FORMATION OF YIELD AND PRODUCT QUALITY OF BROCCOLI CABBAGE DEPENDS ON HYBRID CHARACTERISTICS IN LEFT BANK FOREST STEPPE OF UKRAINE

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Abstract. The article presents the results of a study of the productivity and quality of products of early–ripening and medium–ripening hybrids of broccoli cabbage of foreign selection when grown by the seedling method on typical heavy loam chernozem on forest–like loams in the conditions of the Left Bank Forest Steppe of Ukraine. It was established that the hybrids Batavia F1 (14.8 t/ha) and Larson F1 (12.8 t/ha) are characterized by high yield and good quality indicators of broccoli production.

Keywords: broccoli cabbage, hybrid, productivity, quality.

Vegetable growing, as a branch of agriculture, is an important component of the agro-industrial complex of Ukraine. It is vegetable plants that provide the population with valuable food products, and industry with raw materials. To date, about 452 thousand ha. of cultivated land in Ukraine is occupied by vegetable crops, and the gross collection of products is 9.7 million tons[373].

Broccoli occupies a small area among vegetable crops (1.4 thousand hectares), but the demand for it is constantly growing, and the cultivated areas are increasing every year. Cabbage and broccoli are classified as promising crops suitable for industrial processing and production of frozen semi–finished products. Areas set aside for broccoli and cauliflower make up 1.2% of the total area of vegetable crops in Ukraine. The average productivity of broccoli cabbage in Ukraine reaches 16.1 t/ha[374]. Broccoli cabbage is an important food product. This culture received its recognition thanks to its valuable food and medicinal properties, as well as unpretentiousness to growing conditions. In terms of nutritional value, it takes a leading place not only among cabbage varieties, but also among many other vegetable crops. Its composition includes vitamins of group B, vitamins E, A, PP, K,

[373] Derzhavna sluzhba statystyky v Ukraini.
[374] Ibid.

C and U. Broccoli contains more vitamin C than lemons and oranges; and vitamin U, which is no less in broccoli than in asparagus, is excellent for healing ulcers. In addition to vitamins, broccoli contains macro– and microelements, such as potassium, calcium, magnesium, sodium, manganese, phosphorus, iron, zinc, selenium and copper. The energy value of broccoli cabbage is low and is 126 kJ/100 g. In terms of protein quantity and quality, it is equal to a chicken egg, and in terms of quality and quantity of essential amino acids, broccoli can be compared to beef[375].

Broccoli cabbage plants are not very picky about growing conditions, they are cold–resistant, productive, which makes it possible to grow them in different soil and climatic conditions.

Broccoli is an annual and biennial vegetable plant of the cabbage family. Plants reach a height of 70-100 cm or more. The stem is fleshy, ending in a loose inflorescence (head). During the entire growing season, side shoots 15-20 cm long are formed, on which smaller inflorescences grow. The root system penetrates to a depth of 40-50 cm, but the main mass of the roots lies at a depth of 20-25 cm, therefore shallow inter–row cultivation is used[376]. Broccoli has increased repair properties. It consists in the fact that after cutting the central head in the axils of the leaves, sleeping buds quickly wake up and after 10–20 days, new, smaller inflorescences form on their shoots, which increases the yield to 100% or more. This feature of broccoli cabbage is increasingly used by farms to obtain additional products[377].

In relation to heat, broccoli is a cold-resistant plant. Their seeds germinate at a temperature of 4...5 °C. A well-hardened seedling can withstand a short–term drop in temperature to –5...–8 °C. The optimal temperature for the growth and development of this plant is 16...20 °C. This type of cabbage differs from all others in its greater heat resistance. It is less demanding on growing conditions than flowering, more resistant to diseases and pests, differs from it in higher precocity and cold resistance[378].

In terms of demand for moisture, this culture belongs to the first group – it is very demanding for both soil and air humidity. This is explained by the origin of the culture and the morphological structure of the plants. Broccoli has an increased rate of water consumption. To obtain high yields of high–quality broccoli, it is necessary to maintain moisture in the active layer of the soil at least 75-80% RH. Cabbage is especially sensitive to a lack of moisture after planting seedlings in open ground, as well as in the phase of active growth and head formation[379].

