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## **From Editor**

The Vegetable Crop Research Bulletin publishes mainly research papers and occasionally reports from conferences on topics of science and technology related to vegetable crops. The current issue presents research papers and Proceedings of the Second International Onion Network Meeting “Accelerating technology transfer in East European onion production” organised by Prof. Dr Franciszek Adamicki, Research Institute of Vegetable Crops, Skierniewice, Poland and Prof. Dr Aleksandr A. Autko, Institute of Vegetable Crops, Belarus and held on July 12-13 2005 in Minsk (Belarus). The International Onion Network was established with the aim of collecting and disseminating information and experience with technology, plant protection, storage and marketing of onions, identifying gaps in knowledge and defining new research projects. This International Network is financed by the Polish Ministry of Science and Information Society Technologies.

On behalf of the Editorial Board I would like to thank all contributors of reports presented in this volume. I greatly appreciate the help of organising committee for the International Onion Network in preparing the Proceedings for publication.

I hope that the research papers and Proceedings presented in this volume will prove useful and advance the knowledge in science and vegetable crops technology.

Editor-in-Chief

A. Dobrzański

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**PROCEEDINGS  
OF THE SECOND INTERNATIONAL  
ONION NETWORK MEETING**

**Minsk - Belarus, 12-13 July 2005**

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## FOREWORD

Onions are the world's second most important vegetable crop with a production of 52 million tonnes. Central and East European countries have a significant position in the global production and marketing of onions. Producers from these countries need to consolidate their position by further innovation of production technology, postharvest treatment, storage and marketing to improve quality and keeping ability of onions in order to compete with growers from other countries. There are several national and international programs and initiatives to stimulate progress in breeding and technology. Among this is an International Scientific Network "Accelerating technology transfer in Central and East European onion production" which was granted by the Polish Ministry of Science and Information Society Technologies for 2004-2006. The main aim of this Network is to bring together the scientists from different Central and East European countries to stimulate an international collaboration to improvement technology of onion production by organisation of conferences, workshops and training. In case of the Onion Network, main objectives are as follows:

- Identification of current research and development activities on onion production in co-operating countries
- Identify potential improvements to the existing production technology of onions
- Exchange information on research results and improvements in technology within partnership countries
- Recognition of existing onion producer organisations, exporters and importers
- To identify potential for agreed research priorities among partnership countries
- Information exchange on organisation of basic and applied research in Central and East European countries
- To promote an initiative for joint discussion and work on new project proposals, in collaboration with all members of working group

The papers presented and discussion at the International Onion Network Conference in Minsk, Belarus, covers the goals and objectives for future research, and cooperation towards improving technology of onion production for all members.

Franciszek Adamicki

Co-ordinator of International Project

## **PRODUCTION, MARKETING AND RESEARCH ON ONION (*ALLIUM CEPA* L.) IN BELARUS**

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### Summary

In 2004 total area of onion cultivation in Belarus achieved around 10000 ha, including 2100 ha in state farms. Total volume of onion production exceeded 156000 tons and in state farms 22600 tons. To supply the needs of whole country for onion it is necessary to produce 145000-155000 tons. The narrow choice of good onion cultivars is one of the factors which limit the increase of onion production in Belarus. Since 1983 in Belarus the breeding program was conducted to receive the new onion cultivars and hybrids which are resistant to main diseases appearing during cultivation and long term storage. Among 207 tested cultivars the significant variability in resistance to downy mildew and storage diseases between studied cultivars. Only 8 cultivars (3.78%) were found to be highly resistant. Most cultivars were susceptible to downy mildew (71 cultivars) or very susceptible (61 cultivars). Most of onion cultivars (62.1%) showed low resistance to diseases during storage. Degree of disease infestation lower than 10% was found for 9 cultivars. Observations on development of bulb neck rot caused by *B. alcada* Fresen. and *B. cinerea* have proved that it is very difficult to evaluate the infestation of onion using the 6-degree scale by VNISSOK. The 9-degree scale of evaluation of infestation by bulb neck rot was developed and then accepted. Evaluation of onion collection have shown a great variability of resistance to *Botrytis* among cultivars. Most cultivars characterized with high susceptibility to this fungus. For resistance breeding of onion against bulb neck rot the following cultivars are recommended: Vetrax, Kryvicki ruzowyj, Jantarnyj, Mestnyj, (Minsk area), Szetana, Citausskij, Durko, Strigunowskij mestnyj, as well as hybrids: No 68, 136, 249, 701, 718, 733, 1738, 1743, 9302 and 9717.

key words: onion, cultivars, production, marketing, breeding, diseases, resistance

### **Production of onion in Belarus**

According to Institute of Food and Nutrition the nutritional requirements for onion in Belarus is estimated for 10 kg per person annually, including 7 kg



of bulb onion, 2 kg of onion with leaves and 1 kg of garlic. Before 2000 the yearly total production of onion in Belarus amounted 60000-70000 tons, including 58000-63000 tons of onion from home gardens and recreation plots. In the years 1970-1990 onion was cultivated on area of 400-800 ha, and total yield was not higher than 1500-7000 tons. But it did not meet the demands for onion in the country. Total supply of onion - import and domestic production - made together only 65-80% of necessary volume for whole country. The climatic and soil condition in Belarus, especially in south and south-central regions allow to produce onion not only for local market but also for export. It can be supported with statistic data from history of Belarus. In years 1912-1914 export of onion outside Belarus reached annually 3850 tons, but it was stopped in the first years after October Revolution.

Table 1. Production of onion in Belarus in 2002-2004

Region	2002		2003		2004	
	Total (x1000 tons)	Collective farms (x1000 tons)	Total (x1000 tons)	Collective farms (x1000 tons)	Total (x1000 tons)	Collective farms (x1000 tons)
Brestskaya	15,8	0,1	17,3	0,4	19,8	1,1
Vitebskaya	13,1	0,1	14,4	-	15,7	-
Gomelskaya	26,5	3,8	34,7	10,4	46,5	15,5
Grodnenskaya	14,0	0,5	17,5	0,5	20,4	0,9
Minskaya	21,4	0,2	26,6	1,1	36,5	3,6
Mogilevskaya	11,3	-	13,0	1,0	17,4	1,5
Belarus	102,1	4,7	123,5	13,4	156,3	22,6

In last years production of onion has significantly increased. In 2004 total area of onion cultivation in Belarus achieved around 10000 ha, including 2100 ha in state farms. Total volume of onion production exceeded 156000 tons in 2004, and it is 153% of that from year 2002. In state farms 22600 tons of onion was produced and it made 168.7% of annual production in 2003 year.

To supply the needs of whole country for onion, including the inevitable losses, it is necessary to have 145000-155000 tons. Assuming that onion production in private farms in following years will achieve about 115000-120000 tons, cultivation in public sector of agriculture should amount annually 30000-35000 tons in next 2-3 years, but still 14000 tons of onion should be imported. To achieve such production the area of about 1750-1800 ha should be cultivated in whole country under onion at average yields 20 tons·ha<sup>-1</sup>. In next 2-3 years the program of improvement of cultivation technology, marketing and storage should be developed in Belarus. Based on this program the next step will be undertaken to increase the onion production in the country.

### **Breeding of onion with regard to resistance of plants to diseases**

The narrow choice of good onion cultivars is one of the factors which limit the increase of onion production in Belarus. Sixteen cultivars and hybrids of onions are listed on the “National List of Plant Varieties”, but only 4 of them were bred in Belarus. At the same time most of these cultivars possess some shortcomings of agricultural and biological nature. First of all they have low resistance to diseases.

It is estimated that annual losses caused by pests and diseases in world vegetables crops can reach 1/3 of potential yields. Therefore the effective system of plant protection against pests and diseases is necessary. One of the elements of this system should be resistance breeding.

The current system of plant protection does not properly secure vegetables against diseases especially in intensive technologies, and thus the resistance breeding of plants against pathogens is of special importance. Moreover, the wide use of chemical in plants protection against pests resulted in appearance some ecological problems. Additionally, the new populations of pests resistant to used chemicals have arisen.

Since 1983 in Belarus the breeding program was conducted to receive the new onion cultivars and hybrids which are resistant to main diseases appearing during cultivation and long term storage.

One of the first step of resistance breeding for diseases should be the review and evaluation of the world collection of onion cultivars. In years 1985-2004 the comparative evaluation of 207 cultivar types of onion was conducted but special attention was paid on resistance of onions to main diseases specific for conditions of Belarus. At first step the world collection of onion cultivars from All-Russian Research Institute of Vegetable Crops, as well as local types of onion were investigated. This material was analyzed for resistance to downy mildew and the losses due to diseases were evaluated. After first selection of these cultivars the additional tests and analyses were performed.

Investigations have shown the significant variability in resistance to downy mildew and storage diseases between studied cultivars. Also differences in these parameters were found between individual years with different weather conditions, but it did not influenced significantly the final evaluation of cultivar differences.

No resistant cultivars were found among the tested ones.

All cultivars were sorted into 5 groups according to degree of resistance to downy mildew: highly resistant (7-9 points in scale of SEW), fairly resistant (5-7 points), medium resistant (4-5 points), susceptible (3-4 points), very susceptible (<3 points). Only few cultivars were characterized by high resistance to downy mildew in cultivation during two succeeding years. In the first year of cultivation 8 cultivars (3.78%) were found to be highly resistant. Also 26 cultivars (12.56%) were fairly resistant, 40 cultivars (19.32%) with medium resistance, 71 cultivars (34.3%) were susceptible and 62 cultivars (29.95%) very susceptible.

In seed cultivations only 5 cultivars (2.4%) were found to be highly resistant to diseases, 36 cultivars (17.4%) were fairly resistant, 35 cultivars (16.9%) with medium resistance, 72 cultivars (34.8%) were susceptible and 59 cultivars (28.5%) very susceptible.

Investigations have shown that most of tested cultivars do not possess resistance to downy mildew. Only limited group of cultivars with high resistance and fair resistance could be taken into account for further studies on selection.

Cultivar group with medium resistance can also be considered because plants of this group are becoming significantly affected by downy mildew during cultivation only on the end of growing period. Therefore, it does not affect the total yield.

One of the necessary conditions for obtaining proper results of the tests for disease resistance is preparation of optimal artificial environment where suitable infestation will be secured.

For obtaining correlation between results on downy mildew resistance from natural environment and artificially affected environment the statistic analysis of results on diseases development in different years, which characterized with variable degree of their intensity, was conducted. The high correlation in all investigations have proved that onion cultivar analysis of their resistance to downy mildew can be conducted in both, natural environment and artificially affected cultivations. At naturally affected cultivations the best results were obtained in the years when epiphytic development of diseases occurred. In the years with depression of diseases occurrence the additional artificial infection is necessary.

Experiments on evaluation of onion cultivar resistance to downy mildew can be planned if the possibilities of occurrence of this disease will be considered. It can allow to reduce the costs related to artificially infected cultivation in the years with epiphytic occurrence of downy mildew.

Assessment of breeding material for disease infestation during storage has shown the differences between investigated cultivars.

Most of onion cultivars (62.1%) showed low resistance to diseases during storage. Highly affected were early cultivars, as well as semi-pungent and sweet ones bred in western and south regions of Belarus. About 12.2% of all cultivars were infected at low level. Degree of disease infestation lower than 10% was found for cultivars: Rostovskij, Mestnyj (Udmurtia), Mestnyj (Minskij region), Vetrax, Kryvitskij, Yellow globe Danvers, Stuttgarter (Holland), Curuxoo No 4, Produre. These cultivars can be used as a initial breeding material for obtaining cultivars intended for storage.

At the same time cultivars were evaluated for resistance to main pathogens: *B. alcada*, *F. oxysporum*, *P. glaucum*, *S. cepivorum*, *E. carotovora*, *P. allicola*.

Observations on development of bulb neck rot caused by *B. alcada* Fresen. and *B. cinerea* have proved that it is very difficult to evaluate the infestation of onion using the 6-degree scale VNISSOK. It was often observed that the same

evidences of infestation corresponded partly with one scale and partly with second one. Simultaneously, the following evidences were observed: single wet spots on cross section surface (degree scale 2), area covered with fungus spores (degree scale 3), wet spots and mycelium on whole cross section (degree scale 4), fungus spores on small area (degree scale 3). In such cases an intermediate scale should be used, for example, 2-3 points, 3-4 points etc., or more precise scale could be applied.

Finally, the 9-degree scale of evaluation of infestation by bulb neck rot was prepared and then accepted. Modified 9-degree scale of onion infestation by *Botrytis* comprise the intermediary degrees, 2, 4 and 6 points. This scale is more differentiated than 6-degree scale by VNISSOK. Assessment according to new scale is especially important for onion screening in respect of its resistance to fungus *Botrytis*. Evaluation of onion collection have shown a great variability of resistance to *Botrytis* among cultivars. Most cultivars characterized with high susceptibility to this fungus.

All tested onion cultivars were affected by bulb neck rot. About 8.3% of cultivars were partly resistant (degree of infestation 0-1 points), 11.2% were mid-resistant (2-3 points), 30.6% susceptible (4-5 points) and 49.9% very susceptible (6-8 points).

For future breeding only onion which characterizes with 1-4 points – according to VNISSOK scale of pathogen infestation – was proposed, and it means practically that only cultivars which are resistant to this disease can be taken into consideration. For resistance breeding of onion against bulb neck rot the following cultivars are recommended: Vetrax, Kryvicki ruzowyj, Jantarnyj, Mestnyj, (Minsk area), Szetana, Citausskij, Durko, Strigunowskij mestnyj, as well as hybrids: No 68, 136, 249, 701, 718, 733, 1738, 1743, 9302 and 9717 which were obtained from crossing of resistant types to pathogens with cultivars: Vetrax, Jantarnyj and Belovezskij.

## PRODUKCJA, MARKIETING I BADANIA DOTYCZĄCE CEBULI NA BIAŁORUSI

### Streszczenie

W roku 2004 cebula była produkowana na Białorusi na areale około 10 tys. ha, wliczając w to powierzchnię pod uprawą w gospodarstwach państwowych. Wielkość produkcji cebuli przekroczyła 156 tys. ton, w tym 22,6 tys. ton z uprawy w sektorze państwowym. Do pełnego zaspokojenia potrzeb krajowych rocznie należałoby produkować 145-155 tys. ton cebuli. Jednym z czynników ograniczających wzrost produkcji cebuli na Białorusi jest niewielki wybór odmian do uprawy cebuli. Od roku 1983 realizowany jest w kraju program rozwoju hodowli cebuli zmierzający do uzyskania własnych, nowych odmian i mieszańców, które byłyby odporne na najczęściej występujące choroby roślin podczas uprawy i przechowywania. Wśród 207 przetestowanych odmian stwierdzono wysoką zmienność w odporności cebuli na mączniaka rzekomego. Wysoką odpornością cechowało się tylko 8 odmian, co stanowiło 3.78% ogólnej liczby przetestowanych odmian. Większość odmian (71) była wrażliwa, albo bardzo wrażliwa (61 odmian) na mączniaka rzekomego. Ponad połowa liczby odmian wykazywała niski

stopień odporności na choroby przechowywane cebuli. Na podstawie obserwacji i objawów zgnilizny szyjki cebuli powodowanej przez *B. alceda* Fresen. i *B. cinerea* wykazano, że przy pomocy 6-cio stopniowej skali VNISSOK trudno jest dokonać prawidłowej oceny stopnia infekcji cebuli tą chorobą. Dlatego też opracowano nową 9-cio stopniową skalę, która posłużyła do oceny różnic międzyodmianowych cebuli znajdujących się w kolekcji odmian. Stwierdzono również wysoką wrażliwość większości odmian na *Botrytis*. Na podstawie oceny stopnia wrażliwości cebuli na *Botrytis* wytypowano do dalszych prac hodowlanych następujące odmiany i mieszańce: Vetrax, Kryvicki ruzowyj, Jantarnyj, Mestnyj, (Minsk reg.), Szetana, Citausskij, Durko, Strigunowski mestnyj, No 68, 136, 249, 701, 718, 733, 1738, 1743, 9302 oraz 9717.

