}^{k} n_i - 1}}$

Germination index (GI) is an estimate of the time (in days) it takes a certain germination percentage to occur. Germination index can be calculated by using following expression (AOSA and SCST, 1993):

$$GI = \sum_{i=1}^{k} n_i / t_i$$

Coefficient of velocity of germination (CVG) can be calculated using the following expression (Jones and Sanders, 1987):

$$CVG = \frac{\sum_{i=1}^{k} n_i t_i}{\sum_{i=1}^{k} n_i} \times 100$$

Time to 50% germination (T_{50}) indicates that how much time was taken for half of the seeds to germinate. (T_{50}) can be calculated using the following expression (Coolbear, Francis, and Grierson, 1984):

$$T_{50} = \frac{t_i + \left(\frac{\sum_{i=1}^{k} n_i}{2} - n_i\right)\left(t_j - t_i\right)}{n_j - n_i} \times 100$$

Other germination parameters related to time, such as T_{10}, T_{25}, T_{75}, and T_{90}, can be calculated using the same formula as above, but by substituting $\frac{\sum_{i=1}^{k} n_i}{2}$ with $\frac{\sum_{i=1}^{k} n_i}{10}$, $\frac{\sum_{i=1}^{k} n_i}{4}$, $\frac{3\sum_{i=1}^{k} n_i}{4}$ and $\frac{9\sum_{i=1}^{k} n_i}{4}$.

Mean daily germination percent (MDG) it represents the mean number of seeds germinated per day. This can also be defined as the number of seeds germinating daily relative to the maximum number of germinated seeds. It is calculated using the following expression (Adams and Farrish, 1992):

$$\bar{G} = \frac{GP}{T_n}$$

The peak value (PV) represents the sum of seeds that have germinated at the inflection point on the germination curve, where the rate of germination begins to decline. To calculate the peak value, one must determine the maximum quotient by dividing the cumulative germination values by the corresponding incubation time, as outlined in Adams and Farrish's (1992) methodology.

Germination value is obtained by combining both speed and completeness of germination into a composite score as described by Czabator (1962):

$$GV = \text{MDG} \times \text{PV}$$

Data analysis

The gathered morphological data was evaluated using statistical methods. The obtained analytical data was statistically analysed using the IBM SPSS Statistics software, version 26.0. The ANOVA test was applied to investigate the differences between means, followed by the Tukey's posthoc test. A significant difference was considered at a threshold of $P < 0.05$. The results were presented as means ± standard errors.

RESULTS AND DISCUSSIONS

The quantity of obtained seeds is a crucial aspect in the process of producing autumn white cabbage seeds as it directly affects the efficiency and profitability of the cultivation technology. Insufficient seed quantity can lead to a shortage of raw materials, resulting in additional costs and financial losses. In this experiment, the amount of seeds produced by the studied experimental variants was analyzed. These data allow us to better understand the seed production process in autumn cabbage and identify the corresponding technology and any other factors that may affect this process. The results obtained from the analysis of the quantities of seeds obtained from the experimental variants are presented in Table 1.

Table 1. Results regarding the quantities of seeds from the experimental variants

Date x Density	No. of seeds / silique	TSW	Seeds obtained (grams)	G / m^2	kg ha^{-1}
EH	29.41±0.99 ab	5.05±0.15 b	3219.52±182.84 a	127.72±9.75 a	1277.28±97.53 a
EM	35.5±1.72 a	6.17±0.19 a	2445.9±69.52 b	101.91±2.89 ab	1019.12±28.96 ab
EL	30.58±1.69 ab	6.11±0.09 a	1970.42±314.12 b	82.1±13.09 b	821.01±130.88 b
MH	24.88±2.90 bc	4.76±0.10 b	1095.65±88.72 c	45.65±3.69 c	456.52±36.96 c
MM	25.11±2.07 bc	4.73±0.10 b	970.27±111.62 c	40.43±4.65 c	404.28±46.51 c
ML	24.11±1.90 bc	4.65±0.09 b	1009.56±183.28 c	42.06±7.63 c	420.65±76.36 c
LH	26.44±2.67abc	4.78±0.10 b	811.94±88.16 c	33.83±3.67 c	338.31±36.73 c
LM	19.88±2.14 c	4.71±0.12 b	680.77±86.35 c	28.36±3.59 c	283.65±35.98 c
LL	25±2.51 bc	4.62±0.10 b	420.78±58.71 c	17.53±2.44 c	175.33±24.46 c

The values denote the arithmetic mean ± standard error. Lowercase letters represent the results of the Tukey test for $p < 0.05$ (a - represents the highest value, and ns - non-significant) (EH - Early x High; EM - Early x Medium; EL - Early x Low; MH - Mid-season x High; MM - Mid-season x Medium; ML - Mid-season x Low; LH - Late x High; LM - Late x Medium; LL - Late x Low).