Plants of this culture are light–demanding and belong to long-day plants. A long day accelerates the growth of seedlings, the formation of heads, and in plants of the second year of life – flowering. With a lack of light, the seedlings stretch and become vulnerable to diseases. During a long day, all phases of growth and development pass

[375] Basa V. I. A., Melnichuk O.Ye. (2016). Vikoristannya kapusti brokoli dlya stvorennya fermentovanih produktiv harchuvannya, p.215-216.
[376] Bolotskih A.S. (2005). Enciklopediya ovoshevoda.
[377] Skokova G. (2011). Prihovani rezervi brokoli, p.47-49.
[378] Bondarenko V.A. (2017). Lezhkozdatni vlastivosti kapusti brokoli ta bryusselskoyi.
[379] Puzik L. M., Bondarenko V. A. (2015). Ekologichna stabilnist gibridiv kapusti brokoli, p.15-20.

faster in them. Broccoli cabbage can grow and produce good crops on various types of soil, except for sandy soils poor in organic matter, but light loamy soils with a high content of nutrients and a slightly acidic reaction that warm up quickly and easily give plants moisture and nutrients are best suited for it[380].

The yield and qualitative biochemical indicators of broccoli depend on many factors, among which an important place belongs to the selection of the assortment. Stable production of broccoli cabbage in Ukraine is possible only if the latest approaches to its cultivation technology are implemented. The correct selection of hybrids adapted to certain soil and climatic conditions is an important condition for improving the cultivation technology and obtaining high-quality products of this cabbage. The main requirements that manufacturers set for modern varieties and hybrids of broccoli cabbage for industrial production are as follows: high yield, dense heads (inflorescences), high quality and longness of inflorescences, suitability for the fresh market and processing, plasticity and resistance to stressful situations[381].

In the State register of plant varieties suitable for distribution in Ukraine, there are no varieties and hybrids of broccoli cabbage of domestic selection, therefore, only hybrids of foreign selection of various production companies are used in production. The Netherlands is the leader in the assortment of hybrids. An analysis of the assortment of broccoli during 2017-2020 by the number of varieties and hybrids recommended for cultivation in Ukraine and entered into the State Register of plant varieties suitable for distribution in Ukraine showed that the assortment is expanding every year. Thus, in 2017, it was 19, and in 2020 – 29 varieties and hybrids[382].

Broccoli cabbage belongs to the rare vegetable plants in Ukraine. However, the demand for it grows every year, and the price fully satisfies consumers. The reason for the absence of broccoli in industrial crops of Ukraine is limited knowledge about this culture, the lack of high–yielding varieties and hybrids, and the necessary recommendations on growing technologies in different climatic zones. That is why one of the tasks of our research was to select high–yielding hybrids of broccoli to obtain a marketable and high–quality harvest of broccoli in the conditions of the Left Bank Forest Steppe of Ukraine.

Research methodology and conditions. The research was carried out during 2021-2022 at the research field of the Department of Fruit and Vegetable Growing and Storage of KhNAU named after V.V. Dokuchayev, which is located on the territory of the Kharkiv district, the soil and climatic conditions of the field are typical for the Left Bank Forest Steppe zone of Ukraine.

The topography of the region is dominated by undulating plains dissected by river valleys, streams and ravines. The topography of the area where the research was conducted is characterized as flat and undulating.

[380] Didiv O., Didiv I., Didiv A. (2018). Komercijna kultura brokoli, p.26-32.
[381] Kovtunyuk Z., Usatyuk O. (2016). Pidbir sortimentu ta osoblivosti viroshuvannya kapusti brokoli v litno-osinnij period, p.47-49.
[382] Hromova A.V. (2021). Analiz sortimentu kapusti brokoli v Ukraini, p.147-150.

According to the weather station of Khnav named after V.V. Dokuchaeva, the climate of the region where the experimental field is located is temperate–continental with unstable humidity and air temperature. The average long–term air temperature is 7.2 °C. The lowest air temperature was observed in January. According to the amount of precipitation, the territory of the experimental field belongs to the zone of insufficient moisture. 529 mm of precipitation falls per year. The largest amount of precipitation – 767 mm was observed, which is 145 % of the norm. The lowest amount of precipitation was observed – 342 mm, which is 65 % of the norm[383].

The soil of the experimental field is a typical heavy loam chernozem on loess loams.

Field experiments were conducted according to generally accepted methods: according to B. A. Dospekhov[384], V. F. Moiseichenko[385], V. F. Belik[386], G.L. Bondarenko[387], A. O. Rozhkov[388]. Soil preparation for cabbage and plant care were carried out in accordance with generally accepted recommendations. The research was conducted with early–ripening broccoli hybrids Agassi F1, Besti F1, Batavia F1 (control – Agassi F1) and medium–ripening Orantes F1, Bathory F1, Larson F1 (control – Orantes F1), which are included in the State Register of plant varieties suitable for distribution in Ukraine[389].