## **THE PRODUCTION AND RESEARCH WORK ON ONION IN RUSSIAN FEDERATION IN 2004**

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### Summary

Different organizational forms of farming and managing are involved in onion production in Russia: agricultural enterprises (agricultural co-operatives, collective farms, state farms, the state enterprises, the municipal enterprises and others), economies of population and farmer economies. In 2004 onion was cultivated in Russia on the area of 129100 ha compared to 119300 ha in 2003, taking into account the all categories of farming units. Total onion production in 2004 amounted 1673400 tons, with the yield of 13 tons·ha<sup>-1</sup>. The highest contribution of economies of population (80.2%) and sowing area (76.2%) to total onion production was noticed. More than 84% of onion area cultivation is located in three federal districts: Southern 45200 ha, Pryvolzhsky 35600 ha and Central 27700 ha. About 62-66% of onion - depending on year - is cultivated from sets. Import of onion from European and Central Asia countries - including China - makes about 40% of total onion production in Russia. Many research institutes of Russia are involved in onion breeding, including: All-Russian Research Institute of Breeding and a Seed Production of Vegetable Crops (ARRIBSPVC), All-Russian Research Institute of Vegetable Crops (ARRIVC) (Moscow region), Krasnodar Research Institute of Vegetables and Potato (Krasnodar), Kuban State Agrarian University (Krasnodar). Research work on onion breeding are carried out at 3 experimental stations belonging to ARRIVC which are located in zones of Siberia, the Centre and the South of the country. The main task of breeding for this crop is development of onion cultivars grown from seeds for mentioned zones of the country.

key words: onion, production indexes, yield, modes of farming, prices, research

### **Area and yield of onion production in different forms of farming in Russia**

With reference to production of onion the Russian Federation enters in ten leading countries of the world cultivating this crop.

Economies (structures) of different organizational forms of managing are involved in onion production in Russia: agricultural enterprises (agricultural

co-operatives, collective farms, state farms, the state enterprises, the municipal enterprises and others), economies of population, farmer economies.

In 2004 the area occupied with onion, grown for consumption in all categories of economies has made 129,1 thousand hectares (th. ha). In comparison with 2003 it has increased by 9,8 th. ha or 8.2% (Table 1).

In the greater measure the increase of the production area was observed in agricultural enterprises which expanded their plantations by 5,6 th. ha (32.7%) and farmer economies by 2,9 th. ha (56.9%). Economies of the population have increased onion sowing area only by 1,3 th. ha (1.3%).

The total production of onion in 2004 in comparison with 2003 has increased from 1560,6 thousand tons (th. t) to 1673,4 th. t (7.2%). Agricultural enterprises have increased onion production by 86,6 th. t (58.5%), farmer economies by 47,2 th. t (96.5%), and economies of population have reduced it by 21,0 th. t (-1.5%).

The yield of this crop in the country in 2004 has made, on the average, 13,0 t·ha<sup>-1</sup> and practically it has remained at the level of the previous year. But in farmer economies it has increased by 2,4 t·ha<sup>-1</sup> (25.0%), in agricultural enterprises by 1,6 t·ha<sup>-1</sup> (18.4%), and in economies of population it has decreased by 0,4 t·ha<sup>-1</sup> (-2.9%).

Table 1. The main parameters of onion production in Russian Federation in 2004

Categories of economies	2003	2004	2004 to 2003	
			+, -	%
<b>The sown area (th. ha)</b>				
Economies of all categories including:	119,3	129,1	9,8	8.2
- agricultural enterprises	17,1	22,7	5,6	32.7
- economies of population	97,1	98,4	1,3	1.3
- farmer economies	5,1	8,0	2,9	56.9
<b>Total production (th. t)</b>				
Economies of all categories including:	1560,6	1673,4	112,8	7.2
- agricultural enterprises	148,1	234,7	86,6	58.5
- economies of population	1363,6	1342,6	-21,0	-1.5
- farmer economies	48,9	96,1	47,2	96.5
<b>Yield (t·ha<sup>-1</sup>)</b>				
Economies of all categories including:	13.1	13.0	-0.1	-0.8
- agricultural enterprises	8.7	10.3	1.6	18.4
- economies of population	14.0	13.6	-0.4	-2.9
- farmer economies	9.6	12.0	2.4	25.0

In 2004 economies of population obtained the highest productivity of onion – 13.6 t·ha<sup>-1</sup>, next farmer economies (12.0 t·ha<sup>-1</sup>) and agricultural enterprises (10.3 t·ha<sup>-1</sup>). Average productivity remains low and for last year it

has not grown. Therefore the increase of total production of onion has taken place mainly due to expansion of sowing area.

Economies of population has the greatest share in sowing area and total production of onion - accordingly 76.2% and 80.2% (Table 2).

Agricultural enterprises made 17.6% of total sowing area in the country and 14.0% of total production, but farmer economies contributed accordingly 6.2% and 5.8%.

In 2004, compared with 2003, there were some changes. The share of agricultural enterprises in sowing area has increased by 3.3%, in total production by 4.5%; farmer economies accordingly by 1.9% and 2.7%, but economies of population has dropped by 5.2% and 7.2%. However it has not affected arrangement of priorities of the specified categories of economies in production of onion in the country.

Table 2. Share of different categories of economies in production of onion in Russian Federation in 2004

Categories of economies	Share in %					
	sowing area			total production		
	2003	2004	2004 to 2003	2003	2004	2004 to 2003
Agricultural enterprises	14.3	17.6	3.3	9.5	14.0	4.5
Economies of population	81.4	76.2	-5.2	87.4	80.2	-7.2
Farmer economies	4.3	6.2	1.9	3.1	5.8	2.7

### Distribution of onion production in regions of Russia

Distribution of this crop on the territory of Russia is extremely non-uniform (Table 3).

Table 3. Sowing area of onion on federal districts of Russian Federation in 2004

Federal districts	Sowing area (th.ha)				Share of districts in sowing area (%)		
	2003	2004	2004 to 2003		2003	2004	2004 to 2003
			+, -	(%)			+, -
Russian Federation	119,3	129,1	9,8	8.2	100,0	100,0	-
Central	26,9	27,7	0,8	3.0	22.5	21.5	-1.0
Northwest	6,3	5,7	-0,6	-9.5	5.3	4.4	-0.9
Southern	36,5	45,2	8,7	23.8	30.6	35.0	4.4
Pryvolzhsky	34,9	35,6	0,7	1.9	29.3	27.6	-1.7
Ural	6,0	6,2	0,2	3.3	5.0	4.8	-0.2
Siberian	7,7	7,5	-0,2	-2.6	6.5	5.8	-0.7
Far East	1,0	1,2	0,2	20.0	0.8	0.9	0.1



From 129,1 th. ha occupied in 2004 with onion 108,5 th. ha (84.1%) is located in three (from seven) federal districts: Southern 45,2 th. ha (35.0%), Pryvolzhsky 35,6 th. ha (27.6%), Central 27,7 th. ha (21.5%). The total expansion of sowing area in Russia was observed because of expansion of sowing area in these districts. Especially it is appreciable on Southern district where production of onion has increased by 8,7 th. ha (23.8%).

The ratio of onion areas cultivated from seeds and sets has changed (Table 4).

Table 4. Sowing area of onion cultivated from seeds and sets in Russian Federation in 2004

Years	Area of cultivated onion (th.ha)		Share of cultivated onion (%)	
	seeds	sets	seeds	sets
<b>Economies of all categories</b>				
2003	40,4	78,9	33.9	66.1
2004	49,5	79,6	38.3	61.7
<b>Agricultural enterprises</b>				
2003	14,8	2,3	86.6	13.4
2004	19,8	2,9	87.2	12.8
<b>Economies of population</b>				
2003	21,1	76,0	21.7	78.3
2004	22,4	76,0	22.8	77.2
<b>Farmer economies</b>				
2003	4,5	0,6	88.2	11.8
2004	7,3	0,7	91.3	8.7

In 2004 in comparison with 2003 in the whole country in all categories of economies small increase of share of onion cultivation area from seeds and decrease from sets were observed. The portion of onion sowing area cultivated from seeds has increased from 33.9% up to 38.3%, and from sets has decreased from 66.1% down to 61.7%. The agricultural enterprises cultivated 87.2% of onion from seeds and 12,8% from sets, population accordingly 22.8% and 77.2%, farmers – 91.3% and 8.7%.

### Import & export of onion

In Russia the volume of production of own onion is rather high and in 2003 it amounted to 10.7 kg/inhabitant, including production by economies of population 9.4 kg/inhabitant, agricultural enterprises and farmer's economies – 1.3 kg/inhabitant. In 2004 these numbers were accordingly 11.5 kg, 9.2 kg and 2.3 kg.

The concentration of onion production in population reduces market resources. The mentioned above producers can fill up them. However the total production of onion of these two categories of economies is obviously small and in 2003 it reached 197,0 th. t (12.6%), but in 2004 increased to 330,8 th. t (19.8%). It was necessary to import onion. In 2003 it was delivered from 10

European countries, Central Asian countries and China 632,2 th. t of onion, including some garlic, and 606,0 th. t in 2004. Import of onions for two last years estimated around 40.5%.

Export of onion for these years was not sufficient - agricultural enterprises have exported 46 - 268 t, and it equaled to 0.003 - 0.02% of onion produced in the country.

The total quantity of onion available in Russia including domestic production, import and export in 2004 amounted to 2279354 t against 2192532 t in 2003 and has increased by 86822 t (4.0%). There was increasing the consumption upon the inhabitant from 15.1 kg up to 15.7 kg that is higher than average norm of consumption recommended in the country (10 kg).

On the background of general increase of available resources of onion its volume being at agricultural enterprises and farmer's economies, and also delivered from import, has risen from 828932 t up to 936754 t (13%).

### **Onion prices**

Such increasing onion production has affected the prices (Table 5). The monthly average prices of onion in Russia in 2004 changed from 4.2 (November) to 10.3 rubles/kg (April). They were lower than the level of prices in 2003 for all months, except of April and September, and they were within the limits 1.9% (June) - 35.7% (December). In regions the mid-annual price of produced onion by agricultural enterprises in 2004 consisted of from 2.4-2.5 rubles/kg in Republic of Kalmykia and Astrakhan region to 11.8 – 12.7 rubles/kg in the Sakhalin and Chita regions.

Monthly average consumer prices of onion oscillated from 10.7 rubles/kg (October - November) to 16.1 rubles/kg (May). Small decrease of consumer prices, has taken place in all months from 0.7% (January - February) to 10.4% (December). Consumer prices exceeded producer prices by 1,5 times (June) - 2,5 times (November, December, January).

Relatively low productivity of onion in the country dictates the necessity of its increase. In connection with that the priority direction in research work on onion is breeding. Its contribution to increase of yield of vegetable crops is estimated by some scientists for 30-40%.

### **Research on onion in Russia**

Many research institutes of Russia are involved in onion breeding. The main of them: the All-Russian Research Institute of Breeding and a Seed Production of Vegetable Crops (ARRIBSPVC) and All-Russian Research Institute of Vegetable Crops (ARRIVC) (Moscow region), Krasnodar Research Institute of Vegetables and Potato (Krasnodar), Kuban State Agrarian University (Krasnodar).

Table 5. The monthly average prices of onion in Russian Federation in 2004 (rubles/kg)

Months	Producer prices			Consumer prices		
	2003	2004	2004 to 2003 (%)	2003	2004	2004 to 2003 (%)
January	6.7	5.4	80.6	13.9	13.8	99.3
February	9.6	8.3	86.5	14.9	14.8	99.3
March	9.2	7.8	84.8	15.8	15.3	96.8
April	9.2	9.4	102.2	17.0	15.6	91.8
May	9.5	9.3	97.9	17.8	16.1	90.4
June	10.5	10.3	98.1	16.8	15.5	92.3
July	10.6	8.4	79.2	15.6	14.5	92.9
August	7.9	6.5	82.3	13.4	12.6	94.0
September	4.7	4.8	102.1	12.0	11.3	94.2
October	4.7	4.5	95.7	11.4	10.7	93.9
November	4.7	4.2	89.4	11.7	10.7	91.5
December	7.0	4.5	64.3	12.5	11.2	89.6

Russian Ministry of Agriculture in 2004 has allowed to use 80 cultivars and hybrids of onion of domestic and foreign breeding. From all of them 23 hybrids are domestic and 22 - foreign. Among recommended cultivars - 7 ones are ARRIVC's breeding. In comparison with 2003 the state registry has replenished by 2 new cultivars and 2 hybrids of onion (Table 6).

Research work on onion breeding is carried out at 3 experimental stations belonging to ARRIVC which are located in zones of Siberia, the Centre and the South of the country. The main task of breeding for this crop is development perspective for their zones of onion cultivars cultivated by cheaper way from seeds.

West - Siberian Vegetable Experimental Station in 2004 has finished the work on breeding of new onion cultivar under the name Velina which has passed the state cultivar testing. This cultivar is early maturing, vegetative period is 62-68 days, the shape of a bulb is round with the mass 60 - 70 g, colour of dry scales is yellow, taste of a bulb is semisharp, the content of dry matter - 12.0%, a total content of sugar - 9.0%, maturity before harvesting - up to 98.5%, total yield - 26.7 t·ha<sup>-1</sup>, marketability - 23.9 t·ha<sup>-1</sup> (89.5%), storage ability of bulbs during 7-8 months storage - 90.1%. Damage of cultivar Velina by fungus diseases is 0.68%. Industrial test was carried out in experimental farm "Vegetable grower" of Altai region.

The Voronezh Vegetable Experimental Station in 2004 has conducted the state cultivar testing of a new onion cultivar Odnoletny Voronezhsky. This cultivar is early maturing, the shape of a bulb is round with mass - 60-90 g, colour of dry scales - yellow, taste of a bulb semisharp, total yield - 19.0-20.0 t·ha<sup>-1</sup>.

Table 6. The main parameters of onion cultivars and hybrids included in the State List of Russia in 2004

Parameters	Cultivars		Hybrids F <sub>1</sub>	
	Kuzmichevsky	Tervin	Music	Sheron
Way of growing	seeds	seeds (and sets)	seeds	seeds
Time of maturing	middle	middle	middle-late	early
Vegetative period*	90-115	90-105	90-110	75-90
Form of a bulb	round	round -flat	oval	oval
Mass (g)	90-120	90-100	110-130	45-70
Colour of dry scales	brown	yellow	yellow	brown
Quantity of scales	2-3	3-4	3	3
Buds in bulb	1	3	2	2
Taste	semisharp	sharp	semisharp	semisharp
The content (%)				
- dry matter	13.1	13.6	11.5	11.5
- total sugar	6.6	10.3	5.4	8.5
- marketable yield (t·ha <sup>-1</sup> )	29.2-37.2	16.7-20.0	19.9-34.0	15.9-25.2
Maturation (%)				
- before harvesting	75-76	72-80	80-92	90-97
- after drying	91-100	95-100	96-100	97-100
Period of storage	-	-	short-term	6 months
Regions of application	Nizhnevolzhsky	Central	Central	Central
Originator	VES	ARRIBSPVC	BZ	BZ

\* - Vegetative period (from full shoots up to a mass lodging of leaves), days;

VES - Volgograd Experimental Station of All Russian Institute of Plant Growing;

ARRIBSPVC - All Russian Research Institute of Breeding and Seed Production of Vegetable Crops;

BZ - BEJO ZADEN B.V. (Holland)

Biruchecut Vegetable Breeding Experimental Station (Rostov region) carries out the work on development of semisharp cultivar of onion with yield 40 t·ha<sup>-1</sup> and resistance to some fungal diseases. The testing carried out in 2004 showed that 4 investigated cultivars (Chalcedony, Lugansk, Ellan, Rossana) and 4 hybrids F<sub>1</sub> (Hyper, Hyton, Leon, Comet) has not exceeded parameters of semisharp, middle maturing cultivar Yantarniy 29 developed by this station and adopted since 2002, which is accepted as a standard. The yield of this cultivar – 38.6 t·ha<sup>-1</sup>, marketability – 98.2%, maturity before harvesting – 92.8%, sensitiveness to fungal diseases 5%, bacteriosis - 5%.