Regarding the number of seeds per silique, a significant variation was observed among the studied experimental variants, with values ranging between the means of 19.88 and 35.5, with the minimum recorded on September 10th (late) combined with a planting distance of 40 x 96 cm (medium) (LM), and the maximum recorded on July 10th combined with a planting distance of 40 x 96 cm (EM). These results suggest that the differences among the studied variants have a significant impact on the number of seeds per silique. In terms of the thousand-seed weight (TSW), the average values ranged from 4.62±0.10 g to 6.17±0.19 g, with a significant variation observed among the experimental variants studied. Concerning the total production expressed in grams, the maximum mean value obtained was 3219.52 grams, recorded by the EH combination. Moreover, a significant variation was observed among the studied variants in terms of both the production per square meter and the yield per hectare. These variations suggest that the differences among the experimental variants have a significant impact on the cabbage seed production.

These results suggest that there is an inverse relationship between plant density and individual plant yield, meaning that as plant density increases, the individual plant yield decreases. However, this effect is compensated for by the larger number of plants in high-density treatments, resulting in a higher total production in these variants compared to those with lower density. This can be observed by comparing the total production, production per square meter, and production per hectare, where the values are higher in high-density treatments.

In conclusion, from the analysis of the presented data, it can be observed that the number of seeds per silique, total production, and production per unit area vary significantly among the studied experimental variants. This suggests that there are significant differences in plant performance depending on the cultivation method used and the establishment period. However, these are not the final results, and the experiment must be repeated to confirm these findings and obtain more precise information about the factors that influence autumn cabbage seed production.

The quality of seeds is a crucial factor that directly affects crop performance and production. High-quality seeds have a higher germination percentage, which results in more plants growing properly. Furthermore, good-quality seeds have a shorter germination time, which can lead to faster and better plant growth. Conversely, low-quality seeds are more susceptible to diseases and pests, which can have a detrimental impact on the crop. Therefore, seed quality evaluation is essential to ensure high and profitable production. The purpose of germination tests is to assess seed quality by analysing the percentage of germination and the time required for it. The Tables 2, 3 and 4 presents the results obtained from the germination study, which was based on several specific indicators that were subjected to statistical interpretation.

Table 2. Results regarding the analysis of seed germination capacity (part 1)

Date x Density	G %	R %	MGT	MGR	U
EH	99.33±0.66 ns	99.33±0.66 ns	1.49±0.23 ns	0.70±0.09 ns	0.83±0.06 ns
EM	100±0 ns	100±0 ns	1.75±0.12 ns	0.57±0.04 ns	1.01±0.27 ns
EL	98.66±0.66 ns	98.66±0.66 ns	1.47±0.24 ns	0.71±0.10 ns	0.78±0.11 ns
MH	97.66±0.66 ns	97.66±0.66 ns	1.67±0.10 ns	0.60±0.04 ns	1.17±0.03 ns
MM	98.66±0.88 ns	98.66±0.88 ns	1.63±0.06 ns	0.61±0.02 ns	1.28±0.12 ns
ML	98.33±0.33 ns	98.33±0.33 ns	1.54±0.09 ns	0.65±0.03 ns	1.24±0.11 ns
LH	98.66±0.66 ns	98.66±0.66 ns	1.61±0.11 ns	0.62±0.04 ns	1.19±0.05 ns
LM	99.33±0.66 ns	99.33±0.66 ns	1.54±0.11 ns	0.65±0.05 ns	1.03±0.08 ns
LL	99.33±0.33 ns	99.33±0.33 ns	1.61±0.19 ns	0.63±0.08 ns	0.92±0.16 ns

The values denote the arithmetic mean ± standard error. Lowercase letters represent the results of the Tukey test for $p < 0.05$ (ns - non-significant) (EH - Early x High; EM - Early x Medium; EL - Early x Low; MH - Mid-season x High; MM - Mid-season x Medium; ML - Mid-season x Low; LH - Late x High; LM - Late x Medium; LL - Late x Low).

