Production peculiarities of Brussels sprouts in Crime for conveyor delivery of its heads to the retail chain

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Abstract. The results of a long-term study on the theoretical foundation of the adaptation capabilities of Brussels sprouts of the Franklin F1 and Diablo F1 hybrids to growing in the natural and climatic conditions of Crimea are figured. Recommended terms of outdoor transplanting of seedlings, substantiated the acceptance of the cultivation Brussels sprouts in winter culture, shows the duration of the phases of laying, growth, development and maturation of Brussels sprouts. The proposed elements of growing technology permit to wide the range of vegetables consumed by the population of Crimea, prolong the delivery period of Brussels sprouts to the retail chain. Research on the agrobiological assessment of brussels sprouts hybrids, development and validation of the main agrotechnological techniques affecting the formation of brussels sprouts in the natural and climatic conditions of the Russian South was performed in stationary field experiments at the Department of Vegetable Production and Plant Protection of the Academy of Bioresources and Nature Management of the Crimean Federal University during 2007-2018. The article is aimed for vegetable growers, agricultural production entrepreneurs, gardeners, farmers, research institutions staff, graduate students and students.

1 Introduction

Brussels sprouts are a biennial vegetable plant. In the first year of vegetation, it forms a thickened stem 20-60 cm, sometimes up to 1 m or more in height. Leaves with thin petioles 15-30 cm long, green or gray-green with a waxy coating, with smooth or slightly curved edges. In the axiles on the shortened stems formed heads 3-4 cm in diameter, 20-60 pcs in a single plant. In the second year, it blooms with yellowish flowers and forms pods with seeds. Brussels sprouts are used for food [1, 2]. These heads contain a large number of vitamins A and C, folic acid and dietary fiber. In accordance with vitamin C content, Brussels sprouts exceed all other types of cabbage and can store it in the leaves of the heads - up to 328 mg% [1-4]. The contain of b vitamins in Brussels sprouts is: B1-0.13 mg%, B2-0.15 mg%, B6-0.28 mg%, B9-31 mg%. This kind of cabbage contains 15.5...17.5% of dry matter, rich in proteins, carbohydrates, and minerals [4-6].

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The protein content varies in the heads in the range from 2.4 to 6.9% [7]. 16 amino acids were detected in the heads. They are tyrosine and histidine-19 mg%, tryptophan-11 mg%, lysine and methionine-14 mg%, arginine-79 mg% and others [8, 9]. Brussels sprouts have a large amount of nitrogenous compounds: folates (folic acid and its derivatives). They are also known as vitamin B9 and indoles, which prevent the occurrence of cancer. It is considered that result of these substances, cabbage can prevent the development of breast and lung cancer. Brussels sprouts' indoles stimulate the liver. Nonprotein nitrogen compounds average about 50-70% of the total protein [10].

The ability of Brussels sprouts to grow, develop and crop formation is strongly influenced by temperature. Plants vegetate at a temperature of 7 to 25 °C. The optimal temperature is 18 °C. This crop is relatively nonresponsive to frost. In the seedling stage, Brussels sprouts can withstand freezing to minus 5 ... 6 °C, hardened seedlings can withstand short-term temperature drops to minus 8 ... 10 °C. For the growth and development of an adult plant, the optimal temperature is 15 ... 18 °C. When the temperature rises to 25 °C or more, the heads become pithy or do not form, and with long-term exposure to low temperatures, the commercial quality of goods decreases [13].

The climate zones of Crimea are characterized by a relatively high diversity level. Research on Brussels sprouts growing was performed in the submontane agroclimatic region of Crimean. In accordance with natural and climatic conditions, the area is conducive to carry out agricultural production. The area's climate is characterized by very warm and dry summers, wet and mild winters. On the findings of long-term data of the meteorological station of Simferopol, the sum of effective temperatures is 3100-3300 0C, the average annual air temperature is 10.1 0C. The coldest month of the year is February, with an average monthly temperature of 0.7 0C. The average absolute minimum temperature in this area is about minus 19 ... 20 0C. In the winter there are frequent periods of thaw, which leads to large changes of air temperature and to frailty and instability of snow cover. A mild winter allows to retain young cabbage plants in the open ground until spring, but with compulsory hilling of the ground. The average long-term temperature of the warmest month of the year - July is 21.1 0C. On some summer days, the amplitude of the air temperature can reach 30 0C or more. Autumn is characterized by quiet, sunny and moderately warm weather. The first autumn frost is seen in mid-late October. A dramatic change in weather usually occurs in the second half of November. The duration of the frost-free period is 160-170 days. The natural and climatic conditions of Crimea give opportunities to grow a wide range of vegetables with a high content of biologically active substances that are irreplaceable for humans. We consider that one of the promising crops for growing is Brussels sprouts, but the technology of growing it in the Crimean conditions is little known.

