Comparative carpological assessment of F1 hybrids of *Brassica napus* L.

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Abstract. The article presents the results of a study of the morphological structure of the fruits of 26 commercial winter hybrids *Brassica napus* L., collected in July 2023 at the Breeding Station named after N.N. Timofeev Russian State Agrarian University - Moscow Agricultural Academy named after K.A. Timiryazev. Marker carpological characteristics of pods of *B. napus* hybrids have been established, which can be used in identifying and assessing the potential seed productivity of plants. Statistical analysis showed that the pods of the studied *B. napus* hybrids were characterized by stable and slightly varying morphometric parameters. The ratio of fruit length to its diameter was the greatest in F1 BS10, amounting to 19.4, and the smallest ratio of fruit length to its diameter was found in F1 BS22 - 8.34. The largest number of seeds in pods was observed in F1 BS10, and amounted to an average of 36.45 pieces; F1 BS22 (12.5 pieces) was characterized by the smallest number of seeds in the fruit. The longest pod stalk was observed in F1 BS17, which averaged 2.28 cm, and the shortest pod length was observed in F1 BS22 (1.28 cm). The greatest angle of departure of the pod stalk from the raceme was observed in F1 BS16 plants, which averaged 94.33°; the smallest angle is set for F1 BS4 (75.4°). As a result of the initial selection assessment and analysis of carpological data, a promising hybrid F1 BS10 was isolated, which differs from other *B. napus* hybrids in large pods with the largest number of seeds in the fruit.

1 Introduction

Rapeseed (*Brassica napus* L.) is the third most important oilseed crop in the world. High-quality rapeseed oil, with a low content of erucic acid and glucosinolates, is widely used in the food industry [1-3]. Currently, natural antioxidants attract much attention from scientists [4]. Therefore, modern trends in the selection of *B. napus* are focused on obtaining rapeseed oil with a high content of polyphenols (phenolic acids and polyphenolic tannins) as well as optimizing its fatty acid composition using traditional and genetic engineering approaches [5-8]. It has been established that more than half of the dry matter for seed formation is provided by the pericarp of *B. napus* pods [9]. Moreover, the architecture of the pods, in particular the angle of the peduncle from the axis of the *B. napus* raceme, significantly affects the efficiency of photosynthesis and plant yield. *B.*

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napus breeders require straight pod orientation because the pods of most cultivated Brassicaceae plants tend to form an acute pod angle, which favors the development of diseases, especially stem rot caused by the fungus *Sclerotinia sclerotiorum* (Lib.) de Bary [10] . Since carpological characteristics are important marker traits that directly affect the yield and quality of seed oil of *B. napus*, the study of pods of hybrid rapeseed lines is relevant, which was the purpose of this work.

2 Materials and methods

Experimental work was carried out at the Selection and Seed Center of Vegetable Crops of the Russian State Agrarian University - Moscow Agricultural Academy named after K.A. Timiryazev. The objects of the study were the fruits of 26 commercial hybrids of winter *B. napus*, collected in July 2023 at the Breeding Station named after N.N. Timofeeva. The study of the structure of fruits was carried out in accordance with the requirements of the "Methods of state variety testing of agricultural crops" [11]. Fruit measurements were carried out using a ShTs-II-250-0.05 caliper. The microsculpture of the pericarp of *B. napus* pods was determined using an MSP-2 stereomicroscopic microscope. Quantitative data were processed by methods of variation statistics: the arithmetic mean and its error ($M \pm m_m$), confidence interval (tm_m) and coefficient of variation (V, %) were calculated [12].

3 Results and Discussion

The fruit of *B. napus* is a simple, dry multi-seeded paracarpous dehiscent linear cylindrical pod. The pod is formed by two carpels and is divided lengthwise into two halves by a thin, evenly thickened septum formed by overgrown placentas. The pod opens acropetally, with two valves (laminally). The pod has a long spout at the top that does not contain seeds. According to the nature of the microstructure of the pericarp surface, the pods of all studied *B. napus* hybrids are glabrous (hairless) and veined. The consistency of the pericarp of the pods is leathery. The orientation of the pod on the hand (the angle of departure of the pod stalk from the axis of the hand) is deviated. The carpological characteristics of *B. napus* pods obtained during the work are presented in Table 1.

Table 1. Morphometric parameters of F1 pods of *Brassica napus* L. hybrids.

