Intra-varietal Variability of Morphological Elements of Dill Seeds

A F Bukharov\textsuperscript{1}, A F Razin\textsuperscript{1}, D N Baleev\textsuperscript{1}, O A Razin\textsuperscript{1} and M I Ivanova\textsuperscript{*}\textsuperscript{1}

\textsuperscript{1} All-Russian Scientific Research Institute of Vegetable Growing - a branch of the Federal State Budgetary Scientific Institution “Federal Scientific Center of Vegetable Growing,” Moscow region, 14 Selektssionnaya str., VNIISSOK Village143080 Russia

E-mail: ivanova_170@mail.ru

Abstract. The authors of this study sampled the seeds of the “Centaur” dill variety, grown in the open field in the Moscow Region (Russia). The main morphometric parameters of dill seeds, i.e., the length of seed, endosperm, and embryo, varied significantly. Samples No. 3, 8, 17, and 30 consistently exceeded the average values in all three parameters. The authors note the high variability of all morphological elements of seeds. The embryo demonstrated the maximum index of variability (V=22.8%). The authors established the $I_{EMB/END}$, denoting the embryo-to-endosperm ratio, and demonstrated its importance. Samples No. 8, 14, 17, and 27 had the maximum index values in the sample (1.5 times higher than the average). The reasons for the observed seed variability, especially the influence of hereditary and non-hereditary factors, constitute further research agenda.

Keywords: Dill · Seeds · Morphometric parameters · Seed growing · Selection

1. Introduction
Dill belongs to the Umbelliferae family (Apiaceae). As a rule, Umbelliferae plants are prone to embryo underdevelopment. The seeds of these plants mature in umbels of different orders. Seed germinability directly depends on the umbel order, from which it was harvested [5, 13, 14]. In carrots, the length of an embryo changes depending on seed maturity, plant architecture, environmental conditions, and varietal features [6, 8]. Embryo underdevelopment may cause significant quality problems. The morphometric parameters of the internal structure of seeds vary considerably. They regulate dormancy, germination, and the timing of shoot emergence [2, 3]. This is also typical for the seeds of dill – an essential herb, widely grown in the open and protected ground for its culinary uses [1].

Therefore, this research is aimed to examine the morphometric parameters of seeds collected from individually selected dill plants of the “Centaur” variety.

2. Materials and Methods
The research was carried out in 2018–2019 at the All-Russian Scientific Research Institute of Vegetable Growing – a branch of the Federal State Budgetary Scientific Institution “Federal Scientific Center for Vegetable Growing.” The authors studied the seeds of individually selected dill plants of the “Centaur” variety, grown in the open field in the Moscow Region. The seeds were sown in the second decade of May. The seeding rate is 1–2 g/m\textsuperscript{2}. The plants were sown in a 10 m\textsuperscript{2} plot in a 45×10 cm layout. The seeds were embedded 1.5 cm deep. The experiment was replicated three times.
Harvesting was carried out 50 days after the beginning of flowering. The seeds were dried and stored under laboratory conditions.

The length of the seed and endosperm was measured using calipers. The embryo length was measured using a Micromed 1 microscope (Micromed, China) and a DCM 300 MD digital microscope camera (Microscope Digital, China) at × 40 magnification, using the Scope Photo program (Image Software V. 3.1.386). The seeds were pre-soaked in a 14% aqueous solution of sodium hypochlorite for 1 hour. The length of each source, endosperm (longitudinal incision), and embryo (isolated by incision) were sequentially analyzed. The experiment was replicated four times, with 50 seeds in each replication. The statistical parameters and the statistical significance of the deviation from the average were determined using B. A. Dospekhov method [7]. The correlation between the parameters was evaluated using Pearson correlation analysis.

3. Results and Discussion

Thirteen samples (42%) had an average seed length. Ten samples (32%) significantly exceeded the average, and eight samples (26%) were below at p-value of 5% or 1%. The largest seeds (5.01 ± 0.09 mm) were observed in samples No. 15 (4.79 ± 0.075 mm) and No. 3 (4.76 ± 0.081 mm). The length of their seeds was 0.28–0.31 mm longer than in the control group (see table 1).

The endosperm length varied from 3.04 ± 0.044 mm in sample No. 27 to 4.25 ± 0.068 mm in sample No. 3. The average value endosperm length was 3.41 ± 0.061 mm. Fifteen (48%) samples were average, eight (26%) samples significantly exceeded the average level, and eight (26%) samples were below average.

The embryo length is of particular interest since it is mostly underdeveloped in dill seeds [3]. During germination, the embryo of dill, as is the case with other Umbelliferae crops, grows and develops for a long time (up to 10 days depending on temperature) before the seed sprouts [1]. On average, the embryo length was 1.19 ± 0.045 mm. In 11 (36%) samples, this index was significantly higher than in the control group. The other samples were either average (45%), or significantly below average (19%). Samples No. 3, 8, 17, and 30 consistently exceeded the average values in all three parameters.

The I_{EMB/END} index, denoting the embryo-to-endosperm ratio, is extremely important. This sample maximum of the index was observed in samples No. 8, 14, 17, 27. It was 1.5 times higher than the average in the experiment (table 2).