The aim of the research is to develop and validate agrotechnological methods of growing Brussels sprouts growing in the Crimea for conveyor delivery of its heads to the retail chain.

2 Materials and methods

In order to achieve this aim, the staff of the Department of vegetable growing and plant protection of the V. I. Vernadsky Crimean Federal University performed a long-term research, which included the following experiments.

Experiment 1. Evaluation of adaptive capabilities of plants hybrids Franklin F1 and Diablo F1 of Brussels sprouts to determine the timing of ripening of heads and the duration of harvesting in Crimea.

Experiment 2. Determining the influence of seedling planting dates on the duration of formation and ripening of Brussels sprouts, on the size and quality of the crop. The seedling method of Brussels sprouts growing in the open ground has been investigated. With a view

to extending the ripening period and crop becoming, the possibility of winter planting seedlings in the open ground was studied.

Experiment 3. Evaluation of single and double harvesting methods for plant productivity and quality of Brussels sprouts. The stem of the Brussels sprouts plant is constantly growing and reaches a height of 70 to 100 cm or more. Long-stemmed leaves are arranged in a spiral on the stem. In the leaf axils are formed from 30 to 70 heads. The size of the heads varies from the base of the stem to the apical bud. The heads are smoothed in size in 20-40 internodes. In the lower part of the stem, the heads are stage-by-stage more ripened, grow faster and reach technical ripeness earlier. When untimely harvesting, such heads become over-ripe and lose their marketability. The purpose of the study is to identify the feasibility of double harvesting, in order to obtain the maximum number of product heads.

Experiment 4. Studying ways to extend the period of obtaining Brussels sprouts. This problem was resolved by applying repeated harvesting of heads, leaving plants with ripened heads in the field, growing plants with underdeveloped heads in the greenhouse, storing the entire aboveground part of plants with heads in non-cooled storage facilities, storing heads on the stalk and separated from the stalk in refrigerated conditions, storing heads in frozen form.

Seedlings of Brussels sprouts were grown by cassette method in unheated greenhouses or open seedlings with pickling. Seeding was conducted at various times for the purpose of conveyor production of seedlings. In the stage of formation of the first real leaf, a pick was made. Before planting, the seedlings had five to seven real leaves, a shortened thick stem 0.4-0.6 cm in diameter and a well-developed root system.

The crop quality, in accordance with the requirements of the interstate standard [11], was defined by the appearance of the heads, the largest cross diameter and weight by measuring methods. The commodity considered the heads which cross diameter, mm, is not less than: heads with the removed external leaves with the pruned stalk (pruned heads) - 10 mm, heads with the uncut external leaves (uncut heads) - 15 mm. For a comparative assessment of differences in quality indicators, the average weight of the head on the plant was determined depending on the experiment options.

3 Results and discussion

Brussels sprouts derives from Central and Northern Europe [2]. It is widespread in England, Belgium, Germany, Holland, Denmark, the Netherlands, and France. In these countries, seed production and selection of this crop is actively performed. The comparative research of the phenology of varieties and hybrids, the study of the seasonal rhythm of their growth and development is very important for the scientific justification of agrotechnical methods of cultivation in new natural and climatic conditions, since the phenological heterogeneity is fixed genetically. The population of the Russian Federation cultivates Brussels sprouts on small areas in small farms and knowledge of biology and agricultural technology of this crop is insufficient. Varieties and hybrids may not respond adequately to the impact of new growing conditions. Identification of such changes occurring in varieties and hybrids is vital for technology development for Brussels sprouts growing in the natural and climatic conditions of Crimea.