Plant	Parameter	$M \pm m_M$	tm_M	V
F1 BS1	Fruit length, cm	7.82±1.25	2.03	9.85
	Length of the fetal nose, cm	1.34±0.12	0.17	4.35
	Fruit diameter, mm	5.23±0.30	0.82	7.12
	Number of seeds per fruit, pcs	29.1±3.15	4.20	6.53
	Length of the stalk, cm	1.65±0.17	0.25	3.97
	Angle of departure of the pod stalk from the hand, °	87.67±4.82	5.40	6.81
F1 BS2	Fruit length, cm	8.19±0.93	1.87	9.30
	Length of the fetal nose, cm	1.31±0.10	0.15	2.17
	Fruit diameter, mm	5.45±0.22	0.76	5.95
	Number of seeds per fruit, pcs	32.2±2.30	3.15	4.25
	Length of the stalk, cm	1.73±0.12	0.27	6.14
	Angle of departure of the pod stalk from the hand, °	89.87±5.43	6.85	7.32
F1 BS3	Fruit length, cm	8.11±0.93	1.34	8.57
	Length of the fetal nose, cm	1.39±0.12	0.17	3.85
	Fruit diameter, mm	4.78±0.19	0.81	6.33
	Number of seeds per fruit, pcs	31.3±4.25	5.85	9.80
	Length of the stalk, cm	2.0±0.17	0.31	5.34
	Angle of departure of the pod stalk from the hand, °	83.87±9.12	8.67	8.89

Plant	Parameter	$M \pm m_M$	tm_M	V
F1 BS4	Fruit length, cm	8.0±0.85	1.07	9.73
	Length of the fetal nose, cm	1.33±0.09	0.15	3.17
	Fruit diameter, mm	4.97±0.25	0.67	5.27
	Number of seeds per fruit, pcs	23.6±3.40	2.55	9.62
	Length of the stalk, cm	1.88±0.14	0.29	4.70
	Angle of departure of the pod stalk from the hand, °	75.40±8.20	8.79	9.45
F1 BS5	Fruit length, cm	6.24±0.32	0.53	3.85
	Length of the fetal nose, cm	1.20±0.06	0.09	4.87
	Fruit diameter, mm	5.18±0.53	0.70	6.34
	Number of seeds per fruit, pcs	28.3±2.67	3.85	7.80
	Length of the stalk, cm	1.53±0.25	0.35	8.77
	Angle of departure of the pod stalk from the hand, °	81.67±7.55	8.35	7.15
F1 BS6	Fruit length, cm	9.16±0.57	0.89	4.55
	Length of the fetal nose, cm	1.30±0.09	0.18	6.10
	Fruit diameter, mm	4.94±0.60	0.85	5.12
	Number of seeds per fruit, pcs	34.1±2.25	4.73	7.31
	Length of the stalk, cm	2.05±0.20	0.29	8.65
	Angle of departure of the pod stalk from the hand, °	89.27±3.45	5.05	6.20
F1 BS7	Fruit length, cm	8.50±0.75	1.29	6.17
	Length of the fetal nose, cm	1.46±0.07	0.15	5.32
	Fruit diameter, mm	5.05±0.34	0.59	3.90
	Number of seeds per fruit, pcs	28.30±3.45	5.20	6.15
	Length of the stalk, cm	1.90±0.12	0.24	8.52
	Angle of departure of the pod stalk from the hand, °	84.07±4.85	5.34	5.75
F1 BS8	Fruit length, cm	7.72±0.45	0.93	4.27
	Length of the fetal nose, cm	1.15±0.08	0.12	2.15
	Fruit diameter, mm	4.91±0.23	0.56	2.80
	Number of seeds per fruit, pcs	30.65±2.85	1.85	8.73
	Length of the stalk, cm	1.93±0.12	0.32	3.65
	Angle of departure of the pod stalk from the hand, °	82.13±6.41	7.56	8.37
F1 BS9	Fruit length, cm	8.20±0.36	1.20	3.72
	Length of the fetal nose, cm	1.29±0.06	0.35	7.90
	Fruit diameter, mm	4.33±0.71	0.69	4.63
	Number of seeds per fruit, pcs	29.55±2.15	2.53	7.78
	Length of the stalk, cm	2.14±0.16	0.27	8.42
	Angle of departure of the pod stalk from the hand, °	83.86±5.47	6.42	7.54
F1 BS10	Fruit length, cm	9.34±0.67	1.48	7.95
	Length of the fetal nose, cm	1.39±0.12	0.49	6.97
	Fruit diameter, mm	4.81±0.92	0.12	5.14
	Number of seeds per fruit, pcs	36.45±3.45	4.23	8.92
	Length of the stalk, cm	2.10±0.07	0.15	5.74
	Angle of departure of the pod stalk from the hand, °	79.0±3.22	8.45	9.05
F1 BS11	Fruit length, cm	7.61±0.85	1.62	7.95
	Length of the fetal nose, cm	1.27±0.09	0.15	5.37
	Fruit diameter, mm	5.40±0.55	0.80	3.95
	Number of seeds per fruit, pcs	31.20±3.50	5.35	6.20
	Length of the stalk, cm	1.83±0.10	0.22	7.75
	Angle of departure of the pod stalk from the hand, °	86.27±3.91	5.12	8.23
F1 BS12	Fruit length, cm	9.05±0.95	1.65	8.35
	Length of the fetal nose, cm	1.48±0.08	0.17	4.89
	Fruit diameter, mm	4.85±0.45	0.76	4.25
	Number of seeds per fruit, pcs	28.6±4.20	6.55	7.75
	Length of the stalk, cm	1.90±0.11	0.34	8.87