Research carried out on Primorian Vegetable Experimental Station are aimed on improvement of system of protection against weeds in onion fields for conditions of the southern part of Far East. It was studied the doses and terms of application of herbicides Goal, Betanal progress AM and Beteren Express AM.

Introduction of the mechanized "know-how" of onion production in one-year crop (Dutch variant) was continued in agricultural enterprises of Moscow

region in 2004. The area of cultivation has increased from 330 ha to 400 ha (21.2%), yield has increased from 32.4 t·ha<sup>-1</sup> to 32.8 t·ha<sup>-1</sup>, the total yield has increased from 10692 t to 13120 t (22.7%).

Now investigations on onion storage in ARRIVC are not carried out. The onion in fruit-and-vegetable bases of Moscow is stored in refrigerating chambers under the recommendations developed in the institute earlier.

The problem of onion branch of Russia is to increase the production of marketable onion in agricultural enterprises, to reduce its dependence on import, to increase yields and quality on the basis of introduction of new cultivars and hybrids, progressive technologies of cultivation and storage of onion, to increase the economic efficiency.

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#### PRODUKCJA CEBULI I BADANIA PROWADZONE W FEDERACJI ROSYJSKIEJ W 2004 ROKU

##### Streszczenie

W Rosji wyróżnia się kilka form organizacyjnych gospodarowania i zarządzania w rolnictwie, w tym również w dziedzinie produkcji cebuli. Są to: przedsiębiorstwa rolnicze (spółdzielnie produkcyjne, kolchozy, gospodarstwa państwowe, przedsiębiorstwa państwowe, przedsiębiorstwa samorządowe i inne), gospodarstwa przydomowe i gospodarstwa farmerskie. Całkowity areal uprawy cebuli w Rosji we wszystkich typach gospodarstw zajmował w 2004 roku powierzchnię 129100 ha, a w 2003 roku powierzchnię 119300 ha. Ogólna produkcja cebuli wynosiła w 2004 roku 1673400 ton przy średnim plonie około 13 ton z hektara. Najwyższy udział w ogólnej produkcji cebuli mają gospodarstwa przydomowe (80.2%). Ponad 84% cebuli jest uprawiane w trzech okręgach federalnych: Południowym (45200 ha), Nadwołżańskim (35600 ha) i Centralnym (27700 ha). Najwięcej cebuli (62-66%) jest uprawiane z dymki. Import cebuli z krajów europejskich, krajów Azji Centralnej i Chin stanowi około 40% produkcji krajowej. Badania z zakresu uprawy i hodowli cebuli są prowadzone w kilku instytutach naukowych, znajdujących się głównie w rejonie moskiewskim i krasnodarskim. Prace hodowlane nad cebulą są prowadzone głównie w trzech stacjach doświadczalnych Wszechrosyjskiego Instytutu Naukowego Warzywnictwa. Stacje te są umiejscowione na Syberii, w centrum i na południu Rosji. Głównym celem ich działalności jest hodowla nowych odmian przydatnych do uprawy cebuli z siewu w warunkach klimatyczno-glebowych wymienionych części kraju.

## **ONION PRODUCTION, MARKETING AND RESEARCH IN POLAND**

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### **Summary**

Onions are still on the third place among all vegetables grown in Poland with annual production over 800 thousand tonnes. Consumption of onions slightly decreased during last decade from over 8 kg per person to about 7.4 kg. High production, especially in some seasons, and stable consumption and processing industry demand caused some problems with usage of high volume of onions. Due to high quality and storage ability the Polish onions is very seeking for export and yearly about 150-200 thousand tonnes is exported to EU countries as well as to South and East European countries. Production of onions in Poland is still dominating on small farm ranged from 1 to 5 ha, however in new regions of production onion is grown on the area of 20-100 ha of one farm. Lack of farmer organisation groups, modern storage facilities on individual farms and logistic centres make difficulties in proper marketing of onions. Increase of onions production from sets and overwintering crops to fill up the supply of market with fresh onions from end of May to beginning of August is also observed. Research is concentrated on breeding of new varieties suitable for long storage, new methods of growing, crop protection against weeds, insects and fungal diseases, improving of storage techniques and searching of new solutions to prevent sprouting and rooting of onions during long period of storage.

key words: onion production, storage, marketing, export

### **Onion production in Poland**

Poland is the one of the important producers of onion in Europe and takes the third place after Spain and the Netherlands (Adamicki 2005). Total production of onion in Poland varies from year to year depending on price index in previous year. In 2004 exceptionally high production of onion – 866 thousand tonnes from area of 36 thousand ha – was noted in Poland (Table 1)(Adamicki 2004a). Despite high total production the yield from one hectare is still low and is estimated for 24 tonnes per hectare. Low average yield of onion from 1 ha is caused by high index of small-scale agriculture production, since the area of onion cultivation on one farm in Poland ranges from 0.25 ha to 100 ha or higher. In big specialized farms yields of onion ranges from 40 to 60 tonnes, and it makes possible to cover the costs of production with small profit,

even at low onion prices on market. Relatively high prices of onion last season resulted in increase of cultivation area by about 11% up to 36 thousand ha (Fig. 1). At the same time production of onion has increased from 678 thousand tonnes to 866 thousand tonnes. Similar tendencies were observed in all European countries, but the highest onion production was noted in the Netherlands – 1200 thousand tonnes. This situation caused the breakdown of onion prices in whole Europe and made difficulties in utilization of onion. In consequences the high losses of onion in many farms were noted, especially in the Netherlands, where 25-30% of total onion production was lost. During the autumn and winter period the low onion price - not higher than 0.09 €/kg - was maintaining, while in 2003 the onion price was recorded on level 0.15 €/kg. At such low prices of onion the costs of storage and costs of onion preparation for market were not covered. As result of that the lower acreage of onion sowings in 2005 by 15-20% was observed. It makes hope for better onion prices next season.

Still the main method of onion production in Poland is cultivation directly from seeds, and it makes about 91% of total production area (Adamicki 2004a). Only 5% of area is cultivated for overwinter onions from autumn sowing and 4% of onion is produced from sets (Table 2). The slight increase of onion grown from sets is observed because of higher prices for such onion and better possibility for sale of onion before beginning of onion harvest cultivated from direct seed. Incomes from onion grown from sets in 2004 were more profitable than for onion cultivated from seeds. Moreover, there is no need to store the onion cultivated from sets. Cultivation of onion from autumn sowing in our climate conditions is considered to have a high production risk because of high plant death during winter.

Table 1. Production, export and import of onions in Poland

Year	Acreage onions (thousand ha)	Production      Export      Import		
		(thousand tonnes)		
2000	35,7	720	135,7	21,6
2001	34,0	650	169,2	37,6
2002	27,7	585	95,1	44,0
2003	32,5	678	168,5	56,4
<b>2004</b>	<b>36,0</b>	<b>866</b>	<b>210,0</b>	<b>48,5</b>

Source: IAFE, 2004

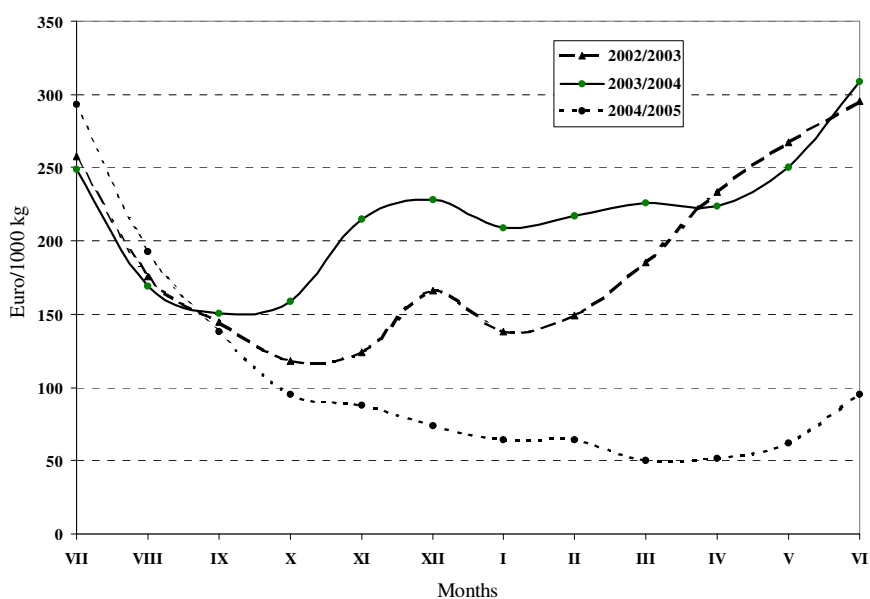


Fig. 1. Onion growers average prices paid by horticultural cooperatives (Euro rate different for each year)

Table 2. Characteristics of onion production in 2003-2004

Details	2003	2004
Area of overwintered onions (ha)	1 700	1 200
Area of spring onions (sets) (ha)	1 200	1 400
Area of onions direct from seeds (ha)	29 600	33 400
Total onion area (ha)	32 500	36 000
Yield of overwintered onions (t·ha <sup>-1</sup> )	40 – 50	40 – 50
Yield of spring grown onions from sets (t·ha <sup>-1</sup> )	30 – 50	40 – 60
Yield of onions grown from seeds (t·ha <sup>-1</sup> )	20	21
	(20 – 50)	(21 – 60)
Total tonnage of onions to be marketed from September till end of July	520 000	570 000

Source: RIVC, 2004

Producers in Poland cultivate about 50% of Polish cultivars, 40% of cultivars imported from the Netherlands and 10% from other countries. Main cultivars grown from autumn sowing in Poland are: Hi-Keeper F<sub>1</sub>, Keep Well F<sub>1</sub>, Omega F<sub>1</sub>, Glacier, Wolf F<sub>1</sub>, Amigo, Swift F<sub>1</sub>, Aldabo i Labrador. For onion cultivated from sets mainly domestic cultivars are used: Wolska, Sochaczewska, Rawska, Błońska, and some cultivars from abroad: Jetset F<sub>1</sub>, Centurion F<sub>1</sub>, Pico Bello and Rumba. Basic cultivars for spring sowing are: Czerniakowska,



Sochaczewska, Błońska, Grabowska, Oporto, Polanowska, Kristine, Efekt, Ursusowska, Dawidowska and foreign cultivars: Corona F<sub>1</sub>, Hilton F<sub>1</sub>, Spirit F<sub>1</sub>, Stamford F<sub>1</sub>, Armstrong F<sub>1</sub>, Renate F<sub>1</sub>, Marathon F<sub>1</sub>, Sherpa F<sub>1</sub>, Tamrock F<sub>1</sub>, Rocky F<sub>1</sub>, Hyfield F<sub>1</sub> and Hyduro F<sub>1</sub>. Among the red onion three cultivars are grown: Red Baron, Redmate and Wenta. Mostly Sterling F<sub>1</sub> as white scale onion cultivar is grown in Poland.

Demands of producers for onion seeds in 2004 were so high that it was lack of seeds of good quality. Some companies have sold seeds of poorer quality and lower percentage of germination. After onion sowing in most regions there was chilly and wet weather, and it delayed germination (Fig. 2). Due to uneven emergency of onion some onion producers had to plough down the fields. In some regions poor weather conditions negatively affected the further growth and plant development. Simultaneously, the dry weather during bulb development and maturation caused the decrease of yield and higher percentage of onion with smaller diameter of bulb. During vegetation season onion was seriously affected by downy mildew. It also resulted in yield decreasing, quality reduction and storage ability of onion. The average yield of onion from spring sowing was on medium level, although on farms with good soils and irrigated fields, yields reached 40-60 tonnes per hectare. High yields of onions were obtained from overwintering or sets production. Quality of onion from these cultivations were very good. Also market demand for onion during harvest was high and it enabled their sale.

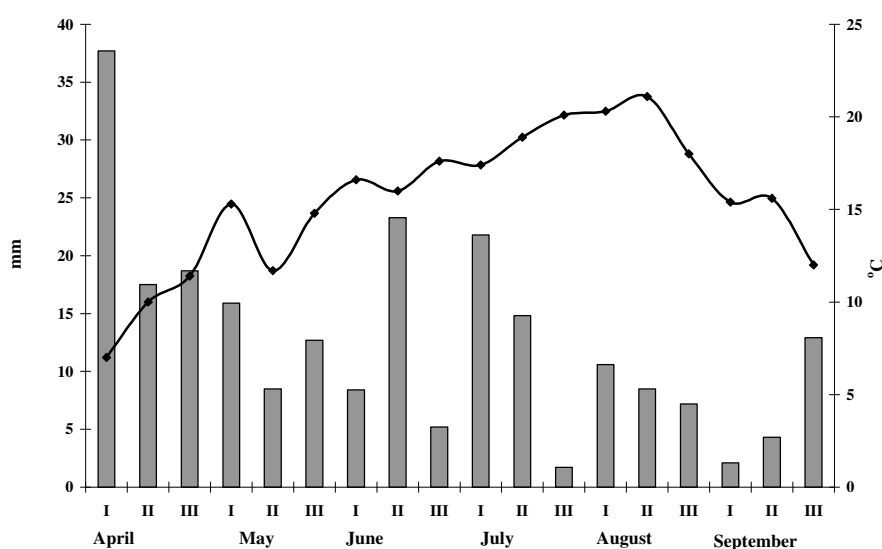


Fig. 2. Average air temperature and rainfall during onion cultivation (Skierniewice, 2004)

There were weather permitting conditions for early sowing of onion in the spring this year. Before sowing seeds are treated with fungicides and

insecticides containing following active ingredients: carbendazim + carboxin, metalaxyl, thiophanatemetyl + thiram + diazinone. For protection against pathogens, pests and weeds in onion cultivation from direct seeds 46 fungicides, 35 insecticides and 40 herbicides are registered. Most frequently occurring pests in onion are onion fly and onion thrip, nematodes and onion leaf miner. Among onion diseases very important are dumping off, onion smut, white rot, downy mildew, onion neck rot, onion fusarium rot and bacterial rot.

Maleic hydrazide Fazor 80 SG (potassium salt of 1,2-dihydro-3,6-pyridazine-dione) according to Ministry of Agriculture and Rural Development – Permission No 870/2001 - can be still used in onions at rate  $4 \text{ kg}\cdot\text{ha}^{-1}$  with 300 L of water, two weeks before harvest (Adamicki 1995). Onion for long storage is harvested when 3-4 leaves on each plant are still green and 60-80% of tops are fallen over (Adamicki & Sypień-Perłowska 1983, Suojala 2001). Two phase harvest system is prevailing in Poland considering the lack of sufficient storage capacity of modern stores where onion could be dried. Curing of onion in the field usually is performed during 10–14 days. Very often due to unfavourable weather condition, such as often rains and low temperature, curing in the field is prolonged and it negatively effects the quality of dry skin (staining). It also decrease storability of onion due to rooting and rotting of bulbs. After drying up in the field, onion is transported to stores that are cooled with ambient air or with using of refrigerating facilities. On small farms with cultivation area around 2-3 ha onion is usually held in crates in ventilated stores from September until the end of March. After loading to the crates onion is dried under roof and before first autumn frost is placed into traditional store or cooling room. Before putting to store or cooling room onion is topped and bulbs are graded and calibrated. On farms with area cultivation of 5–120 ha, onion is mostly stored in bulk with force air ventilation and onion layer height up to 4 m. After store is loaded the onion is dried with flow of ambient air at temperature 20-25°C. Sometimes the air is heat up by 5°C higher than outside temperature. Period of onion drying in the store usually lasts 3-4 weeks and depends on time of curing in the field. After the onion skins and neck become completely dry the cooling process of onion bulbs begins using the ambient cool air. Period of onion cooling in store usually takes 1-1.5 months, depending on outside air temperatures. During winter period temperature can be maintained at the level of 3-4°C in November, 1-2°C in December, 0-1°C in January and February, 2-4°C in March and 5-8°C in April. Onion treated with maleic hydrazide can be successfully stored in such stores up to the end of April, but prolonged storage can result in higher losses and poor quality of onion bulbs. Still small amount of onions is stored in box pallets in stores and cooling rooms. Stores capacity for onion in Poland is still too low if compared to demands and it does not exceeds 80 thousand tonnes (Table 3).