In order to study the phenological features of Brussels sprouts hybrids, we have distinguished the stages that determine the duration of crop formation and ripening: from seed sowing to the beginning of axillary bud formation, the beginning of the formation of cabbages, the onset of technical ripeness of cabbages. Setting dates and duration of each stage gives opportunity to clarify the possible timing of the harvest, refer the hybrid to a certain group of maturation in the natural and climatic conditions of Crimea. In order to study the above questions, cabbage plants were grown by seedling method. Mass shoots, depending on

the average daily temperature in different years, appeared in the Franklin F1 hybrid in five to seven days, in the Diablo F1 hybrid in seven to nine days after sowing the seeds. Top removal of seedlings was performed on the 17th day after sowing, according to all variants of the experiment. At the time for planting, the age of seedlings was 50-51 days. Transplanting of seedlings for all variants of the experiment on June 15.

Studies have shown that in the natural and climatic conditions of Crimea, which differ from the region of origin of Brussels sprouts, in particular, the average daily temperatures of the growing season and relative humidity are not best for the genus Brassicaceae, the plants of the studied hybrids have preserved their genetic identity and preserved inherited genetic differences. The Franklin F1 hybrid proved to be early-maturing or mid-early. The duration of the period of growth and development of plants of this hybrid of Brussels sprouts from planting seedlings to the onset of technical ripeness of the heads in our studies was 113 days. Hybrid Diablo f1 characterizes itself in the natural and climatic conditions of Crimea as late-maturing. For the formation of product heads, plants of this hybrid require 136 days from planting seedlings in the field. Thus, Brussels sprouts growing of these two hybrids at the same time of planting plants in the open ground, may give you commercial products in 23 days. Products of early-ripening varieties of Brussels sprouts can be sold at the beginning of the first decade of October, late-ripening varieties - in the third decade of October [12].

Plants of Brussels sprouts form a fairly large biological crop of the aboveground part. Of all the components of the biological crop, the main value is the indicator of the mass of cabbages, since in this case, Brussels sprouts are grown for food. The yield of Brussels sprouts is defined by standard heads number per plant, their size, and the number of plants per unit area. According to the requirements of the interstate standard [11], Brussels sprouts should be fresh, whole, healthy, clean, fully formed, of various degrees of density, not opened. The heads formed in the axils of the lower leaves are older in age relative to the heads formed in the axils of the higher leaves. The lower the head is situated on the plant, the earlier it reaches the typical size of the variety (hybrid) and technical ripeness. After reaching technical ripeness, the outer leaves of the cabbage gradually age, lose their luster, get rough, forego from the head, lose immunity to fungal diseases. During commodity processing, these leaves have to be removed, which leads to a decrease in the total weight of the crop, table 1.

Table 1. Biological yield components of Brussels sprouts hybrids depending on the area of plant nutrition when reaching the standard size of 70% of heads on the stalk.

The area of plant nutrition, m ²	Weight of the overground part of the plant, g	Weight of stalk, g	Weight of leaves on the plant, g	Weight of heads, g	Standard heads per plant, pcs.
Franklin F ₁					
0,49	2802±132	812±111	1276±104	714±94	45,3±1,9
Diablo F ₁					
0,49	3011±327	853±83	1373±250	785±55	44,0±6,3

The food part of the Brussels sprouts plant (heads), which are used for food, develop on shortened shoots in the leaf axils. The head formation is connected to the increasing activity of the apical bud and the slow growth of the shortened shoot, similar to the head formation of white cabbage. Under favorable temperature conditions for the variety (hybrid), the growth rate of the shortened shoot slows down, and new developing leaves, overlapping each other, are placed under the growth cone, forming heads. Under unfavorable temperature conditions for the variety (hybrid), the growth rate of the shortened shoot of the future heads outstrips the laying of new fragment leaves and the growth of new leaves in the rosette. It was

identified that when the temperature rises to 25 °C or more during the growing season, the heads become pithy or do not form, and with prolonged exposure to low temperatures, the commodity quality of food organs decreases. In order to determine the optimal dates in the natural and climatic conditions of Crimea for the stages of laying axillary buds and forming heads of Brussels sprouts, the experiment of planting seedlings at different times was performed, table. 2.