Broccoli cabbage was grown by the seedling method. Seeds of early–ripening hybrids were sown in the third decade of March, and of medium–ripening hybrids in the second decade of April. Seedlings with three to four true leaves were planted at the age of 40–45 days. The term for planting seedlings of early–ripening hybrids is the second decade of May, and mid–ripening hybrids – the third decade of May. The method of placing plants is tape with a placement scheme – (40+100) × 35 cm. Plant density – 40.8 thousand pcs./ha. Repeatability in experiments is three times. The experiment is univariate. The area of the accounting plot is 19.6 m². Placement of options is systematic. The predecessor is a carrot.

According to the methods in vegetable growing, phenological observations were made, namely, the dates of sowing, the emergence of seedlings, the appearance of the first true leaf, diving, planting of seedlings, the formation of productive organs, the beginning of technical ripeness, the beginning and end of harvesting were determined. The beginning of the phase was recorded when it was noted in 10% of the plants on the plot, in mass – in 75 %. Biometric measurements were taken every 15 days, on the first and sixteenth of the month. At the same time, the following measurements were taken to determine the dynamics of mass growth: stem diameter

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[384] Dospehov B. A. (1985). Metodika polevogo opyta (s osnovami statisticheskoj obrabotki rezultatov issledovanij).
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[386] Belik V. F. (1992). Metodika opytnogo dela v ovoshevodstve i bahchevodstve.
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[389] Derzhavnij reyestr sortiv roslin, pridatnih dlya poshirennya v Ukrayini na 2020 rik.

near the soil surface, plant height, number of leaves, leaf rosette size, leaf plate size. Harvesting was carried out selectively as the heads formed and reached technical maturity. At the same time, the heads were weighed and divided into commercial and non–commercial products. Commercial products were divided into standard and non–standard according to the requirements of the current standard – "Fresh broccoli cabbage: technical conditions" – DSTU 8147 – 2015"[390]. The biochemical composition of the heads was determined, namely the content of dry matter, total sugar, and ascorbic acid. Harvest accounting was carried out separately for each plot. At the same time, to determine the quality of products, the mass of the central head, the diameter of the central head, and the total mass of the side heads were determined. Characteristics of the researched hybrids of cabbage and broccoli:

Agassi F1. An early hybrid of broccoli. Harvest hybrid for cultivation from the end of May to the beginning of September. Vegetation period – 65-75 days. Suitable for cultivation in all regions of Ukraine. Tolerates a hot climate well. Inflorescences are not prone to negative reactions to stress factors. To ensure the conveyor, it is recommended to plant seedlings in several periods (with an interval of 7-10 days). The recommended stand density is 40-45 thousand plants per hectare. This hybrid is characterized by its resistance to heat[391].

Besti F1. Mid-early hybrid of broccoli cabbage. Vegetation period – 55-60 days from planting seedlings. The heads are compact, dense, weighing 1.2-1.5 kg. Undemanding to growing conditions, tolerates adverse weather conditions and lack of nitrogen in the soil quite well. Resistance to high temperatures. For growing in the spring-summer period. Recommended for collection in May – August. Purpose: fresh market. The recommended planting density is 40-45 thousand plants/ha. Recommended for collection in May – August. Versatility. An ideal form for the fresh market[392].

Batavia F1. An early hybrid of the Dutch company Bejo Zaden B.V. Vegetation period – 65–68 days from planting seedlings. The hybrid forms fairly marketable, dark green, elastic, dense heads weighing 1.0–1.5 kg with a fine-grained structure. The hybrid is highly productive and is in demand on the market. It is characterized by high transportability and lightness. Resistant to Fusarium wilt and cracking. Differs in resistance to stressful growing conditions and heat resistance. It can be grown by seedling method and by direct sowing in open soil. Purpose: fresh consumption and for processing[393].