Export of onion from Poland ranges from 100 thousand to 170 thousand tonnes annually, but import during last three seasons is stable on the level of 40-50 thousand tonnes (Table 4). The major changes of importers of Polish onion is observed during last decades. Few years ago most of Polish onion was

exported to Germany, Russia and the Netherlands. Now, export to Germany and Russia has decreased, especially to Russia due to some limitations and restrictions in foreign trade with country. In 2003 the biggest importers of Polish onion were: Romania, the Netherlands and Czech Republic. Besides the export of onion bulb with skin also quite a lot quantities of the peeled onion for freezing or direct use for meat and fish industries, as well as for gastronomy is exported from Poland. In some centres of onion production the specialized plants have established for export only peeled onion. Some of them employ more than one hundred women for hand peeling. The whole peeling process is partly mechanized except removing of root, neck and dry skin. One worker can peel more than 200 kg of onion a day.

Table 3. Storage facilities for onion in Poland

Type of storage buildings	Capacity (x 1000 tonnes)	Remarks
Buildings without proper isolation (adapted buildings)	150	Cooling with ambient air, temporary ventilation system
Modern buildings	100	Cooling with ambient air, new ventilation system
Cold storage	80	Mechanical refrigeration
Cold storage with CA	2	Mechanical refrigeration & control and monitoring equipment for CA
Total	332	

Source: RIVC, 2004

Table 4. Export of Polish onions in 2003

Country	Quantity (x 1000 tonnes)	Price (€ / kg)
Romania	30,8	0.09
Holland	30,5	0.27
Czech Republic	15,3	0.18
Moldavia	14,4	0.08
Germany	13,2	0.21
England	11,7	0.36
Total	168,5	0.18

Source: IAFE, 2004

Onion for sale is packed in consumer packages, mostly in nylon nets and sometimes cotton nets of 0.5-2.0 kg capacity. In some supermarkets onion is sold in perforated film bags, similarly to EU countries. It has to be emphasized that most of onion is sold in bulk in plastic boxes. Quality of onion sold in

supermarkets leaves much to be desired. There is no distinguished two quality classes of onion according to the standard.

### **Research conducted in the Research Institute of Vegetable Crops in Skierniewice**

Actually, there is no investigation in genetics and breeding on onion in our institute, but the existing breeding material is still used for obtaining new cultivars. New onion cultivar was registered last year, namely **Wiktoria Skierniewic**. It is medium late cultivar, with big spherical bulbs covered with well adherent skin of yellow colour. The onion tissue is white-greenish with mild flavour. Simultaneousness of top falling over is excellent. This onion characterizes with high total yielding and market yielding, as well as high percentage of bulbs of diameter above 7 cm. Cultivar is suitable for long storage.

The following studies with regard to onion are conducted in our research units.

#### **Laboratory of Plant Genetic Resources**

Maintaining the collection of wild species of *Allium*: the biggest collection in Central Europe.

#### **Department of Crop Science and Nutrition**

Study on winter hardiness of onion grown from summer sowing and influence of nitrogen fertilisation on the yield and quality of some cultivars.

Development of new growing methods of bunching onions (*Allium fistulosum* L.).

#### **Department of Plant Protection**

Control of onion pest (*Delia antiqua*) resistant to applied insecticides.

Improvement of methods of onion disease control (downy mildew, bacterial rot).

The development of weed control programme in drilled and sets onions.

#### **Laboratory of Vegetable Storage and Postharvest Physiology**

Comparison of quality and storage ability of some new cultivars of onion grown from seed and sets.

The effect of controlled atmosphere (including ultra low oxygen) on the storage potential and shelf life of onions.

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## PRODUKCJA CEBULI, TECHNOLOGIA PRZECHOWYWANIA, HANDEL ORAZ BADANIA NAUKOWE PROWADZONE W POLSCE

### Streszczenie

Polska jest jednym z większych producentów cebuli w Europie zajmującym trzeci miejsce po Hiszpanii i Holandii. Zbiory cebuli w Polsce wahają się od 600 do 800 ton i są głównie uzależnione od ceny uzyskiwanej w poprzednim sezonie. Spożycie cebuli w ostatnich latach uległo zmniejszeniu z 8 kg do około 7.4 kg na osobę, co stwarza duże problemy z jej zagospodarowaniem, szczególnie przy rekordowych zbiorach. Ze względu na dobrą jakość i trwałość przechowalniczą polska cebula jest poszukiwana na rynkach zachodniej i wschodniej Europy i rocznie eksportuje się od 150 do 200 tys. ton. Większość producentów uprawia cebulę na małej powierzchni w granicach 1 do 5 ha w jednym gospodarstwie i tylko w niektórych specjalistycznych gospodarstwach uprawiana jest na powierzchni od 20 do 100 ha. Podstawowym sposobem uprawy cebuli jest bezpośredni wysiew nasion w okresie wiosennym, który stanowi ponad 90% powierzchni, i tylko 4-5% powierzchni zajmuje uprawa z dymki i siewu jesienno. W pracy omówiono zalecane odmiany cebuli zależnie od sposobu uprawy oraz scharakteryzowano stosowane w praktyce metody długotrwałego jej przechowywania. Pojemność komór chłodniczych przeznaczonych do przechowywania cebuli wynosi zaledwie 80 tys. ton, a większość towaru przechowuje się w przechowalniach schładzanych chłodnym powietrzem zewnętrznym. Przedstawiono tematy prac badawczych aktualnie prowadzonych w Instytucie Warzywnictwa z zakresu technologii uprawy, ochrony i przechowalnictwa cebuli.

## PECULARITIES OF EDIBLE ONION PRODUCTION AND RESEARCH IN LITHUANIA

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### Summary

Edible onion growing area in Lithuania in 2004 increased by 41.4% compared to 2003. During the last three years onion import reached 15-23% out of the total amount of imported vegetables. The biggest amounts of bulbs came mainly from Netherlands, Poland, Spain. About 20% of onions was exported.

Onions are mainly (approximately 90%) sown and grown in business farms. Average yield in the year 2004 was approximately 30 t·ha<sup>-1</sup>.

Seven cultivars of onion are listed in the “Lithuanian National List of Plant Varieties” in 2004-2005.

Onion maggot, onion thrips, green peach aphids were the most harmful pests in edible onions in 2004. Onion moth, onion bulb fly were regular pests in onions sporophyte.

The basic onion diseases in Lithuania in 2004 were: downy mildew (*Peronospora destructor*); rot and bulb rot (*Botrytis* spp.) during vegetation while black mould (*Aspergillus niger*) and soft bulb rot (*Erwinia carotovora* subsp. *carotovora*) - during storage.

key words: onions bulb, yield, seeds, sets, diseases, pests, prices

### INTRODUCTION

Vegetable growing area in Lithuania varies from year to year. It depends on the demand and prices in the preceding year. This area decreased by 27.2% in 2004 compared to 2003 (data according to the Lithuanian Statistics Department) resulting in 20.1 thousand of hectares in total. Edible onion growing area in Lithuania in 2004 increased by 41.4% compared to 2003. During the last three years onion import reached 15-23% out of the total amount of imported vegetables. The biggest amounts of bulbs came mainly from Netherlands, Poland, Spain. About 20% of onions were exported.

Lithuanian soil and climatic conditions are favorable for field vegetables, including onion, growing. Edible onions are grown in the central and north western part of Lithuania - Kaunas, Kedainiai, Siauliai and some other districts.

Onions are sown and grown mainly in business farms (approximately 90%). Average yield in the year 2004 was approximately 30 t·ha<sup>-1</sup>.

Export data showed that demand of onions in Lithuania can be fulfilled by the growing onions on a larger scale and increasing productivity.

Our report involves the main peculiarities concerning onion marketing, research and development system in 2004.

All investigations which results are discussed in the publication were carried out at the Lithuanian Institute of Horticulture. Statistical data were obtained from the Ministry of Agriculture of Lithuanian Republic, the Lithuanian Statistical Department and Lithuanian Institute of Agrarian Economics.

## MARKETING REPORTS

### 1. Area, onion production methods and cultivars

Edible onion growing area in 2004 in Lithuania was 3.4 thousand ha. Approximately 75-85% of the area is occupied by onions sown in spring. Seeds under Lithuanian climatic conditions usually are sown in the I-II decade of April – in spring as early as possible. Traditional sowing system is 1.4 m width beds with a four double-row made with a precision drill. Optimal seeding rate for onions used for marketing and storage is 1 million seeds per ha.

Long day varieties and hybrids of onions are grown in Lithuania. According to the results of investigations that were carried out at the Lithuanian Institute of Horticulture in 2004, the best yield in the group of varieties was obtained from varieties Olina and Fiesta (22.4 and 22.9 t·ha<sup>-1</sup>) while in the group of hybrids-from the hybrids Barito F<sub>1</sub> and Durco F<sub>1</sub> (29.7 and 33.6 t·ha<sup>-1</sup>) (Table 1).

More simple and easy method of onion growing is cultivation from sets. Approximately 25-15% onions were grown using this method in 2004. Onion growing from sets is the most popular method among gardeners. Cultivars Lietuvos didieji, Stutgarten Riesen, Centurion F<sub>1</sub> are used for this method. Seedlings are planted usually in the 1<sup>st</sup> decade of May. The yield of onions grown from sets reached 45-55 t·ha<sup>-1</sup>.

Seven cultivars of onions are listed in the “Lithuanian National List of Plant Varieties” in 2004-2005 (Table 2). Two of them are a product of Lithuanian breeding. Bابتu didieji is a new variety that was included “Lithuanian National List of Plant Varieties” in 2004. It is the middle-early ripening variety, obtained by using individual and breeding method. Bابتu didieji is suitable for -bulb and fresh leaves production. Bulbs are suitable for freezing and drying as well. While using directly sowing of seeds in spring, vegetation period from sowing till harvesting lasts 68-99 days. Marketable yield of onions was 28.9-64.8 t·ha<sup>-1</sup> during different years of investigations. Bulbs are big and oval in shape. The weight of one marketable bulb reached 95-116g. Outer peel of Bابتu didieji is yellow - orange colour, flesh is white colour with middle strong flavour. Bulbs are suitable for storage (7 month).

Table 1. Productivity of investigated onion varieties and hybrids in field collection

Variety / hybrid	Total yield (t·ha <sup>-1</sup> )	Marketable yield (%)	LIH, Babtai 2004
			Average weight of marketable bulb (g)
Lietuvos didieji	21.8	87	100.0
Kristine	20.1	84	82.8
Wolska	19.2	81	94.7
Fiesta	22.9	86	110.0
Kutnowska	15.4	78	64.5
Supra	17.0	83	102.3
Stuttgarten Riesen	20.1	83	85.4
Olina	22.4	93	110.0
Alice	15.6	89	85.5
Virtus	16.3	84	76.1
Balusta	16.1	87	77.8
Pino	17.9	76	77.2
Zolotnichok	19.1	88	88.0
Durco F <sub>1</sub>	29.7	89	87.1
Nerato F <sub>1</sub>	19.7	95	94.0
Marco F <sub>1</sub>	20.7	82	96.3
Friso F <sub>1</sub>	27.7	77	89.2
Barito F <sub>1</sub>	33.6	84	100.0
Renate F <sub>1</sub>	22.3	95	111.3
Stamford F <sub>1</sub>	21.4	71	93.9

Table 2. Varieties and hybrids of edible onions included in the “Lithuanian National List of Plant Varieties” for years 2004-2005

Denomination of variety	Entry into the “National List”	Country, variety breeder, maintainer
Lietuvos didieji	1954	Lithuania, Lithuanian Institute of Horticulture
Stuttgarten Riesen	1992	Germany, Quedlinburg
Alamo F <sub>1</sub>	1998	Netherlands, S&G, Syngenta Seeds
Hilton F <sub>1</sub>	2001	Netherlands, S&G, Syngenta Seeds
Babtu didieji	2004	Lithuania, Lithuanian Institute of Horticulture
Setton	2004	Netherlands, S&G, Syngenta Seeds
Stamford F <sub>1</sub>	2005	Netherlands, S&G, Syngenta Seeds

## 2. Onion quality

Mandatory Requirements for onion quality in Lithuania are prepared and confirmed according to the European Community (EU) directives. Requirements adjusted to the onions that are prepared for realization. Onion quality according requirements consists of external quality when bulbs are graded according to classes (2 classes), varieties, sizes, aesthetically packed and labeled. Bulbs of both classes must be healthy, without rotting, accessory acceptable smell, flavour. The leaves must be cut while 4 cm long pieces must be left.



## Classification

### First class:

- onions are of good quality, typical for variety shape and color;
- bulbs of hard texture, not germinated, not too big, without roots and any stems;
- they can have trace amounts of outer peel coming off;

### Second class (belongs onions that are not suitable for the first class):

- bulbs of hard enough texture;
- can be not typical for variety shape and color, with minor damages of pests and diseases;
- can be with roots;
- not more than one third of bulb peel can be broken, but the flesh must be without damages;
- part (no more than 10%) of onion in the package can be germinated while the mentioned bulbs stems size can be up to 5 mm.

## Size requirements

Size of onion is determined by measure of the maximal diameter of bulb. The smallest size of bulb is 10 mm. Differences between the bulb's smallest and biggest diameter in the package can be not more:

- 5 mm if diameter of the smallest bulb size is from 10 to 19 mm;
- 10 mm if diameter of the smallest bulb size is from 15 to 24 mm;
- 15 mm if diameter of the smallest bulb size is from 20 to 39 mm;
- 20 mm if diameter of the smallest bulb size is from 40 to 69 mm;
- 30 mm if diameter of the smallest bulb size is 70 mm and more.

## Possible deviation from the requirements

First class package can include not more than 10% of onions which are not suitable for the mentioned class requirements, but suitable according to the second class requirements.

Second class package can include not more than 10% of onions which are not suitable for the mentioned class requirements, but in the package can not be spoiled onions and not suitable for eating.

## Packaging and labeling requirements

Onions must be of the same variety, country origin, quality class, size category in each package. Label on each package must indicate packer's and sender's name and address or packer's and sender's identification code, country of origin, quality class, size, minimal and maximal diameter and weight of onions.

## 3. Import, export and onion prices

Import of edible onions during eight months (May - December) in 2003 and 2004 reached 686.7 and 341.4 tons respectively, export - 13.0 and 45.1 tons respectively (Table 3). Investigation data shows increase of onion import by 47% in 2003, while export was higher in 2004 - increase of 71% established.

Average prices of onions in supermarkets during June - December in 2004 was by 9% lower, compared to prices in 2003 and reached 1.0 and 1.3 litas per kilogram respectively (Table 4). The price during June - September was by 4-20% higher but due to following import the increase of sale prices fell down.

Table 3. Import and export of edible onions during May-December in 2003 and 2004 (t)

Trade method	V	VI	VII	VIII	IX	X	XI	XII	Average
2003									
Import	915.2	831.8	666.7	715.8	881.9	796.1	223.2	462.5	686.7
Export	6.0	6.1	6.3	0.7	0.9	48.3	101.6	2.3	13.0
2004									
Import	1251.7	1028.3	868.6	357.5	584.2	361.2	741.5	333.4	341.4
Export	176.8	86.7	56.2	3.3	7.8	10.1	15.1	4.9	45.1

Table 4. Average prices for edible onions in supermarkets during June – December in 2003 and 2004, Lt/kg\*

Year	VI	VII	VIII	IX	X	XI	XII	Average
2003	1.5	1.3	1.2	1.1	1.1	1.2	1.4	1.1
2004	1.5	1.5	1.4	1.3	1.0	0.9	0.8	1.0

\* Euro rate to litas is 1:3.4

Reviewing average sale prices for onions in commercial farms in Lithuania and foreign countries in 2004 it is obvious that onion prices in Lithuania was 32% higher than in Germany, 30% higher than in Czech Republic and 25% higher than in Slovakia (Table 5). High expenses for drying and preparation of marketable production were influenced by unfavourable climatic conditions in 2004, therefore onion prices in Lithuania in big commercial farms were high.