Analyzing the complex values of the indicators shown in table. 2, it can be concluded that the optimal weather conditions in the Crimea for product heads formation are shaped when planting seedlings of the Franklin F1 hybrid in the third decade of June. Planted in this period of time, the plants of Brussels sprouts of the Franklin F1 hybrid form the maximum number of product (standard) heads per unit area with a single method of harvesting. For plants of Brussels sprouts Diablo hybrid F1, favorable conditions for planting seedlings of this hybrid were formed as in the third decade of June and in early July. Notwithstanding, there is a trend towards greater heads yield when planting seedlings in early July.

An essential indicator of the cabbages ' quality is the maximum cross-section diameter. The interstate standard (GOST 33851-2016) sets the limit values for this indicator. For heads with removed outer leaves, the size of the largest cross diameter should be at least 10.0 mm.

Table 2. Duration of phenological stages of development in plants of Brussels sprouts depending on the planting seedlings period in the open ground, days

Date of transplanting of seedlings	Number of days from transplanting of seedlings to			Product heads from one plant, pcs.	Average mass of a product head, g
	the beginning of the formation of axillary buds	beginning of the head formation			
Franklin F ₁					
15.06	46± 1	66± 1	126± 7	45,5±2,9	13,5±2,1
25.06	39± 1	63± 2	120± 5	46,6±4,2	14,3±2,3
05.07	50± 3	59± 2	119± 3	41,9±3,7	13,8±2,5
15.07	47± 2	52± 2	113± 2	39,3±2,7	13,2±2,4
Diablo F ₁					
15.06	51± 1	73± 1	143± 3	41,9±6,5	14,6±2,7
25.06	45± 3	71± 1	136± 2	44,0±7,5	14,7±2,3
05.07	53± 2	64± 1	127± 2	44,2±6,5	15,1±2,1
15.07	52± 1	57± 1	123± 2	42,3±7,4	14,0±2,4

For heads with non-removed outer leaves, the size of the largest cross diameter must be at least 15.0 mm. Heads of consumer ripeness should be fully formed. They should have different density levels. The current regulatory document does not specify the mass of the head, but it depends on the individual components of the indicators, this is the maximum cross diameter and length of the inner poker. The influence of the timing of planting seedlings on the size of the cross diameter of the heads is shown in table 3.

Table 3. Maximum cross diameter of heads depends on the timing of seedling planting

Date of transplanting of seedlings	Cross diameter, mm	Length of the inner cabbage stalk, mm	Cross diameter, mm	Length of the inner cabbage stalk, mm
Franklin F ₁			Diablo F ₁	

15.06	27,0 ± 1,0	12,0 ± 1,0	28,0 ± 2,0	13,0 ± 1,0
25.06	28,0 ± 2,0	12,0 ± 2,0	29,0 ± 3,0	13,0 ± 1,0
05.07	28,0 ± 2,0	12,0 ± 1,0	29,0 ± 4,0	14,0 ± 1,0
15.07	26,0 ± 2,0	11,0 ± 1,0	27,0 ± 1,0	13,0 ± 1,0

The highest indicators of the studied parameters were found when planting seedlings during the third decade of June and the first decade of July. When planting in these periods in both varieties studied, the heads formed a maximum cross diameter of 28.0 ÷ 29.0 mm with the length of the inner poker from 12.0 to 14.0 mm.

One of the ways to prolong the period of production of Brussels sprouts is growing in the open ground in autumn and winter. In a number of European countries, in accordance with the weather conditions close to the climate of Crimea, this method is widely used. The results of our experiment prove that in the soil and climate conditions of Crimea, summer and autumn sowing periods for cold-resistant vegetable crops, in particular Brussels sprouts, may be used. On the example of a hardy, early-ripening hybrid Franklin F₁, four terms of planting seedlings of Brussels sprouts in the open ground were studied: September 15, October 01, October 15, November 01. Plants planted in the first three terms formed 6-7 leaves by the onset of a steady cold snap and remained in this state until spring warming. Vegetables planted in the open ground on November 01, could not withstand prolonged exposure to low temperatures and, during the winter, died. In the spring period, Brussels sprouts planted on September 15, moved to the generative phase of development. These plants began to increase the growth of stems and the formation of flower buds. In this variant, the plant color was close to 100%. Plants of the second and third terms of planting seedlings with the onset of warm days continued to grow and develop. In terms of repeated harvesting, seedlings planted in the open ground in the first and second decades of October can ensure the crop becoming of commodity heads during July, August and September, table 4.