Table 3. Results regarding the analysis of seed germination capacity (part 2)

Date x Density	Z	CVt	GI	CVG	T_{50}
EH	0.66±0.02 ns	33.07±7.02 ns	76.33±11.20 ns	70.25±9.69 ns	1.48±0 ns
EM	0.58±0.13 ns	30.48±8.83 ns	64.63±7.03 ns	57.73±4.05 ns	1.36±0.13 ns
EL	0.67±0.08 ns	30.64±4.33 ns	76.22±11.53 ns	71.39±10.88 ns	1.46±0 ns
MH	0.49±0.005 ns	33.88±1.78 ns	66.64±4.32 ns	60.34±4.05 ns	1.32±0.04 ns
MM	0.45±0.03 ns	38.54±3.67 ns	70±2.88 ns	61.35±2.69 ns	1.16±0.10 ns
ML	0.46±0.02 ns	39.65±1.70 ns	73.77±3.80 ns	65.17±3.93 ns	1.22±0 ns
LH	0.47±0.01 ns	35.50±1.58 ns	70.28±4.83 ns	62.66±4.37 ns	1.23±0.11 ns
LM	0.52±0.02 ns	33.84±2.61 ns	73.03±5.01 ns	65.6±5.11 ns	1.18±0.10 ns
LL	0.60±0.07 ns	29.73±4.38 ns	69.83±9.29 ns	63.88±8.42 ns	1.35±0.05 ns

The values denote the arithmetic mean ± standard error. Lowercase letters represent the results of the Tukey test for $p < 0.05$ (ns - non-significant) (EH - Early x High; EM - Early x Medium; EL - Early x Low; MH - Mid-season x High; MM - Mid-season x Medium; ML - Mid-season x Low; LH - Late x High; LM - Late x Medium; LL - Late x Low).

The statistical analysis of the germination capacity of cabbage seeds revealed a low variation between the different variants tested. The percentage of germination (G %) showed a low variation of means, ranging from 97.66 to 100 percent. The lowest germination percentage was recorded by the experimental variant MH, while the highest was recorded by the variant EM. The germination percentage is directly proportional to the number of seeds germinated because 100 seeds were taken under examination for each repetition of the tested variants. The relative germination percentage (R %) displayed the same values as the germination percentage indicator (G %).

The mean germination time (MGT) values ranged from 1.47 days, obtained by variant EL to 1.75 days, obtained by variant EM. The mean germination rate (MGR) is an indicator that can be also expressed as a percentage, showing an average percentage of seed germination of approximately 60-70% for all studied variants, with a variation of about 4-10%. These values are similar and fall within the acceptable limits for cabbage seed germination.

Regarding the uncertainty of the germination process (U), it can be noted that slightly higher variations in the mean were observed, with a minimum of 0.78 recorded by the EL combination and a maximum of 1.28 attained by the MM variant. It should also be noted that a low value of uncertainty (U) indicates a higher degree of uniformity, with a more concentrated and synchronized germination. This can be considered a positive indicator of seed quality, as it suggests better germination capacity and more balanced plant growth.

Regarding the means obtained by the synchrony of germination process (Z), a non-significant variability was observed between the experimental variants, with 0.66 being the maximum value recorded by the variant EH and 0.47 being the lowest value recorded by LH combination. Higher values of this indicator indicate more synchronized germination, and thus it is considered a positive indicator of seed quality.

In the case of the coefficient of variation of germination time (CV_t), a relatively insignificant variation was observed in the means obtained, with the highest mean of 39.65 being attained by the variant ML and the lowest value of 29.73 being recorded by the variant

LL. Regarding the germination index (GI), a non-significant variability was observed among the studied variants, with the highest value of 76.33 being marked by the EH factors combination and the lowest value of 64.63 being attained by the variant EM. A lower value of this indicator illustrates a shorter time to reach the germination percentage, and thus is considered a positive indicator of seed quality.

The coefficient of velocity of germination (CVG) measures the uniformity of germination time for seeds in a sample. The range of CVG values obtained suggests that there is variability in the uniformity of germination times across the different samples tested. The highest value of 71.39 is marked by EL combination, thus indicate that the germination times for the seeds in those samples were less uniform, while the lower CVG values of 57.73 being attained by EM variant. A lower value of this indicator implies a positive future of seed quality.