Orantes F1. A medium–ripe hybrid of broccoli from the manufacturer Rijk Zwaan. The average vegetation period after planting seedlings (60–75 days). Dense compact inflorescence. High productivity. Uniformity and marketability of inflorescences. Resistance to stressful conditions. Its head is quite massive, weighing up to 0.5 kg. The optimal growing time is the end of summer and autumn. A long

[390] DSTU 8147 – 2015. Kapusta brokoli svizha: Tehnichni umovy.
[391] Rijk Cvaan Ukraina. Katalog nasinnia 2019-2020. Asortiment ovochevih kultur.
[392] Syngenta. Katalog nasinnya ovochevih kultur 2019-2020.
[393] Bejo. Katalog nasinnya ovochevih kultur 2021-2022.

period of standing in the field. Easy to harvest. Recommended thickening – 40-45 thousand plants/ha. Suitable for fresh consumption and processing[394].

Batory F1. Medium ripe. Owner of Syngenta Seeds B.V. Vegetation period – 70–75 days from planting seedlings. The heads are compact, aligned, dome–shaped, dense with a good weight of up to 1.8–2 kg. Universal. It can be grown both indoors and outdoors. High resistance to high temperatures. For growing and harvesting from mid–August. Purpose: fresh market, processing. It is characterized by high qualities of transportation. The hybrid is well stored without losing its marketable appearance (color and freshness). The recommended planting density is 35-40 thousand plants/ha[395].

Larson F1. A medium–ripe hybrid of broccoli cabbage from the producer Rijk Zwaan. Very dense inflorescences of dark green color. Vegetation period – 70–80 days. A plant with high growth energy and a powerful root system. The hybrid is suitable for autumn harvesting. High resistance to stress. The recommended density is 40–45 thousand plants per hectare. Recommended for fresh market and processing[396].

Research results. As a result of research conducted with hybrids of cabbage and broccoli, it was found that the course of phenological phases depended on the terms of maturity and characteristics of the hybrid (Table 1). During phenological observations, it was established that the growing season from planting seedlings to mass technical maturity depended on the weather conditions of the year and was within 61-72 days for the group of early–ripening hybrids. The Agassi F1 hybrid had a longer growing season, which was 72 days in 2022. In the group of medium–ripe hybrids, the growing season lasted 75–82 days. The Orantes F1 hybrid had a shorter vegetation period compared to other variants, which was 78 days in 2021 and 75 days in 2022.

Table 1 – Dates of the onset of the phenological phases of the development of broccoli cabbage plants (2021–2022)

Hybrid	Ripeness group	Year	Transplanting	Formation of productive organs		Technical maturity		Vegetation period
				beginning	massive	beginning	massive	
Agassi F1 (control)	PC	2021	14.05	13.07	15.07	17.07	23.07	70
		2022	17.05	10.07	15.07	15.07	28.07	72
Batavia F1	PC	2021	14.05	11.07	13.07	14.07	17.07	64
		2022	17.05	11.07	15.07	15.07	23.07	67
Besti F1	PC	2021	14.05	10.07	14.07	14.07	17.07	64
		2022	17.05	09.07	12.07	13.07	17.07	61
Orantes F1 (control)	CC	2021	25.05	29.07	02.08	02.08	11.08	78
		2022	28.05	30.07	03.08	05.08	11.08	75
Batori F1	CC	2021	25.05	05.08	10.08	11.08	15.08	82
		2022	28.05	07.08	10.08	10.08	15.08	79
Larson F1	CC	2021	25.05	06.08	10.08	11.08	15.08	82
		2022	28.05	05.08	07.08	09.08	11.08	75

[394] Rijk Cvaan Ukraina. Katalog nasinnia 2019-2020. Asortiment ovochevih kultur.
[395] Syngenta. Katalog nasinnya ovochevih kultur 2019-2020.
[396] Rijk Cvaan Ukraina. Katalog nasinnia 2019-2020. Asortiment ovochevih kultur.

An important component of the technology of growing any agricultural crop, including broccoli, is the correct choice of hybrid. One of the main indicators of the effectiveness of cultivation technology is yield. Characterizing the yield of broccoli cabbage hybrids, we can say that the lowest yield on average over two years was obtained for the cultivation of the Orantes F1 hybrid – 11.8 t/ha (Table 2). The highest yield of marketable heads was provided by the Batavia F1 hybrid – 14.8 t/ha. Plants of the early–ripening hybrid Agassi F1 and medium–ripening hybrid Orantes F1 were distinguished by a larger diameter of the central head – 12.5 and 12.6 cm, respectively.