Plant	Parameter	$M \pm m_M$	tm_M	V
	Angle of departure of the pod stalk from the hand, °	84.74±5.15	6.10	5.45
F1 BS13	Fruit length, cm	7.47±0.53	1.29	5.85
	Length of the fetal nose, cm	1.44±0.10	0.41	8.34
	Fruit diameter, mm	4.93±0.65	0.77	4.85
	Number of seeds per fruit, pcs	25.7±4.50	5.20	9.25
	Length of the stalk, cm	1.57±0.07	0.25	7.45
	Angle of departure of the pod stalk from the hand, °	84.60±3.22	6.67	8.15
F1 BS14	Fruit length, cm	8.39±0.41	1.30	4.85
	Length of the fetal nose, cm	1.42±0.09	0.14	8.51
	Fruit diameter, mm	4.37±0.75	0.87	9.62
	Number of seeds per fruit, pcs	29.10±3.17	3.65	9.87
	Length of the stalk, cm	2.01±0.08	0.23	6.24
	Angle of departure of the pod stalk from the hand, °	82.67±2.55	5.63	8.71
F1 BS15	Fruit length, cm	7.64±0.37	1.24	4.30
	Length of the fetal nose, cm	1.40±0.07	0.12	7.25
	Fruit diameter, mm	5.31±0.64	0.53	8.12
	Number of seeds per fruit, pcs	27.7±4.29	5.85	8.90
	Length of the stalk, cm	2.0±0.09	0.25	7.12
	Angle of departure of the pod stalk from the hand, °	86.90±3.23	5.82	7.95
F1 BS16	Fruit length, cm	8.22±0.55	1.20	3.45
	Length of the fetal nose, cm	1.32±0.06	0.11	6.17
	Fruit diameter, mm	5.09±0.44	0.60	5.67
	Number of seeds per fruit, pcs	27.6±3.35	4.50	6.90
	Length of the stalk, cm	1.89±0.10	0.30	7.05
	Angle of departure of the pod stalk from the hand, °	94.33±2.58	4.12	6.35
F1 BS17	Fruit length, cm	9.33±0.85	1.45	9.12
	Length of the fetal nose, cm	1.82±0.07	0.10	5.34
	Fruit diameter, mm	5.21±0.28	0.45	4.20
	Number of seeds per fruit, pcs	32.2±2.55	3.50	5.85
	Length of the stalk, cm	2.28±0.21	0.43	6.72
	Angle of departure of the pod stalk from the hand, °	87.87±2.15	3.50	5.17
F1 BS18	Fruit length, cm	8.36±0.55	1.05	4.30
	Length of the fetal nose, cm	1.51±0.05	0.09	3.85
	Fruit diameter, mm	4.75±0.25	0.35	5.29
	Number of seeds per fruit, pcs	25.1±3.47	4.70	8.25
	Length of the stalk, cm	1.88±0.19	0.23	8.10
	Angle of departure of the pod stalk from the hand, °	85.67±3.85	4.30	7.45
F1 BS19	Fruit length, cm	8.42±0.47	1.25	6.50
	Length of the fetal nose, cm	1.31±0.03	0.07	2.95
	Fruit diameter, mm	4.14±0.18	0.30	6.12
	Number of seeds per fruit, pcs	24.7±3.85	4.55	7.90
	Length of the stalk, cm	2.27±0.22	0.37	8.65
	Angle of departure of the pod stalk from the hand, °	87.89±2.44	3.38	6.25
F1 BS20	Fruit length, cm	8.04±0.54	1.05	4.85
	Length of the fetal nose, cm	1.36±0.02	0.06	2.37
	Fruit diameter, mm	5.02±0.21	0.35	5.50
	Number of seeds per fruit, pcs	25.7±4.05	5.85	8.63
	Length of the stalk, cm	1.91±0.18	0.21	6.32
	Angle of departure of the pod stalk from the hand, °	88.60±1.75	2.17	4.45
F1 BS21	Fruit length, cm	7.27±0.25	1.15	4.85
	Length of the fetal nose, cm	1.10±0.06	0.10	6.18
	Fruit diameter, mm	4.94±0.32	0.48	6.07
	Number of seeds per fruit, pcs	18.80±4.80	5.35	9.87