Table 4. Results regarding the analysis of seed germination capacity (part 3)

Date x Density	T_{90}	MDG	PV	GV
EH	1.75±0.11 ns	7.09±0.04 ns	67±10.01 ns	474.95±69.99 ns
EM	2.14±0.22 ns	7.14±0 ns	50±2 ns	357.14±14.28 ns
EL	1.56±0.27 ns	7.04±0.08 ns	66±12.16 ns	465.04±84.96 ns
MH	1.90±0.04 ns	6.97±0.08 ns	48.5±2.75 ns	338.2±17.99 ns
MM	2±0.13 ns	7.04±0.10 ns	47.83±1.58 ns	337.27±13.82 ns
ML	1.89±0.06 ns	7.02±0.04 ns	53.5±4.64 ns	375.83±32.9 ns
LH	1.89±0.05 ns	7.04±0.08 ns	50.3±4.41 ns	354.59±30.28 ns
LM	1.81±0.06 ns	7.09±0.08 ns	54.5±5.75 ns	386.14±37.94 ns
LL	1.81±0.11 ns	7.09±0.04 ns	56.8±9.63 ns	403.7±69.94 ns

The values denote the arithmetic mean ± standard error. Lowercase letters represent the results of the Tukey test for $p < 0.05$ (ns - non-significant) (EH - Early x High; EM - Early x Medium; EL - Early x Low; MH - Mid-season x High; MM - Mid-season x Medium; ML - Mid-season x Low; LH - Late x High; LM - Late x Medium; LL - Late x Low).

In terms of the time for 50% of the seeds to germinate, the average results varied insignificantly, with a minimum of 1.16 recorded for the variant MM and a maximum of 1.48 recorded for the EH variant. The averages for the time to 90% germination varied between 1.75 and 2.14, with a minimum recorded for EH experimental factors combination and a maximum recorded by EM variant. It needs to be stated that low values of T_{50} and T_{90} indicators express faster germination, thus a low value indicates good germination quality of the seeds subjected to the experiment.

In relation to the mean daily germination percentage (MDG), there was an insignificant variation in the means of the studied variants, with a minimum of 6.97 recorded for the variant MH and a maximum mean of 7.14 recorded for the EM combination.

In the case of the peak value (PV), there was a non-significant variability observed among the examined variants, with a minimum mean of 47.83 marked by the variant MM and a maximum mean of 67 marked by the EH variant.

Regarding the obtained means of the germination value (GV) indicator, a low variability of means can be observed, with a minimum of 337.27 marked by the MM variant and a maximum of 474.95 marked by the variant EH.

These results indicate a high germination rate with low variations among the studied variants. This suggests that the seeds used in the study have good quality and should provide efficient germination when used in agricultural practices.

CONCLUSIONS

The results of the study on the quantities of seeds obtained from experimental variants show significant variations in the number of seeds per silique, total production, and production per unit area. These significant differences suggest that the cultivation density and the time of establishment have a strong impact on plant performance and, consequently, on the quantities of seeds obtained. However, these are provisional observations, and it is necessary to repeat the experiment to confirm these results and better understand the factors influencing seed production in autumn cabbage.

Regarding the seed germination capacity obtained from transplanted mother plants, the results indicate high germination rates, which can be interpreted as an adequate level of seed vigor. Additionally, the low and insignificant variations among the studied variants suggest a uniform production process, which can be an important factor in ensuring high yields in seed production. These results are essential for farmers trying to optimize their production and ensure access to high-quality seeds for their crops.

The study results presented here examine the germination performance of autumn cabbage seeds obtained through various experimental variants and the analysis of key morphological characteristics of generative cabbage plants. This is crucial for producing high-quality seeds and improving yield. The 'Silviana' variety is one of the most important types of autumn cabbage cultivated in Romania, developed through research conducted at the Bacău Research and Development Station for Vegetable Cultivation.

While some of the results obtained cannot be fully explained by the collected data, this highlights the importance of continuing research and investigating these unconventional results to fully understand the mechanisms and processes involved. Further research is necessary to provide a clearer picture of the processes required for optimizing the technology of autumn cabbage seed production. These findings are significant for farmers seeking to maximize yield and obtain high-quality seeds.

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