Table 4. Occurrence dates of phenological development stages in Brussels sprouts plants of the autumn term for planting seedlings in an open ground.

Date of transplanting of seedlings	The beginning of the formation of axillary buds	beginning of the head formation	beginning of technical ripeness of the heads	Product heads from one plant, pcs.	Average mass of a product head, g
Franklin F ₁					
01.10	15.04 ± 1	01.06 ± 1	01.07 ± 7	35,5±1,9	10,3±1,9
15.10	25.04 ± 1	15.06 ± 2	15.07 ± 5	42,6±2,2	12,6±2,4

Brussels sprouts are relatively insensitive to frost. This biological feature allows to prolong the period of harvesting Brussels sprouts, save a certain period of heads on the plant in the field. The issue of quality preservation of the resulting crop to extend its implementation in winter, when the problem of providing fortified products to the population and vacationers in the Crimea is a pressing issue and it is up-to-date. Our research included the study of adaptive abilities to various ways of storing plants in general and the commercial part of the crop of Brussels sprouts hybrids grown in Crimean conditions. Various techniques were used to prolong the period of consumption and long-term storage of fresh Brussels sprouts.

Two-time gathering of cabbages with an interval of 30-40 days enables to considerably extend the period of consumption of fresh cabbages. The number of additional formed heads at double collection, depending on the hybrid, ranged from 19 to 24 pcs. on the plant. The growth of additional heads also promoted an increase in productivity. Planting seedlings of

Brussels sprouts in the open ground, in the third decade of June – the first decade of July, gives an opportunity to harvest product heads during October, November, December, table 5.

Table 5. Brussels sprouts yield depending on the gathering number, t / ha

Variety, hybrid	Per plant, pcs.		T / ha			Increase, t / ha
	gathering	gathering (2 times)	increase	gathering	gathering (2 times)	
Franklin F ₁	41	60	19	12,87	13,99	+1,12
Diablo F ₁	39	63	24	9,54	10,04	+0,50

Natural and climatic conditions of Crimea give an opportunity to leave the plants of Brussels sprouts in the field to prolong the period of cabbages consumption. In our researches, when leaving plants in the field, the stems and heads withstood repeated freezing to minus 18 ... 20 0C, after which the turgor was restored. This frosts occur in Crimea in the winter months rarely. One of the options for storing heads on the stem can be to move the entire plant with undeveloped heads to a protected ground. When a stable decrease in temperature occurred, the Brussels sprouts were dug up with their roots and the root system was dug in a glazed, unheated greenhouse, placing the plants tightly together in a well-moistened soil. The growing period lasted from the third decade of November to January-February of the following year. During this time, the plants continued to vegetate, the heads became larger, and some of the underdeveloped ones acquired standard sizes. Depending on the variety (hybrid), each plant added from three to six standard heads, table 6.

Table 6. Commercial quality of Brussels sprouts after growing in an unheated greenhouse

Hybrid	Heads on a plant, pcs		Heads mass after growing		
	when digging	after growing	uncut, g	cut, g	waste product, %
Franklin F ₁	55	60	1320	1160	12,2
Diablo F ₁	57	62	1132	820	27,6

Up to three months, without a considerable decrease in quality, the heads were stored in an uncooled warehouse at a temperature of 10 ... 12 0C on cut and installed in a container with water plants. After three months of such storage, the upper leaf coverts began to wither on the heads of the lower tiers of the stem, then their withering, shrinking and dying. However, the heads remained quite dense. Stems of the heads when storing on the stump lengthened, and under dead leaves formed a new small heads. The lower the stalk of the Brussels sprouts plant is located, the more its stem lengthens and the more rudimentary heads are formed on it when storing the entire plant in uncooled conditions. At the same time, the heads remain fittable for use.