This year (in March) the price for ecological onion was 33% higher compared to that in 2004 during same period and 114% higher in comparison with the conventional onions growing.

Table 5. Average sale - price of edible onions in commercial farms in Lithuania and foreign countries during June – November, 2004, Lt/kg\*

Month	Lithuania	Latvia	Estonia	Poland	Germany	Czech Republic	Slovakia
VI	1.0	1.6	-	1.0	1.3	0.9	0.9
VII	-	1.5	-	0.8	1.1	0.6	0.5
VIII	1.1	0.8	-	0.6	0.5	0.5	0.5
IX	0.6	0.5	-	0.4	0.4	0.4	0.4
X	0.4	0.6	0.9	0.3	0.3	0.4	0.3
XI	0.4	0.8	0.9	0.3	0.3	0.3	0.2

\* Euro rate to litas is 1:3.4

## RESEARCH AND DEVELOPMENT REPORTS

Vegetable quality depends on selected variety, soil properties, agrotechnical means applied.

### 1. Agrotechnical means

#### Fertilization

Most growers fertilize onions with complex fertilizers according to the recommended rates and agrochemical soil analyses. Selection of fertilizers for the main fertilization does not cause bigger problems. NPK 16:16:16 or NPK 11:10:11 (rate 500 kg·ha<sup>-1</sup>) are used in the beginning of vegetation. Most often supplementary fertilization is done through leaves. Rationally applied fertilizers increase marketable yield by 5-10% (Bobinas, Viskelis 2003).

#### Irrigation

In our agroclimatic conditions irrigation is vital. Trials revealed 20-30% higher yield in irrigated fields and around 10% higher marketable yield (Bobinas, Viskelis 2003).

### 2. Plant protection and application of pesticides

Lithuanian vegetable growers apply smaller amounts of pesticides than vegetable growers in Western countries. During the last three years higher than permitted pesticide residues were not found in the marketed production. However it is difficult to obtain production of a good quality, especially of onions, without application of pesticides.

#### Application of herbicides

Stomp (4 L·ha<sup>-1</sup>) is the most popular herbicide for onion treatment. Last year the efficiency of herbicide Aramo (tepraloxidim 500 g·L<sup>-1</sup>) was investigated against monocot weeds in onions (annual monocot weeds, spec *Poa annua*) at the Lithuanian Institute of Horticulture. Fiusilade Forte 1.0 L·ha<sup>-1</sup> was considered as standart standard variant (Table 6). Assessments were made after 21-28 days after first application.

Table 6. Investigation scheme of herbicide Aramo (tepraloxidim 500 g·L<sup>-1</sup>) efficiency

		LIH, Babtai, 2004
Plot no*.	Treatment	Dosage per ha
1	Untreated	-
2	Aramo	1.5 L
3	Aramo	0.75 L
4	Aramo	3.0 L
5	Fiusilade Forte (standard)	1.0 L

\* Plot size - 10 m<sup>2</sup>, 4 replications and random plot distribution

The number of monocot weeds 21 days after application of herbicide Aramo (a.i. tepraloxidim 500 g·L<sup>-1</sup>) 0.75 L·ha<sup>-1</sup> decreased by 83.67%, after application of herbicide Aramo (a.i. tepraloxidim 500 g·L<sup>-1</sup>) 1.5 L·ha<sup>-1</sup> – by 93.88%, after application of herbicide Aramo (a.i. tepraloxidim 500 g·L<sup>-1</sup>) 3.0 L·ha<sup>-1</sup> – by 100% (Table 7). Results of investigation showed significantly lower amounts of monocot weeds in all Aramo (a.i. tepraloxidim 500 g·L<sup>-1</sup>) treatments compared to untreated treatment, but no significant difference was found in comparison with standard herbicide Fiusilade Forte 1.0 L·ha<sup>-1</sup> treatment.

Table 7. Efficiency of herbicide Aramo for control of monocot weeds in onions

Treatments	LIH, Babtai, 2004					
	Total number of weeds (pcs·m <sup>-2</sup> )		Number of annual dicot weeds (pcs·m <sup>-2</sup> )		Decrease of monocot weed % in comparison with untreated treatment	Decrease of monocot weed % in comparison with Fiusilade Forte (standard) treatment
	before spraying	after spraying	before spraying	after spraying		
Untreated	40.5	106.5	16.5	24.5	-	-
Aramo 1.5 L·ha <sup>-1</sup>	40.75	109.75	16.75	1.5*	93.88	-3.6
Aramo 0.75 L·ha <sup>-1</sup>	33.5	82.3*	15.8	4.0*	83.67	-13.59
Aramo 3.0 L·ha <sup>-1</sup>	32.75	78*	14.25	0*	100	2.74
Fiusilade Forte 1.0 L·ha <sup>-1</sup> (standard)	44.5	85*	17.0	0.67*	97.26	-

\* significantly lower than in untreated treatment (LSD<sub>0.05</sub>)

Herbicide Aramo (a.i. tepraloxidim 500 g·L<sup>-1</sup>) did not have negative impact on onion crop, onion yield and external quality of bulbs. Average marketable yield, reached 17 t·ha<sup>-1</sup>, while using different rate of Aramo, this is 35% higher compared to untreated treatment and 14% lower in comparison with standart treatment (using Fiusilade Forte) (Table 8).

Table 8. Yield of onions after application of herbicide Aramo

Treatments	LIH, Babtai, 2004		
	Total yield (t·ha <sup>-1</sup> )	Marketable yield (t·ha <sup>-1</sup> )	% of marketable yield out of total yield
Untreated	17.5	11.2	64
Aramo 1.5 L·ha <sup>-1</sup>	22.1*	15.9*	72.3
Aramo 0.75 L·ha <sup>-1</sup>	26.3*	19.1*	72.6
Aramo 3.0 L·ha <sup>-1</sup>	23.2*	16.0*	68.9
Fiusilade Forte 1.0 L·ha <sup>-1</sup> (standard)	26.1*	19.8*	75.7
LSD <sub>0.05</sub>	2.7	2.49	-

\* significantly lower than in untreated treatment (LSD<sub>0.05</sub>)

### Plant protection against pests and diseases

Onion maggot, green peach aphids were the most harmful pests in edible onions in 2004. Damages of onion thrips were also found in onion quite often last year. Damages of onion thrips were less harmful in leek.

Onion moth, onion bulb fly were regular pests in onions sporophyte. Application of insecticides and alternative control measures increased onion yield. Insecticides 2,5 EC decis 0.3 L·ha<sup>-1</sup> was the most effective against pests in onions. Insecticide actara 25 WG (0.2-0.4 L·ha<sup>-1</sup>) for onions is listed in the "List of pesticides used in Lithuania in 2004". Actara is used against thrips and onion maggot.

The main onion diseases in Lithuania in 2004 were: downy mildew (*Peronospora destructor*), rot and bulb rot (*Botrytis* spp.) - during vegetation; black mould (*Aspergillus niger*) and soft bulb rot (*Erwinia carotovora* subsp. *carotovora*) - during storage.

Last year increase of *Botrytis* spp. diseases was observed. In further investigations establishment of species of *Botrytis* spp. - *B. cinerea*, *B. allii*, *B. squamosum* is provided.

Fungicide Pencoceb 75 DG (2.0 L·ha<sup>-1</sup>) against onion downy mildew is registered in the "List of pesticides used Lithuania in 2004".

Effect of seed treatment on germination of onions was investigated in 2004 at the Lithuanian Institute of Horticulture. Seeds of onions were infected by *Fusarium*, *Aspergillus* and *Penicillium* spp. Treatments of seeds with Cruiser OSR (a.i. tiaamethoxam 280 g·L<sup>-1</sup>+ fludijoxonil 8 g·L<sup>-1</sup>+ metalaxil-M 33.3 g·L<sup>-1</sup>), Kemikar T (carbixin 200 g·L<sup>-1</sup>+ thiram 200 g·L<sup>-1</sup>) and compound of Actara 25 WG + Maxim 025 FS (tiamethoxam 250 g·kg<sup>-1</sup> + fludijoxonil 25 g·L<sup>-1</sup>) protected them from pathogenic diseases and increased their germination by 2-13% in comparison with untreated seeds in laboratory tests and by 18.5-24.4% in field tests. The best results were obtained after Kemikar T (rate 5.0 L·100 kg<sup>-1</sup>) and Cruiser OSR (rate 1.5 L·100 kg<sup>-1</sup>) seeds treatment, 75.5% and 63.2% respectively.

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## CHARAKTERYSTYKA PRODUKCJI CEBULI I BADAŃ NAUKOWYCH NA LITWIE

### Streszczenie

Powierzchnia uprawy cebuli na Litwie w 2004 roku powiększyła się o 41.4% w porównaniu do roku 2003. W okresie ostatnich trzech lat import cebuli stanowił 15-23% całkowitej ilości warzyw sprowadzanych z zagranicy. Najwięcej cebuli importowano głównie z Holandii, Polski i Hiszpanii. Eksport z Litwy stanowił około 20% produkowanej cebuli. Cebula na Litwie jest uprawiana głównie w gospodarstwach specjalistycznych. Produkcja cebuli w małych gospodarstwach rolnych stanowi około 10% ogólnej powierzchni uprawowej. Średni plon cebuli w roku 2004 wynosił około 30 t·ha<sup>-1</sup>. W Litewskim Rejestrze Odmian Roślin Uprawnych na lata 2004-2005 znajduje się obecnie siedem odmian cebuli. Najpoważniejsze szkodniki występujące na plantacjach cebuli w roku 2004 na Litwie to: śmietka cebulanka, wciornastek tytoniowiec, mszyca brzoskwińowa. Powszechnie występowały też: wgryzka szczypiorka i udnica cebulanka. Choroby cebuli w 2004 roku na litewskich plantacjach były powodowane najczęściej przez *Peronospora destructor* (mączniak rzekomy), *Botrytis* ssp. (zgnilizna szyjki cebuli), a w czasie przechowywania cebuli przez *Aspergillus niger* (czarna pleśń) i *Erwinia carotovora* ssp. *carotovora* (bakteryjna zgnilizna cebuli).

## SOME RESULTS OF GROWING TECHNOLOGY EXPERIMENTS ON ONION IN ESTONIA

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### Summary

In 2004 three experiments with bulb onions were carried out at the Estonian Agricultural University. In first experiment 17 direct-sown onion varieties were compared to two varieties grown from sets in two locations with different soil types. The highest total yield in both soil types was obtained from varieties grown from sets. From direct-sown onions varieties RenateF<sub>1</sub> and Musica F<sub>1</sub> had the highest yield. In second experiment the influence of different rates of nitrogen fertilization as top dressing on the yield of four onion varieties was studied. Our results indicate that fertilization rates could be reduced because the yield increase in variants of total nitrogen over 80 kg N·ha<sup>-1</sup> was minimal. In experiment with planting density and mulching of salad onion Exhibition the results showed that denser planting led to higher yields and mulching increased the yield up to 20%.

key words: onion, variety test, top dressing, planting density, mulching

### INTRODUCTION

Onion cultivation area in Estonia have been relatively small, but recently, during couple of years, interest for onion production has remarkably increased. According to Estonian Statistical Office the production area of onion in 2004 was 455 hectares and in the year 2003 was 303 hectares (ESA 2005). As the demand for fresh onion in Estonian vegetable market is greater than supply, missing quantity is imported from other countries. According to customs statistics 5351 tons of onion and shallot was imported to Estonia in 2004 and 7307 tons the year before. In recent years onion import has decreased, probably because of the increase of local production. Most of onion is imported from Poland and from the Netherlands.

Since the interest towards production of *Allium*-vegetables was notable, Estonian Ministry of Agriculture funded the research project „Improvement of agrotechnology of *Allium*-vegetables”, which was initiated at the Estonian Agricultural University, Institute of Agricultural and Environmental Sciences. This

applied research project is mainly directed to introduce new growing technologies for local conditions. The purpose is to find out growing technologies for onion, shallot, leek, and garlic, which would enable to gain high quality vegetables for both fresh consumption and food industry. In this paper we present the results of the experiments carried out in 2004 with bulb onion (variety comparison and top dressing) and with salad onion (planting density and mulching).

## MATERIALS AND METHODS

Seventeen onion varieties sown directly from seed to open field, were monitored in 2004. Ten varieties from company Bejo Zaden (Hyfort F<sub>1</sub>, Summit F<sub>1</sub>, Copra F<sub>1</sub>, Musica F<sub>1</sub>, Hyred F<sub>1</sub>, Albion F<sub>1</sub>, Mustang F<sub>1</sub>, Renate F<sub>1</sub>, Jagro F<sub>1</sub>, Centurion F<sub>1</sub>), 6 from company Nickerson-Zwaan (Friso F<sub>1</sub>, Tasco F<sub>1</sub>, Drago F<sub>1</sub>, Nerato F<sub>1</sub>, Blancato F<sub>1</sub>, Marco F<sub>1</sub>) and one Estonian variety (Jõgeva 3) were used as direct sown onions. Varieties Albion F<sub>1</sub> and Blancato F<sub>1</sub> were white onions and Hyred F<sub>1</sub> red onion. Variety Musica F<sub>1</sub> has been used as new mild taste onion. Additionally varieties Hercules F<sub>1</sub> (Bejo Zaden) and Stuttgarter Riesen (Daenefeld) were planted from sets as control plots. Experiments were conducted in two locations with different soil types (sandy loam and clay loam soil). Both experimental sites were fertilized before seeding with NPK fertilizer (50 kg·ha<sup>-1</sup> N; 20 kg·ha<sup>-1</sup> P; 85 kg·ha<sup>-1</sup> K) and during growing period with ammonium saltpetre (60 kg·ha<sup>-1</sup> N). Onion seeds were sown in two lines per furrow; the space between lines was 10 cm and between furrows 65 cm. The initial sowing density for direct-sown onion varieties was 90 seeds per m<sup>2</sup>, whereas in varieties planted from sets it was 60 sets per m<sup>2</sup>. No irrigation was used in experimental fields during growing season. Onions were harvested in August and September when 70-80% of plants had tops down. After drying (10 days at 25-30°C) and cleaning the yield was weighed and graded into four different size categories: jumbo – onions with diameter over 7 cm; large – 5-7 cm; medium – 4-5 cm and small – less than 4 cm. Since the share of jumbo onions was small or overall missing in some varieties, jumbo and large onions are shown together further on.

In the second experiment the influence of different rates of nitrogen fertilization as top dressing on the yield of four onion varieties was studied. Experimental field was fertilized in spring, using granulated complex fertilizer Kemira Cropcare 10-10-20 at the rate of 50 kg per hectare. The influence of top dressing on two onions varieties grown directly from seeds (Hyfort F<sub>1</sub> and Musica F<sub>1</sub>), one transplanted onion (Exhibition) and one onion grown from sets (Hercules F<sub>1</sub>) was studied. Onion seeds were sown and set onions were planted analogously with the previously mentioned variants in variety comparison. Variety Exhibition was seeded on March, the 2<sup>nd</sup>, seedlings were planted in open field on May, 7<sup>th</sup> into four-rows beds, where the space between rows was 25 cm and plant to plant space was 20 cm. Ammonium saltpetre (N-34%) at three different rates was used as top dressing. Control variant was not fertilized during growth, but with the preplant fertilization, control variant received 50 kg N·ha<sup>-1</sup> (Table 1). At first, in August 19<sup>th</sup>, variety Her-



cules F<sub>1</sub>, which was grown from set onions, was harvested and then the others as follows: salad onion Exhibition (11.09.), Hyfort F<sub>1</sub> (18.09.) and Musica F<sub>1</sub> (24.09.). The yield was weighed, the structure of the yield determined and nitrate content of bulb analysed.