Table 2 – Quality indicators of the yield of broccoli depending on the hybrid (2021–2022)

Hybrid	Ripeness group	Year	Mass of the central head, g	Diameter of the central head, cm	The total weight of the side heads, g	Productivity, t/ha
Agassi F1 (control) Batavia F1	ER	2021	180,0	11,6	118,8	12,2
		2022	237,7	13,4	139,8	13,2
		Average	208,9	12,5	129,3	12,7
Agassi F1 (control) Batavia F1	ER	2021	236,6	12,0	134,1	15,4
		2022	242,8	12,8	142,4	14,1
		Average	234,7	12,4	138,3	14,8
Agassi F1 (control)	ER	2021	220,4	11,7	72,0	11,9
		2022	194,3	12,0	93,0	12,7
		Average	207,4	11,85	82,5	12,3
$LSD_{0,5}$	ER	2021				2,82
		2022				the differe-nce is not significant
The influence of the factor, %	ER	2021				65
		2022				44
Orantes F1 (control) Batory F1	MR	2021	209,4	12,4	78,3	11,7
		2022	218,2	12,7	112,3	11,8
		Average	213,8	12,6	95,3	11,8
Orantes F1 (control) Batory F1	MR	2021	214,4	11,5	88,5	14,6
		2022	225,7	12,9	98,6	10,7
		Average	220,05	12,2	93,5	12,7
Orantes F1 (control)	MR	2021	203,9	11,4	82,4	11,4
		2022	247,8	11,8	131,5	14,1
		Average	225,9	11,6	106,9	12,8
$LSD_{0,5}$	MR	2021				2,06
		2022				2,40
The influence of the factor, %	MR	2021				74
		2022				68

According to the results of dispersion analysis, the yield of broccoli during the research depended on the characteristics of the hybrid by 44-74%. According to the received data of 2021, in the group of early ripening plants. the Batavia F1 hybrid exceeded the control variant in yield by 3.2 tons, such a difference is significant

(LSD0.5=2.82), but in 2022 there was no significant difference between the experimental variants. Among the plants with an average ripening period in 2021, a significantly higher yield was obtained in the hybrid Bathory F1 (14.6 tons), which is 2.9 tons (LSD0.5=2.06) more than in the control variant.

Research has established that all broccoli cabbage hybrids had high quality products. It should be noted that the productivity of broccoli plants depends on the mass of the central head. In particular, the mass of the central head in the experimental variants was in the range of 207.4-234.7 g.

It was established that the content of the components of the chemical composition in the heads of broccoli cabbage depends on the characteristics of the hybrid (Table 3). Within the studied hybrids, the products differed in terms of biochemical parameters. In our research, the content of dry matter in the central heads was in the range of 11.4–20.73 %, depending on the hybrid, and their greater amount was accumulated in the heads of the medium–ripe hybrid Orantes F1 – 20.73 %. The total sugar content of hybrids ranged from 2.32 to 3.50 %. Batavia F1 and Agassi F1 had a higher amount of ascorbic acid in the central heads.

Table 3 – Biochemical composition of broccoli depending on the hybrid

Hybrid	Ripeness group	Dry matter, %	Total sugar, %	Ascorbic acid, mg/100 g
Agassi F1 (control)	ER	11,4	2,40	78,9
Batavia F1	ER	12,6	3,50	80,9
Besti F1	ER	14,6	2,32	76,3
Orantes F1 (control)	MR	20,73	3,13	24,08
Batory F1	MR	16,62	3,04	25,29
Larson F1	MR	16,90	2,72	30,91

Conclusions. 1. The yield and qualitative biochemical indicators of broccoli depend on many factors, among which the correct selection of hybrids that will be adapted to certain soil and climatic growing conditions is important. Product yield is an important indicator when evaluating hybrids. 2. The duration of the growing season during the research depended on the characteristics of the hybrid and the maturity period to which it belongs. For the group of early-ripening hybrids, this indicator was within 61-72 days. In the group of medium–ripe hybrids, the growing season lasted 75-82 days. 3. On average, over the two years of research, higher yield of marketable heads was ensured: in the early–ripening group – Batavia F1 hybrid (14.8 t/ha), yield increase compared to the control was 2.1 t/ha, or 16.5%; in the medium–ripe group – Larson F1 (12.8 t/ha), the yield increase compared to the control was 1.0 t/ha, or 8.5%. 4. According to the results of dispersion analysis, the yield of broccoli during the research depended on the characteristics of the hybrid by 44-74%. 5. The productivity of broccoli plants depends on the mass of the central head, which in the experimental variants was in the range of 207.4-234.7 g. 6. The content of the components of the chemical composition in the heads of broccoli cabbage depends on the characteristics of the hybrid.

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