Consumption period prolongation of Brussels sprouts by storing cabbage heads on the stalk. For this goal, plants with evenly riped heads were taken. The upper part with underdeveloped heads and the lower part of the stem with overripe heads were removed. A plant with full-fledged heads was placed in the refrigerator and stored at a temperature of 0...1 0C. Taking into account these conditions, the heads remain green and dense for a long time. Gradual withering and dying of the upper leaf coverts begins at the heads of the lower part of the stem. Thus, it is desirable to start consumption with the heads located at the bottom of the plant. The heads of the upper part of the plant gradually increase in size. This way,

without significantly quality reduction it is possible to keep the heads for more than two months.

Separated from the main part of the plant, the heads are well preserved in chilled and frozen form. When storing Brussels sprouts in the refrigerator in fresh form, and in the freezer in frozen form, the development of microbiological diseases on the leaves of the cabbage does not appear. Only natural mass loss was noted. It is worthy to note that the leaf tissues forming the heads of the studied varieties and hybrids have different adaptive ability to retain moisture. Moreover, the mass loss of Brussels sprouts in suspended animation, when stored in the refrigerator, is an order of magnitude higher, compared with the mass loss when stored in a state of abiosis. Thus, when stored for 120 days in fresh form, the heads of the Franklin F1 hybrid lost 2.52% and in frozen form, the weight loss was 0.24%.

An extensive indicator of plant products quality is the content of nutrients. In accordance to the level of dry matter content, the nutritional value of fruit formations is judged [6]. In the natural and climatic conditions of Crimea, Brussels sprouts reach the stage of technical ripeness, accumulating 16.6 % of dry substances, table. 7. Growing conditions have a considerable impact on the accumulation of ascorbic acid. We did not confirm the authors' claims [1-4] that cabbage heads accumulate up to 328 mg% of vitamin C. At the stage of technical ripeness of heads, we recorded 78.8 mg%, and, after storage in frozen form for three months, this vitamin is practically absent. As it is indicated in table 7, the content of sugar and organic acids provides not only the nutritional value of the heads, but also a balanced taste.

Table 7. Chemical composition of Brussels sprouts (average values for the studied hybrids)

Evaluation period	Totally dry substances, %	Total sugar, g / 100 g	Titrateable acidity, %	Ascorbic acid, mg/%
Technical ripeness	16,60	5,93	0,41	78,8
Refrigerator storage	15,07	3,0	0,38	61,25
Growing in a greenhouse	10,83	1,87	0,38	46,82
Frozen form storage	16,37	5,37	0,35	0,88

Therefore, the combination of early and late ripening hybrids in the production of Brussels sprouts, the use of autumn and spring-summer terms for planting seedlings in the field allow for 9-10 months to supply fresh Brussels sprouts to the retail chain. Heads storage with the use of artificial cold and freezing enables to have these products all year round.

4 Conclusion

1. In the natural and climatic conditions of Crimea, the hybrid of Brussels sprouts Franklin F1, Diablo F1 preserve their genetically fixed biological properties. The Franklin F1 hybrid shows itself as early-ripening, the Diablo F1 hybrid should be classified as late-ripening. Plants form heads with a high content of dry matter and ascorbic acid.
2. Favorable weather conditions in Crimea for the formation of product heads are formed when planting seedlings of the Franklin F1 hybrid in the third decade of June, for a hybrid of the late maturation period of Diablo F1 in the first decade of July. Planting seedlings of Brussels sprouts in the open ground in the first and second decades of October allows you to ensure the arrival of the crop of commodity heads during July and August. Plants which were put in the open ground on November 1 go into winter weak and die when exposed to low temperatures during the winter. Plants which were put on September 15, in the spring, go to the generative stage of development and do not form food organs.

3. Double harvesting with an interval of 30-40 days can significantly extend the period of consumption of fresh cabbages. When twice collected, depending on the hybrid on the plant, from 19 to 24 pcs.of standard heads are added.

4. In order to extend the period of consumption of Brussels sprouts in the natural and climatic conditions of Crimea, it is possible to leave the plants in the field until the end of December, grow the plants in structures protected from sub-zero temperatures, store the heads in cooled conditions on the stem or separated from the plant, and store them in a frozen condition.

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