Table 1. The rates of mineral nitrogen (N<sub>min</sub>) (kg·ha<sup>-1</sup>) in different variants given as main fertilization, top dressing and total during growing period

Variant No.	N <sub>min</sub> (kg · ha <sup>-1</sup> )		
	Main fertilization	Top dressing (02.07.)	Total N <sub>min</sub>
1	50	0	50
2	50	30	80
3	50	60	110
4	50	90	140

In third experiment the planting density and mulching of salad onion Exhibition was studied. Variety Exhibition (Bejo Zaden) forms very large sweet-tasting bulb. Seeds were sown into 260-cell transplant trays on March, 2<sup>nd</sup>. The experiment was established on 1 m wide beds. Half of the beds were covered with black textile mulch cover and plants were planted on May, 4<sup>th</sup>. In order to achieve different planting density, seedlings were planted, using 3, 4 and 5 rows. The plant to plant spacing was 20 cm in all rows. In variant with 3 rows, the space between rows was 30 cm, in variant with 4 rows it was 25 cm and in variant with 5 rows it was 15 cm. The yield was harvested on August, 24<sup>th</sup>, bulb diameter and length was measured and bulb shape index calculated (length/diameter).

Statistical analyses were performed using SPSS (SPSS 10.1., SPSS Inc. H, Chicago, IL). Significant differences between varieties and growing technologies were tested by one-way and two-way analysis of variance (ANOVA) at significance level of  $P \leq 0.05$ .

Generally weather conditions in 2004 were not favourable for field crops. Spring in the experimental year became early and onions were sown from April, 26<sup>th</sup> to April, 28<sup>th</sup>. At the end of May it started to rain often and first part of the summer was cooler and with more precipitation than average in Estonia (Table 2). In June it rained 184 mm, which exceeds average for 2.8 times. Cool and very damp weather promoted spread of downy mildew (*Peronospora destructor*).

Table 2. Weather conditions in summer 2003 and 2004 in South Estonia: monthly mean air temperature (°C) and mean monthly precipitation (mm) as compared to averages of the same figures of many years (1966-1998) in Estonia

	2004		1966-1998	
	Temp.	Precip.	Temp.	Precip.
April	5.7	6	4.1	32
May	10.3	38	11.0	55
June	13.4	184	15.1	66
July	16.6	76	16.7	72
August	16.8	105	15.6	79
September	11.8	86	10.4	66

## RESULTS

### Variety comparison

Varieties Stuttgarter Riesen and Hercules F<sub>1</sub>, which had been grown from set onions, were harvested two weeks before direct-sown varieties in both locations, but despite of that, the yield was up to 6.4 kg·m<sup>-2</sup> (Fig. 1). In 2004 the total yield of direct sown onion varieties grown in clay loam soil (location 1) ranged between 0.8-2.1 kg·m<sup>-2</sup> whereas in sandy loam (location 2) between 1.5-3.9 kg·m<sup>-2</sup>. The best varieties in clay loam soil turned out to be Tasco F<sub>1</sub> and Drago F<sub>1</sub>, Summit F<sub>1</sub> and Nerato F<sub>1</sub>. On sandy loam soil the yields of several varieties (Musica F<sub>1</sub>, Hyfort F<sub>1</sub>, Marco F<sub>1</sub>, Copra F<sub>1</sub>, Mustang F<sub>1</sub>, Renate F<sub>1</sub>, Jagro F<sub>1</sub>, Centurion F<sub>1</sub>) were double compared to the location 1. In 2004 the most stable yield in different locations were obtained from varieties Tasco F<sub>1</sub>, Drago F<sub>1</sub> and Nerato F<sub>1</sub>, although the average yield of these varieties was only 2 kg m<sup>-2</sup>. For varieties Copra F<sub>1</sub>, Blancato F<sub>1</sub> and Albion F<sub>1</sub> neither of soil types were suitable in 2004.

In 2004 the percentage of large onions of direct-sown varieties was very small in location 1 (data not shown). Majority of varieties had large onions between 5 and 17% of total yield. Large onions were overall missing in the yield of varieties Copra F<sub>1</sub>, Mustang F<sub>1</sub> and Centurion F<sub>1</sub>. It may be concluded that in particular year growing direct sown onions practically failed in clay loam soil. Majority of direct-sown varieties grown in sandy loam soil (location 2) had more than half of the onions belonging to the large onion fraction. Among these following varieties had also jumbo onions: Musica F<sub>1</sub> (28%), Centurion F<sub>1</sub> (16%), Mustang F<sub>1</sub> (12%), Hyfort F<sub>1</sub> (11%), Marco F<sub>1</sub> (9%), Renate F<sub>1</sub> and FrisoF<sub>1</sub> (7%), others had less. Onion varieties Stuttgarter Riesen and Hercules F<sub>1</sub> grown from set onions, had 98% of total yield belonging to the large and medium grade.

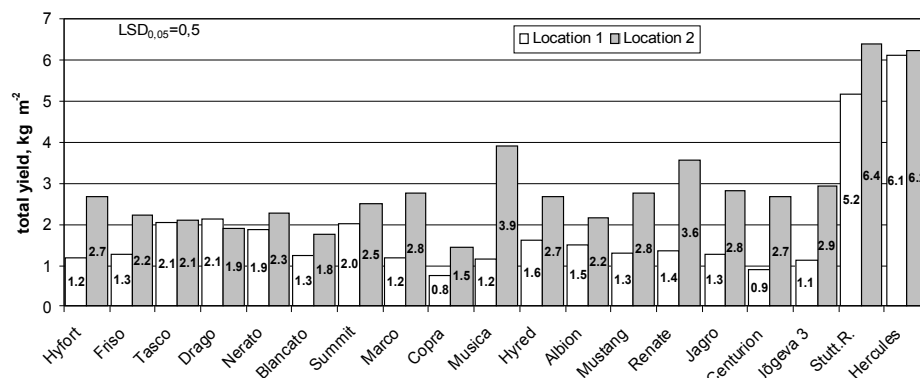


Fig. 1. The yield of direct sown onion varieties depending on the soil type in 2004. Location 1 – clay loam soil; location 2 – sandy loam soil

#### Top dressing experiment

In control plots, without top dressing, the yield of Hyfort F<sub>1</sub> was 1.65 kg·m<sup>-2</sup> (Fig. 2). In this variety only top dressing with the highest fertilization rate (90 kg·ha<sup>-1</sup> N) gave significantly higher yield. The yield of Hyfort F<sub>1</sub> was the lowest compared to the other varieties, also marketable yield was the lowest: only 76-86% of the total yield. The yield of variety Musica F<sub>1</sub> ranged from 3.04 to 3.40 kg·m<sup>-2</sup>. Together with higher fertilization rates, the tendency to increase in yield was noticed, but the difference was not statistically significant. The average total yield of variety Hercules F<sub>1</sub> was 6.1 kg·m<sup>-2</sup>. The yield of the control variant of this variety was 5.6 kg·m<sup>-2</sup>. In Hercules F<sub>1</sub> already the lowest fertilization rate of 30 kg N·ha<sup>-1</sup> (total N<sub>min</sub> 80 kg·ha<sup>-1</sup>) significantly increased the yield. Further on increase in fertilization rate resulted the same yield level, thus all fertilized variants had significantly higher yield compared to the control variant. Variety Hercules F<sub>1</sub> distinguished from other varieties because of the highest and most even yield: 98-99% of total yield was marketable. The average yield of the variants of the salad onion Exhibition was 5.63 kg·m<sup>-2</sup>. The yield of the control variant was 5.18 kg·m<sup>-2</sup>. Additional fertilization at the rate of 30 kg N·ha<sup>-1</sup> as top dressing significantly increased the yield and total yield was 5.99 kg·m<sup>-2</sup>. Higher nitrogen fertilization rates did not increase the yield of salad onion. Marketable yield of this variety was on an average 96-98% of total yield.

Additional fertilization caused similar changes in yield structure. The percentage of jumbo onions with diameter more than 7 cm increased and the percentage of small onions, which are not suitable for marketing, decreased. Fertilization did not influence the amount of medium sized onions in total yield.

The content of nitrates in onion bulbs was significantly influenced by fertilization (Fig. 3). Every additional amount of nitrogen fertilizer made increase of nitrate content in the bulbs. The nitrate content of direct sown Hyfort F<sub>1</sub> increased from 31.8 to 59.7 mg·kg<sup>-1</sup>. The nitrate content of other direct sown variety Musica F<sub>1</sub>, was

about the same, increasing from 35.8 to 59.2 mg·kg<sup>-1</sup>. The nitrate content of variety Hercules F<sub>1</sub> was very low, ranging from 1.6 mg·kg<sup>-1</sup> in control variant to 13.6 mg·kg<sup>-1</sup> in variant which had received the highest amount of fertilizer. The bulb nitrate content of variety Exhibition was also increased by the larger amount of fertilizer, ranging from 10.5 to 21.2 mg·kg<sup>-1</sup>.

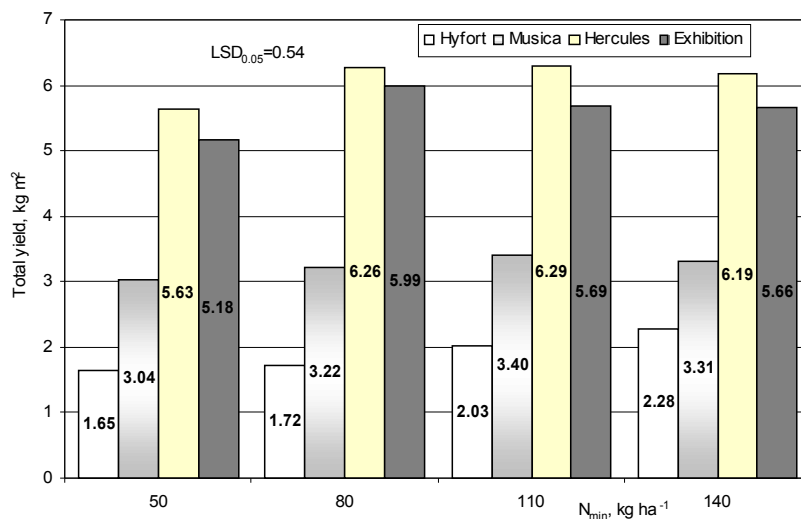


Fig. 2. The total yield of bulb onions (kg·m<sup>-2</sup>), depending on received N<sub>min</sub> in growing period

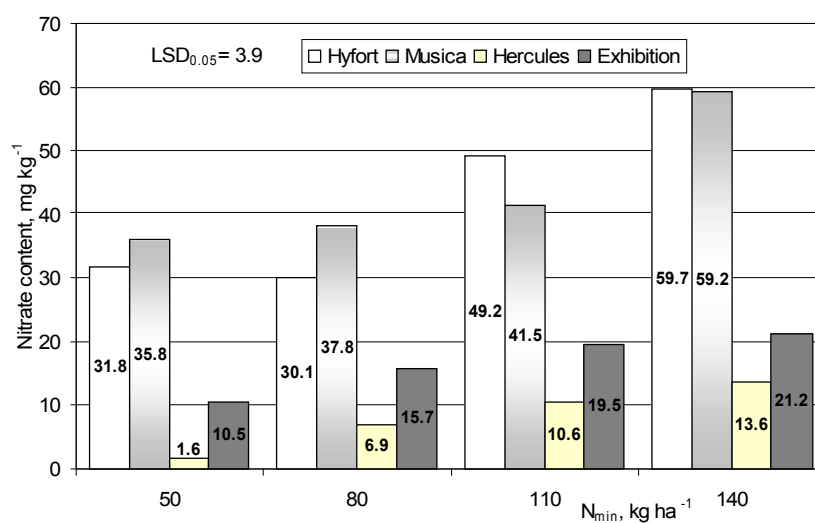


Fig. 3. The content of nitrates (mg kg<sup>-1</sup>) in bulb onions Hyfort F<sub>1</sub>, Musica F<sub>1</sub>, Hercules F<sub>1</sub> and Exhibition depending on fertilization rates

### Influence of planting density and mulching

In different planting densities, the yield of salad onion ranged from 4.53 to 6.45 kg·m<sup>-2</sup> (Fig. 4). The variant, which was covered with mulch and with 5 rows planting, produced the highest yield. The lowest yield was recorded in variant with 3 rows without mulch. Average yield of different planting density variants grown with mulch was 5.76 kg and without mulch 4.91 kg per square meter. Thus, experiment with mulch gave by 20% higher yield. The average weight of single bulb (514 g) was greatest in variant, where onions were grown with mulch in 3-row beds. Together with denser planting, the average weight of the bulb decreased both in variants with and without mulch. However, the decrease in bulb weight was smaller in variant grown without mulch. The average weight of onion bulb in variant grown without mulch, was 358 g and with mulch 430 g. The use of mulch did not influence bulb diameter, but with denser planting bulb diameter decreased (data not shown). Onion bulbs grown with mulch were longer than those grown without mulch. The average bulb shape index in variants grown without mulch was 1.16 and in variants with mulch it was 1.22. The shape index increased when planting density increased.

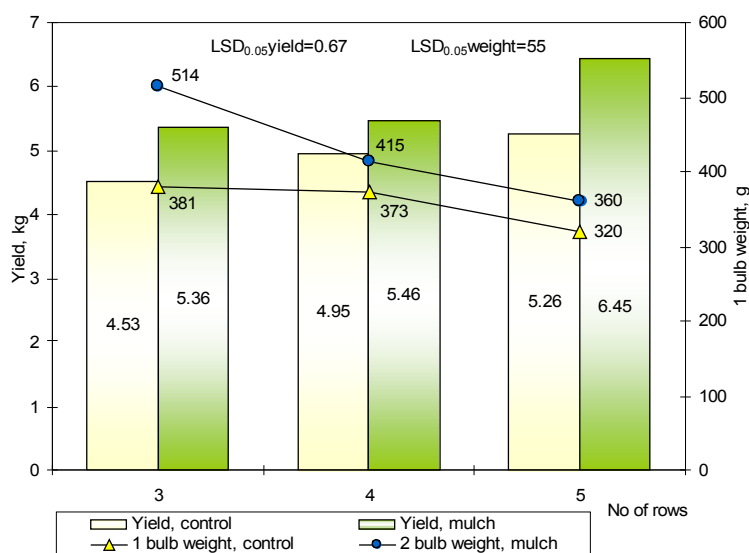


Fig. 4. Total yield (kg·m<sup>-2</sup>) of salad onion Exhibition and the average weight of one bulb (g) depending on planting density and mulching

### DISCUSSION AND CONCLUSIONS

In Estonia bulb onions are grown mostly from set onions. Nowadays more and more varieties are available, which are meant to grow directly from seed. In order to

find most suitable varieties in our conditions for growing onions directly from seed, 17 varieties were grown from seed and two varieties from sets in two different soil conditions. The greatest total yield in both soil types was obtained from varieties grown from sets. On sandy loam soil varieties Renate F<sub>1</sub>, Musica F<sub>1</sub> Mustang F<sub>1</sub> and Marco F<sub>1</sub> were also growing well. Whereas in our experiment the average yield of varieties Renate F<sub>1</sub> and Summit F<sub>1</sub> was 2.5 and 2.3 kg·m<sup>-2</sup>, Rumpel & Felczyński (2000) recorded the yield of the same varieties grown from seed to be 5.2 and 4.9 kg·m<sup>-2</sup>. Mentioned experiments were carried out in Poland, where onions were sown two weeks earlier and the average monthly air temperature was also 2-5 degrees higher than in Estonia. The amount of precipitation was higher in our experiment, but lot of rain at the end of August caused extensive spreading of downy mildew and by that the growing period was shortened. Growing onions directly from seeds in Estonia is more influenced by weather and soil conditions and therefore production risks are greater than in traditional growing system, where set onions are used. If the irrigation system is available, growing direct sown onions is justified at the aim of decreasing planting costs.