Plant	Parameter	$M \pm m_M$	tm_M	V
	Length of the stalk, cm	1.77±0.05	0.08	5.43
	Angle of departure of the pod stalk from the hand, °	87.73±1.75	2.40	3.42
F1 BS22	Fruit length, cm	4.49±0.32	0.45	5.37
	Length of the fetal nose, cm	0.58±0.03	0.05	2.25
	Fruit diameter, mm	5.38±0.29	0.35	3.14
	Number of seeds per fruit, pcs	12.5±3.15	3.85	4.20
	Length of the stalk, cm	1.28±0.03	0.07	6.15
	Angle of departure of the pod stalk from the hand, °	87.67±2.15	3.22	5.04
F1 BS23	Fruit length, cm	6.70±0.53	0.75	9.15
	Length of the fetal nose, cm	0.90±0.08	0.10	3.25
	Fruit diameter, mm	4.99±0.55	0.85	9.35
	Number of seeds per fruit, pcs	19.4±3.27	4.15	7.65
	Length of the stalk, cm	1.70±0.08	0.12	8.44
	Angle of departure of the pod stalk from the hand, °	88.40±1.95	2.45	6.13
F1 BS24	Fruit length, cm	5.67±0.89	1.03	9.42
	Length of the fetal nose, cm	0.73±0.14	0.18	5.94
	Fruit diameter, mm	6.30±1.02	1.85	9.67
	Number of seeds per fruit, pcs	18.60±3.10	4.20	6.77
	Length of the stalk, cm	1.65±0.13	0.20	9.80
	Angle of departure of the pod stalk from the hand, °	88.20±1.07	1.19	5.34
F1 BS25	Fruit length, cm	7.30±0.69	0.97	8.15
	Length of the fetal nose, cm	1.18±0.10	0.15	6.43
	Fruit diameter, mm	4.94±0.11	1.69	9.20
	Number of seeds per fruit, pcs	20.80±2.15	3.45	5.84
	Length of the stalk, cm	1.83±0.11	0.16	7.15
	Angle of departure of the pod stalk from the hand, °	89.13±1.09	1.24	2.42
F1 BS26	Fruit length, cm	5.82±0.69	0.97	8.15
	Length of the fetal nose, cm	0.64±0.10	0.15	6.43
	Fruit diameter, mm	4.43±0.83	1.27	8.54
	Number of seeds per fruit, pcs	18.0±3.20	4.55	9.65
	Length of the stalk, cm	1.30±0.09	0.14	8.10
	Angle of departure of the pod stalk from the hand, °	88.12±0.67	1.95	4.17

From the analysis of Table 1, we can state that the morphometric parameters of the pods of the studied plants are quite stable and weakly varying, because for them the coefficient of variation did not exceed 10%. This allows us to state the stability of the carpological characteristics of winter *B. napus* hybrids, guided by which it is possible to reliably carry out their full morphological analysis. The ratio of fruit length to its diameter was the greatest in F1 BS10, amounting to 19.4, and the smallest ratio of fruit length to its diameter was found in F1 BS22 - 8.34. The shortest pod spout was observed in F1 BS22 plants, the average length of which was 0.58 cm. The longest pod spout was observed in F1 BS17 plants, the average length of which was 1.82 cm. The largest number of seeds per fruit was noted in F1 BS10 , and amounted to, on average, 36.45 pieces. The smallest number of seeds in the fruit was observed in F1 BS22, and amounted to an average of 12.5 pieces. This was due to the fact that the pods of F1 BS10 differed sharply from other studied plants in their greatest length (9.34 cm), and, accordingly, the greater extent of the placenta carrying seeds. Due to the fact that F1 BS22 had the most compact pods (4.49 cm long), therefore the number of seeds in the fruits was the smallest. The longest pod stalk length was observed in F1 BS17, which averaged 2.28 cm, and the shortest pod stalk length was observed in F1 BS22 (1.28 cm). The greatest angle of departure of the pod stalk from the axis of the hand was observed in F1 BS16, which averaged 94.33°; the smallest angle is set for F1 BS4 (75.4°). Thus, as a result of the initial selection assessment, a promising hybrid

F1 BS10 was isolated, which differs from other *B. napus* hybrids in large pods with the largest number of seeds in the fruit. In summary, it should be noted that the morphological structure of the pods of winter hybrids *B. napus* is an important botanical, physiological and agronomic characteristic, the analysis of which will help predict the potential yield of the crop.

4 Conclusion

Analysis of the research results convincingly shows that the studied carpological characteristics of winter hybrids B. napus have a high diagnostic value for breeding and seed production, for assessing the source material for creating new varieties and hybrids of Brassica napus L. As a result of a comparative study of the pods of winter hybrids B. napus were significant morphological characteristics have been established that will allow identification and assessment of the seed productivity of this valuable oilseed crop.

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