Table 1. Morphometric parameters of seeds in different dill samples.

| Sample No. | Seed length | Endosperm length | Embryo length |
|------------|-------------|------------------|--------------|
|            | X_m ± S_x mm | V, %             | X_m ± S_x mm | V, % |
| 1          | 4.57±0.069  | 10.7             | 3.49±0.045   | 9.14 |
| 2          | 4.72±0.077**| 11.5             | 3.56±0.049*  | 9.72 |
| 3          | 4.76±0.081**| 12.0             | 4.25±0.068** | 11.3 |
| 4          | 4.65±0.079* | 12.0             | 3.56±0.065*  | 12.9 |
| 5          | 4.82±0.088**| 12.9             | 3.56±0.054*  | 10.6 |
| 6          | 4.80±0.069* | 10.1             | 3.47±0.062   | 12.6 |
| 7          | 4.32±0.061* | 9.98             | 3.19±0.069** | 15.3 |
| 8          | 4.27±0.074**| 12.3             | 3.15±0.060** | 13.5 |
| 9          | 4.61±0.084  | 12.9             | 3.43±0.054   | 11.1 |
| 10         | 4.74±0.088**| 13.1             | 3.52±0.064   | 12.9 |
| 11         | 4.38±0.062  | 10.0             | 3.34±0.069   | 14.6 |
| 12         | 4.42±0.055  | 8.80             | 3.36±0.042   | 8.84 |
| 13         | 4.54±0.080  | 12.5             | 3.39±0.051   | 10.6 |
| 14         | 4.14±0.069**| 11.8             | 3.05±0.063** | 14.6 |
| 15         | 4.79±0.075**| 11.1             | 3.51±0.072   | 14.5 |
| 16         | 4.75±0.077**| 11.5             | 3.49±0.079   | 16.0 |
A strong correlation was established only between the lengths of the endosperm and the seed (see table 3). The correlation coefficients between the embryo length and endosperm length (0.226 (p=0.7×10^{-4})), and between the embryo length and the seed length (0.264 (p = 7.4×10^{-6})) display a weak correlation. Therefore, these parameters are relatively independent in their development. The correlation coefficients between the I_{EMB/END} index and morphometric parameters are negative; they did not exceed the average level.

The seed length variation coefficient (V) varied from 8.8% to 15.4%. The endosperm length varied even more significantly — from 8.84% to 16.0%. The maximum variability was observed in the embryo length, sample maximum of which reached 22.8%. Thus, all the studied dill samples displayed a high variability of morphological elements. On the one hand, it causes significant difficulties in practical seed production. On the other hand, it provides excellent opportunities for selective breeding.

### Table 2. The relative length of the embryo (I_{EMB/END}) in seeds of various dill samples

| Sample | I_{EMB/END} | Sample | I_{EMB/END} | Sample | I_{EMB/END} |
|--------|-------------|--------|-------------|--------|-------------|
| 1      | 0.39        | 11     | 0.39        | 21     | 0.34        |
| 2      | 0.33        | 12     | 0.35        | 22     | 0.33        |
| 3      | 0.3         | 13     | 0.37        | 23     | 0.4         |
| 4      | 0.34        | 14     | 0.41        | 24     | 0.35        |
| 5      | 0.35        | 15     | 0.29        | 25     | 0.37        |
| 6      | 0.36        | 16     | 0.38        | 26     | 0.37        |
| 7      | 0.4         | 17     | 0.42        | 27     | 0.42        |
| 8      | 0.41        | 18     | 0.4         | 28     | 0.36        |
| 9      | 0.39        | 19     | 0.3         | 29     | 0.39        |
| 10     | 0.38        | 20     | 0.34        | 30     | 0.27        |
| Av     | 0.48±0.074  | 11.6   | 3.41±0.061  | 12.6   | 1.19±0.045  |

*Source: Compiled by the authors.*
Table 3. Correlation coefficients (R) of dill seed parameters.

|          | Endosperm     | Embryo       | IEMBEND       |
|----------|---------------|--------------|---------------|
| Seed     | 0.833 (p = 2.1×10^{-8}) | 0.264 (p = 7.4×10^{-6}) | -0.198 (p = 1.4×10^{-4}) |
| Endosperm| -             | 0.226 (p = 0.7×10^{-4}) | -0.357 (p = 1.2×10^{-4}) |
| Embryo   | -             | -            | -0.373 (p = 5.9×10^{-5}) |

Source: Compiled by the authors.

Understanding the causes of morphological variability of seeds is important to the selective improvement of seed quality. Several factors predetermine seed variability:

1. Environmental factors. It results from the interaction between the plant and its seeds with the environment. This variability type is widely researched [12].
2. Modificational variability. It includes a system of agro-technical factors, such as the timing of sowing and planting, planting layout and density, fertilization, irrigation, and the overall level of agricultural equipment and techniques [10]. This variability type may become the deciding factor in seed quality.
3. Maternal environment variability. The architecture of the mother plant and the placement of generative organs may significantly affect the seed quality [4, 9, 11].
4. Genetic variability. This variability type is severely understudied. However, hereditary factors allow one to selectively enhance the morphological, physiological, and biochemical parameters of seeds. Selective breeding for seed quality is exceedingly rare. It has only been attempted in plants mainly grown for their seeds.

4. Conclusion
The authors selected several samples of the “Centaur” variety of dill and noted significant variability in the morphometric parameters of its seeds. High variability of the embryo and endosperm linear sizes and low correlation between them provide ample selection opportunities.

Samples No. 3, 8, 17, and 30 have consistently exceeded the average values of all three parameters. The IEMBEND index, denoting the embryo to endosperm ratio, is an essential morphometric parameter. The sample maximum of this index was observed in samples No. 8, 14, 17, and 27. The sample maximum value was 1.5 times higher than the average in the experiment.

The reasons for morphological seed variability deserve further attention and research. The results of such studies may be applied to improving the quality of seeds by selective or technological methods.

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