In second experiment the use of additional fertilization as top dressing increased the yields of experimental varieties differently. Variety Hyfort F<sub>1</sub> gave higher yield compared to the control variant only when the highest rate of fertilizer was used. The yield of this cultivar was the lowest compared to the other varieties. The yield of variety Musica F<sub>1</sub> was even and significant differences were not recorded. Variety Hercules F<sub>1</sub> responded already to the smallest amount of additional fertilization, but increasing fertilizer rates further on did not have an effect. The onion yield of mentioned variety was the largest and most uniform. Variety Exhibition gave the highest yield in variant where 30 kg N·ha<sup>-1</sup> (N<sub>min</sub> 80 kg·ha<sup>-1</sup>) was used. Our results indicate that fertilization rates could be reduced, since fertilizing onions with the rate of more than 80 kg N·ha<sup>-1</sup> resulted in negligible or missing increase in yield. At the same time nitrate level in onions was increased by two times by using higher amounts of nitrogen fertilizers. Similar tendencies have been observed also in other studies in Nordic countries (Sørensen 1996; Suojala *et al.* 1998).

The results of the experiment with planting density and mulching of salad onion Exhibition showed that denser planting leads to higher yields, although by increasing the planting density the average weight of onion bulb decreased. Variables with textile mulch had by 20% higher yield per area than in bare soil. Mulch reduces water loss resulting in better conservation of soil moisture, and increases the root-zone temperature (Islam *et al.* 2002; Diaz-Perez *et al.* 2004). In experiments described by Diaz-Perez *et al.* (2004) black plastic mulch decreased the yield of sweet onion because of too high root-zone temperature (>15.8°C). For Estonian climate conditions, especially by cool and damp weather in 2004, the use of black textile mulch was beneficial.

#### Acknowledgements

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## WYNIKI BADAŃ NAD TECHNOLOGIĄ UPRAWY CEBULI W ESTONII

## Streszczenie

Doświadczenia dotyczące uprawy cebuli przeprowadzono w 2004 roku w Estońskim Uniwersytecie Rolniczym. W pierwszym doświadczeniu porównywano uprawę 17. odmian cebuli z bezpośredniego siewu z dwoma odmianami uprawianymi z dymki, w dwóch lokalizacjach, na dwóch typach gleby. Najwyższy plon cebuli na obu typach gleby uzyskano z odmian uprawianych z dymki. Wśród odmian uprawianych z bezpośredniego siewu najwyższym plonem cebuli wyróżniały się Renate F<sub>1</sub> oraz Musica F<sub>1</sub>. W drugim doświadczeniu badano wpływ różnych dawek nawozów azotowych stosowanych pogłównie na plon cebuli czterech odmian. Badania wskazały także na możliwość ograniczenia dawek azotowych w uprawie cebuli, albowiem w doświadczeniu polowym uzyskano zaledwie minimalny przyrost plonu w obiektach nawożonych dawkami azotu powyżej 80 kg N·ha<sup>-1</sup>. Natomiast w doświadczeniu dotyczącym gęstości sadzenia i stosowania okrywy z czarnej folii w uprawie odmiany cebuli sałatkowej Exhibition wykazano, że wyższe zagęszczenie roślin na jednostce powierzchni prowadzi do wyżki plonu. W przypadku stosowania okrywy z czarnej folii wyżka plonu sięgała do 20% w porównaniu z roślinami bez okrywy.

## ONION PRODUCTION IN THE UNITED KINGDOM

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### Summary

Bulb onion production in UK has a long history but has only progressed technically since the 1970's. Up to this time approx. 250-300,000 tonnes were produced on small farms mostly direct seeded and in areas with high waterholding capacity soils to sustain the crop without irrigation.

Over the next 30 years major investment has been made in storage and economies of scale have eliminated nearly all the small farms. Production is up to 1000 ha on a single holding and 30% now grown from sets. Total production is around 400,000 tonnes and consumption approx. 650,000 tonnes, the balance made up by imports.

All onions are now irrigated and mostly grown on sandy soils, the quality demands from the Supermarkets has eliminated production on clay/silt soils which result in surface skin staining.

key words: onion, production area, cultivation methods, plant protection, storage, marketing

### Areas of Production

Production has always been predominately in the Eastern and Southern counties of England where light levels are greatest, rainfall is lowest and soil types most easily selected (see shaded area on map above).

In the last 30 years production has moved from North of the shaded area further South and east due entirely to soil type. In the North of the area very fine sandy loams were used which had a high water holding capacity which assisted yields without the need for irrigation. More recently irrigation has increased (mostly from farm reservoirs filled in the winter) on the sandier soils and with good management these are now the most favoured areas for bulb onion pro-



duction. In addition to this production on peat based soils in Cambridgeshire has been maintained.

Overall it can be said that the best quality onions are produced on sandy clay loams in Bedfordshire and Essex (south of the production area) but skin staining can be a problem if harvest is wet. Greatest increase is in Norfolk and Suffolk on sandy soils, sometimes 100% sand susceptible to wind blow, a problem in some years. On these soils the risk of skin staining is least but skin loss can be a greater problem. Peat soils in Cambridgeshire also have skin staining problems from wet harvests.

### **Demands of the Market**

Changes in production are very much due to demands of the customers. Over the last 30 years sale of fresh onions has become focussed on main retailers, Tesco, Asda, Morrison and Sainsbury.

Firstly there was a big demand for quality which started the changes in production area. Onions were supplied by approx. 22 packers in different areas and there were at least twice as many retailers. From early 1980's to mid 1990's supermarkets paid a good premium price for the best quality, but at this time wastage was too high. Rejected quality was sold in wholesale markets or for peeling.

Ex farm prices from 1998 are summarised on Figure 1 but supermarket prices for traded product are not available.

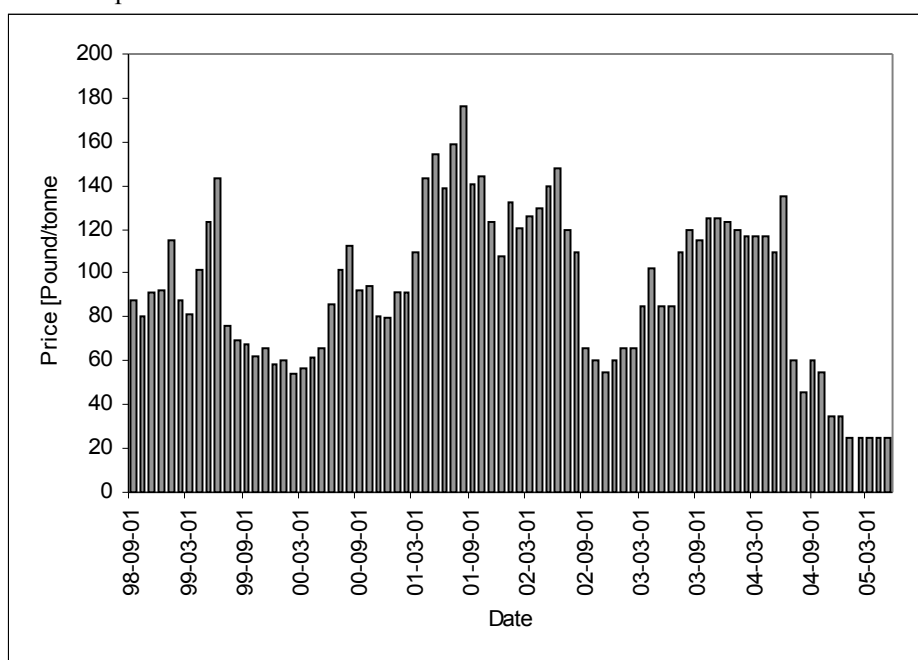


Fig. 1. Average U.K. onion prices, (September 1998 to May 2005)

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In the last 10 years very strong competition has resulted in 4 supermarket chains selling around 200,000 tonnes UK crop as fresh onions. Discounters and one or two small supermarkets have a limited demand. This strong competition has resulted in quality expected and the price as low as possible. Packers have been sent bankrupt and now approximately 6 have survived to supply higher volumes and at lower prices. These packers are independent companies and have a “gentleman’s agreement” with their grower suppliers.

Another major demand of the market has been for processed / peeled onions to use with the increasing demand for “ready meals”. It is now estimated that over 30% of the crop is peeled, a high percentage being crops grown on contract for the purpose. Over capacity in UK peeling factories has resulted in a lowering of prices to levels that are not very economic.

The end result therefore is a “two tier” market place with higher price for supermarket quality and poor prices for contracted or direct sales to peeling factories.

It is anticipated in future that fresh onion sales will decrease and more onions will be used for processing.

### **Production Methods**

Historically the crop was produced directly from seed. Onion sets had been tried but did not store well.

Demands increased to serve the market for as much of the year as possible and production responded with the introduction of overwinter onions and then transplanting of multi seeded peat modules raised under glass.

Overwinter onions were first grown from seed and more recently the majority produced from sets. Quality of overwinter onions is generally poor however and mostly now used for processing. Overwinter only account for 6-7% total area (see Table 1) and are planted August / September for harvest mid June.

Transplants were grown at 5 seeds per module and planted at 100,000 modules/ha. Seed was sown in January / February and planting in April.

This latter technique was slow and expensive and has now been replaced by use of onion sets. Reliable results from sets came with fungicide drenching before planting. Sets are currently treated with carbendazim at 5 litre per 1000 litre water plus Folicur (Tebuconazole) at 2 litre per 1000 litre for 20 minutes as a drench then dried back within 24 hours just before planting. Set size used is mostly 14-21 mm size at 370,000 sets per ha in 1.8 m beds x 5 rows. These are planted in March and harvested from mid July.

An additional trend has been increasing popularity of red onions with 10-15% from sets in 2005 just for the early market, planted March harvested mid August.

The largest production sector is direct drilled using hybrids mostly from Syngenta / Bejo / Advanta in Holland. High quality seed is demanded and precision seed drills (mostly vacuum disc type) used. The 1.8 m bed is universal with 6-8 rows and mostly pelleted seed used. Planting rate is 550-600,000 seeds per ha and germination percentage accepted between 90-100% only. In 2005 year 4650 ha Brown Onions is estimated and 1050 ha Red which can be seen as a major sector of

the market, non existent 15-20 years ago (also see Table 1). Seed is direct drilled from January on sandy soils through to early March. Harvest follows sets from early September.

Table 1. Comparisons of onion production in United Kingdom

	2003 Season			2004 Season			2005 Season provisional		
	ha	yield (t·ha <sup>-1</sup> )	tonnes	ha	yield (t·ha <sup>-1</sup> )	tonnes	ha	yield (t·ha <sup>-1</sup> )	tonnes
<b>Brown Onions</b>									
Overwinter drilled	184	40	7,360	170	44	7,480	140	40	5,600
Overwinter sets	607	36	21,852	539	40	21,560	442	40	17,680
Total overwinter	791		29,212	709		29,040	582		23,280
Spring sets	2,394	48	114,912	2,652	49	129,948	2,253	48	108,144
Spring drilled	5,161	40	206,440	5,737	50	286,850	4,646	45	209,070
Total spring	7,555		321,352	8,389		416,798	6,899		317,214
Total brown (o/w + spring)	8,346		350,564	9,098		445,838	7,481		340,494
<b>Red Onions</b>									
Red drilled	NA			NA			1,056	40	42,240
Red sets	NA			NA			176	40	7,040
Total red onions	1,036	40	41,440	1,262	40	50,480	1,232	40	49,280
Total including reds	9,382	-	392,004	10,360	-	496,318	8,713	-	389,774

Note: Total market for UK grown brown and red onions is around 400,000 – 410,000 tonnes

### The Growing Crop

White rot and stem and bulb eelworm can be problems but now are mostly avoided by the move to new production areas. Initially weed control is the major problem but an adequate range of herbicides (and good agronomists!) results in weed free crops. Propachlor + pendimethalin is used initially, later reinforced by chloridazon as pre emergence then Ioxynil + cyanazine are used as contacts at low dose (2-300 mls of each in 300 litres water/ha) plus graminicides for volunteer cereal and grasses. Some other herbicides can be used for special problems. Main issue is with volunteer potatoes which are difficult to eliminate.

Once the crop is established at 3 true leaves weed control should be complete and the greatest problem yet to overcome – control of Downy Mildew. Increasing numbers of spray applications have been necessary in recent years and control is not always totally successful.

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It is considered that overwinter onions keep mildew ongoing from one season to the next and in addition the winter is less cold than previously with few days giving temperatures below zero. Mostly the winter temperature is between 5-10°C.

A range of fungicides are used, mancozeb, dimethomorph, metalaxyl are the main actives plus some Amistar. Between 5 and 7 sprays are used mainly in July and August.

Approaching harvest a proportion of the seeded crop is treated with Maleic Hydrazide although there is pressure from multiple retailers to use no more than absolutely necessary.

### **Harvest and Storage**

It is accepted that crops need to be harvested when around 50% is still green (and tops 90-100% fallen over). To leave crops later is acceptable for processing (maximum yield!) but increases skinning-loss of skins when graded.

Since 1975 the direct harvest system has been used where high air flows are used and onions dried at 26-28°C. It is necessary to remove field moisture within 3 days and uniformly heat the crop to a minimum of 25°C.

High investment has been made in storage with new stores now around 2000 tonnes capacity. The design of stores is unique to UK and usually there is a central tunnel and fan + heaters in a separate fanhouse at one end. Heated air is fed to the crop through laterals from this central tunnel. Crop is loaded in either side of this tunnel progressively from back to front. It is possible to open and close the laterals that deliver air underneath the stack and therefore concentrate the main air volume on most recently harvested crop. Stores can initially dry and heat 30-50% of total capacity hence sometimes harvesting has to stop. Drying in boxes of 1-3 tonnes is increasingly popular.

Onions are kept at 25°C for 3-4 weeks ventilating 2-4 hours per day (after initial drying and heating) until skins and neck tissue are completely dry. Temperature is then reduced around 0.5°C per day down to 10°C for ambient air stores and 0°C for refrigerated stores. At least 50% of the UK crop is held in refrigerated stores and a small additional quantity in Controlled Atmosphere (about 12,000 tonnes).

The overwintered crop does not store well and is cleared by August, around 4 weeks in store. Sets now store well and some are kept in refrigeration to the following May (there is some preference for processing due to the higher dry matter of Sturon types, circa 15%). Mostly however sets are sold by December and then all is direct seeded for longer term storage.

Ambient air at 10°C is OK for storage to February then refrigerated to mid – late May. C.A. storage extends a further month and substitutes some of the more expensive New Zealand imports which are used by the multiple retailers in June/July and into August (see import summary Table 2).

Table 2. Import of onion to United Kingdom, July 2001 – June 2004

Country	July 2001 - June 2002 (tonnes)	July 2002 - June 2003 (tonnes)	July 2003 - June 2004 (tonnes)
Australia	8,551	6,321	3,629
New Zealand	43,712	35,000	30,921
Chile	24,389	18,055	30,985
Spain	80,578	84,648	61,558
Holland	60,771	46,339	53,482
Poland	988	6,732	21,197

It should be noted that prior to harvest the crop is topped in the field and may be left up to 24 hours in good weather before being loaded into store. Control systems, often by computer, are in all the stores and very up to date facilities can be found on many farms in UK. Economics are difficult as with farming generally and there is no great optimism for the future, except it just has to be better than for the 2004/5 season!

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#### PRODUKCJA CEBULI W WIELKIEJ BRYTANII

##### Streszczenie

Uprawa cebuli w Wielkiej Brytanii ma długą historię, jednakże znaczny postęp w technologii jej uprawy rozpoczyna się dopiero w latach siedemdziesiątych ubiegłego wieku. Do tego czasu roczna wielkość produkcji cebuli sięgała 250 tys. – 300 tys. ton. Cebula uprawiana była wówczas głównie z bezpośredniego siewu, na małych farmach w rejonach z glebami o dużej zasobności wodnej, co nie wymagało dodatkowego nawadniania.

W ciągu ostatnich trzydziestu lat dokonano znacznych inwestycji w dziedzinie przechowalnictwa cebuli w Wielkiej Brytanii. Ze względu na czynniki ekonomiczne w produkcji cebuli wyeliminowane zostały z rynku prawie wszystkie gospodarstwa małe, które nie wytrzymały konkurencji dużych farm. Obecnie cebula uprawiana jest w gospodarstwach o areale dochodzącym do 1000 ha. Ponad 30% produkcji cebuli pochodzi z uprawy z dymki. Uprawa cebuli jest prowadzona głównie na glebach piaszczystych z zastosowaniem nawadniania. Wymagania stawiane przez duże sieci handlowe w Wielkiej Brytanii w odniesieniu do jakości

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cebuli wyeliminowały z rynku produkcję na glebach gliniastych i ilastych, co było częstą przyczyną występowania plamistości łuski cebuli. Ogólna produkcja cebuli wynosi około 400 tys. ton, a konsumpcja sięga 650 tys. ton. Ujemny bilans w produkcji cebuli na rynku brytyjskim jest uzupełniany z importu.

## SHALLOT PRODUCTION AND RESEARCH IN POLAND

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### Summary

Shallots are onions grown at various climatic zones – from Asia and Africa to northern regions of Europe and America. They are especially valued where the production of common onion from seeds is difficult, the growing season is too short and inadequate conditions for early sowing. In Poland approximately 80-100 ha are put into production of shallot. In the cultivation, local populations, which do not produce generative shoots, are widely spread. They are propagated vegetatively from daughter bulbs produced by mother bulbs. The seeds of shallot hybrids produced by Bejo Zaden Seed Co. are available for purchasing in Poland. The studies were performed on seed-producing Creation F<sub>1</sub> cv., the seeds of which are on market in Poland. In experiments the cultivation from seeding directly into the field, transplants and bulbs was applied. The highest yield of shallots was obtained from planting bulbs. The least productive method of Creation F<sub>1</sub> cv. shallots cultivation proved to be seeding directly into the field. Taking into consideration the economic point of view it can be stated that in Poland, like in other countries, shallot should be cultivated from bulbs planting.

key words: shallot onion, cultivars, growing method

### INTRODUCTION

In Poland shallot onion has been known for a long time. An interesting description of this plant together with the characterization of its cultivars is given by Nehring (1923). This author enumerates shallot cultivars, namely the French one from Jersey and the Polish one, Żelazowski. Due to the greater economic significance of common onion, shallot onion is treated in Poland as an amateur plant but it deserves to be widespread. In other European countries onions of the aggregatum group, including the shallot onion, also have a smaller importance as compared to common onion. However, the species propagated in a vegetative manner such as shallot and potato onion, have their tradition in a number of countries, namely Finland, France, Spain, Russia and the countries of central and south-eastern Asia and South America (e.g., Argentina).

In Europe the greatest number of shallots are cultivated in France. The area of its cultivation in this country is estimated for about 2000 ha. France exports shallot onions to other European countries, USA, Canada and Japan. Export to those countries makes the total of 6 000 – 8 000 tons annually (Cohat *et al.* 2001). In the countries of central and south-eastern Asia shallot is a very popular type of onion. In Indonesia its cultivation exceeds 70 000 ha, while in Thailand – 12 000 ha (Permadi 1994, Ruaysoongnern 1994).

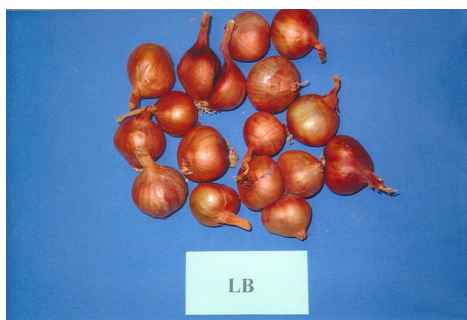
The area of shallot onion cultivation in Poland is not exactly known. It is estimated for 80 – 100 ha. Lack of multiplier bulbs makes an obstacle in organized trade turnover. A lot of local populations are cultivated on amateur scale in Poland. The situation resembles a little the cultivation of garlic, which is of great importance in Poland, but the biggest area of its cultivation is maintained by local cultivars.

Numerous local populations of shallot onions show great variability of morphological and quality features. They are, however, well-adapted to the local conditions of climate and soil.

It is worth to describe what properties of shallot are decisive of its value as an onion that deserves to be spread in the countries of central-eastern Europe.

## RESULTS

Many years of experiments at the Agricultural University in Lublin (Tendaj & Piusińska-Siedlecka 1999) and the studies conducted by Kotlińska (1995) and Horbowicz & Kotlińska (2001) from Research Institute of Vegetable Crops in Skierniewice have shown that shallot onion has a number of positive features that cannot be found in common onion. The most important characteristics are short period of vegetation, unfailing growth and yielding on worse quality soils and in different climatic conditions, and great storage durability



Fot. 1. Shallot local population LB



Fot. 2. Shallot hybrid Creation F<sub>1</sub>



Table 1. Effect of bulbs planting density on yield of shallot and the share of various diameter bulbs

Planting density (cm)	Total yield (t·ha <sup>-1</sup> )	Share of various diameter bulbs (mm) in total yield (%)					
		<10	11-15	16-20	21-25	26-30	>30
30x20	23.86	1.0	5.9	16.0	33.4	20.2	23.4
	13.61	0.2	3.6	11.7	33.8	8.5	42.2
Mean	18.74	0.6	4.7	13.8	33.6	14.4	32.8
30x10	29.60	2.5	16.4	24.0	36.3	12.6	8.2
	23.50	0.3	3.3	17.9	41.1	12.0	25.4
Mean	26.55	1.4	9.8	20.9	38.7	12.3	16.8
30x5	36.04	10.9	30.2	27.9	25.2	4.7	1.1
	27.30	0.1	11.2	25.6	41.4	7.6	14.1
Mean	31.67	5.5	20.7	26.8	33.3	6.1	7.6

The experiments were carried out in eastern regions of Poland in the years 1998-2002. The objective of the study was the shallot local population, which do not produce generative shoots.

Table 2. Storability of shallot local population popular in the cultivations in the Lublin region

Bulb size (diameter, mm)	Storage temperature (October to March)					
	0 – 1°C			2 – 6°C		
	weight losses (%)	rotten bulbs (%)	marketable bulbs (%)	weight losses (%)	rotten bulbs (%)	marketable bulbs (%)
5-10	10.3	1.6	87.9	12.4	23.0	64.6
11-15	7.6	3.6	88.8	11.1	24.3	64.6
16-20	8.6	1.4	90.0	10.8	21.0	68.2
21-25	9.0	0.4	90.6	9.6	33.7	56.7
26-30	8.9	1.2	89.9	11.2	33.2	55.6
>30	8.5	2.1	89.4	12.0	37.7	50.3
Mean	8.9	1.7	89.4	11.2	28.8	60.0

From the dietary point of view shallot onion characterizes by an irreplaceable spice and its leaves contain a lot of vitamin C, phenolic acids, flavonoids and other constituents that are important for health. It was shown that despite its vegetative propagation from bulb divisions, the shallot of many cultivars and populations is characterized by good healthiness (Horbowicz & Kotlińska 1998, Tendaj *et al.* 2003)

Shallot is onion propagated mainly vegetatively from daughter bulbs creating clusters. This results from weak ability to generate seed stalks and seeds. Even in France, where a lot of seed-producing cultivars are grown, the cultivation of shallot from bulbs planting dominates (Cohat *et al.* 2001).

In 1992, a seed company in the Netherlands specializing in onions and shallots (de Groot en Slot bv., Middenweg) released the first "true shallot seed". Recently, Bejo Seed Co. has had limited supplies of shallot true seeds.

Nowadays more and more often new hybrids cultivars are introduced the seeds of which are of good quality. The seeds of shallot hybrids produced by Bejo Zaden Seed Co. (Bonilla F<sub>1</sub>, Matador F<sub>1</sub>, Ambition F<sub>1</sub>) are available for purchasing in Poland. The Dutch cultivar Creation F<sub>1</sub> has been known in Western Europe and in Poland for a long time. The yielding and durability of this cultivar were compared in the experiments conducted at the Agricultural University in Lublin (Tendaj & Piusińska-Siedlecka 1999).

The objective of the study was the evaluation of shallot yield, cv. Creation F<sub>1</sub>, grown from seed and bulbs. The cultivation from seeds, similarly to that of common onion, may promote the healthiness of the bulbs, planting bulbs or transplants, however, ensures earlier yielding. The method of shallot growing significantly affected the number and the weight of the bulbs created in the cluster. It determined the height of the obtained yield. The highest inclination to split and create large clusters was characteristic for the shallots grown from planting bulbs. The least productive method of Creation F<sub>1</sub> shallot cultivation proved to be seeding directly into the field. Comparing with the other growing methods the yield was significantly low and the most differentiated concerning the size of bulbs (Table 3).

Table 3. Effect of cultivation methods on the number and weight of bulbs in cluster of shallot cv. Creation F<sub>1</sub>

Cultivation methods	Number of bulbs per cluster		Weight (g)			
	range	mean	cluster		single bulb	
			range	mean	range	mean
From seeds	1-5	2.07	15.1-121.8	63.59	9.5-78.9	32.5
From transplants	1-4	1.85	57.4-249.4	105.18	8.8-159.9	59.6
From bulbs	6-22	11.38	50.7-342.7	175.49	0.4-57.7	16.52

It turned out that the cultivation from seed sowing directly in the field sometimes failed, since the emergencies on highly compact soils were very poor. The bulbs obtained in the shallot yielding from seed sowing had variable size – ranging from 10 to over 60 mm in diameter (Table 4). Better effects were obtained from planting the seedlings. Also a higher yield and a more balanced proportion of bulbs of the same size were achieved. Shallot of Creation F<sub>1</sub> cv. formed clusters of a small number of bulbs both from the seedlings and seed sowing. The plants obtained from bulbs planting had the greatest tendency to division and formation of clusters of considerable weight.

Table 4. Effect of cultivation methods on total yield structure of shallot cv. Creation F<sub>1</sub> (%)

Cultivation methods	Total yield t·ha <sup>-1</sup>	Bulbs diameter (mm)										
		10-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	>60
From seeds	14.36	3.20	5.95	7.55	7.2	8.2	15.2	23.0	12.15	9.7	4.85	3.0
From transplants	25.46	-	-	-	-	1.08	3.93	6.4	12.3	17.35	19.35	39.65
From bulbs	38.55	4.35	8.65	25.55	10.9	30.1	7.3	7.2	5.95	-	-	-

## CONCLUSION

Taking into consideration the economic point of view it can be stated that in Poland, like in other countries, shallot should be cultivated from bulbs planting. The seeds of hybrids offered for sale are too expensive to encourage the producers. Therefore, it should be recommended to cultivate shallot propagated in a vegetative way from the bulbs obtained from dividing the clusters of mother plants.

Results of the experiments should encourage the cultivation of this onion since they point to a very positive content of important chemical constituents in the bulbs, a possibility of achieving high yields and very good storage ability.

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## PRODUKCJA SZALOTKI I BADANIA NAUKOWE PROWADZONE W POLSCE

### Streszczenie

Szalotka jest cebulą uprawianą w różnych strefach klimatycznych od Azji i Afryki do północnych rejonów Europy i Ameryki. Doceniana jest szczególnie tam, gdzie produkcja cebuli zwyczajnej z siewu bezpośredniego nasion jest zawodna, przy zbyt krótkim okresie wegetacyjnym oraz w warunkach utrudniających wczesny siew. W Polsce szalotkę uprawia się na powierzchni około 80-100 ha. W uprawie powszechnie znane są lokalne populacje szalotki, które nie wydają pędów generatywnych. Rozmnaża się je wegetatywnie z cebul przybyszowych, uzyskiwanych z rozdzielenia gniazd cebul macierzystych. Nasiona odmian heterozyjnych produkowane przez firmę Bejo Zaden są dostępne w Polsce. W przeprowadzonych badaniach uwzględniono odmianę Creation F<sub>1</sub>, której nasiona były oferowane w sprzedaży. W doświadczeniu uwzględniono uprawę tej szalotki z siewu wprost na pole, z rozsady i sadzenia cebul. Największy plon uzyskano z sadzenia cebul. Najgorsze efekty plonowania uzyskano przy uprawie z siewu bezpośredniego w polu. Z ekonomicznego punktu widzenia można twierdzić, że w Polsce, podobnie jak w innych krajach, szalotkę należałoby uprawiać z sadzenia cebul. Nasiona odmian heterozyjnych, oferowane w sprzedaży, są zbyt drogie, aby zachęcało to producentów do ich zakupu.

## **INFLUENCE OF GROWING CONDITION AND THE LEVEL OF ONION (*ALLIUM CEPA* L.) DONOR MATERIAL ON INDUCEMENT FREQUENCY OF GYNOGENIC PLANTS**

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### **Summary**

Condition for growing of donor material for haploid inducement by gynogenesis have considerable effect on regenerative coefficient of initial explants. It is determined, that maximum regeneration frequency from unpollinated ovary was received when buds from the first circle of onion inflorescence were used. The donor material, which was grown in greenhouse conditions, had also much higher index of the regeneration coefficient of gynogenic plants. A hypothesis is suggested; that the particular position of the first circle generative organ is the result of evolutionally worked mechanism action, directed at raising survival rate of populations of vegetational species, especially in unfavorable environment.

key words: onion, haploids, gynogenesis, plant donors, explants, regeneration

### **INTRODUCTION**

The interest to getting haploids is explained by large opportunities, which they give for the technology on the basis of plant tissue culture, especially directed at breeding process. For getting heterotic hybrids on the basis of doubled haploids it is possible to create isogenic lines during a year, while the inbreeding method requires 5-7 years and 8-12 years for annual crops. The investigated lines on the basis of haploids, received in F<sub>1</sub> and F<sub>2</sub> hybrid generation, facilitate evaluation and selection of necessary combinative signs, permit to speed up the process of variety creation by 2-3 times. Wide introduction of onion gynogenic lines is prevented by low frequency of such plants creation in culture of unpollinated ovaries *in vitro* (Tiukavin & Timin 1984, Campion & Alloni 1990, Bohanec *et al.* 1995). The frequency of haploid plants regeneration is influenced significantly, according to literature date, by the state of donor organs development and conditions of their growing (Schum & Mattiesch 1997).

The aim of investigation conducted in 2004 at Institute of Vegetables and Melons, was to determine optimal conditions and to reveal the material, which would give the possibility to raise the output of haploid plants.

### MATERIALS AND METHODS

In the experiments there were used generally accepted methods of biotechnological investigation (Kalinin *et al.* 1980). Donor material – onion seed plants of the variety Khaltседon were grown in a green-house and in the field. A part of cut inflorescences was kept in water.

Plant material for introduction into culture *in vitro* was sterilized in laminar box. In aseptic conditions from buds there were cut out, which were cultivated on hard nutrient medium BDC with added 2,4-D, BAP, vitamins and sugars.

Explants were cultivated for 4-12 weeks on the medium for regeneration induction at 23-28°C, 16-hours photoperiod and illumination of 2 lux.

### RESULTS

The investigations confirmed that plants regeneration frequency significantly depends on the physiological state of the donor inflorescences at the moment of their usage in culture *in vitro*. Their physiological state was different and depended on the phase of development, in which they were selected, and the state of their keeping (culture inflorescence was in water or directly introduced in culture *in vitro*). We have found that maximum frequency of plants – regenerants creation was observed in flowers and buds, selected from inflorescences, on which flowering was only at initial stage.

The results - average by variants - given in Table 1 show the possibility to reveal that the main factor, influencing the quantity of regenerated hypogenic plants, is the circle of the onion buds used for haplo-culture (factor A). The part of its influence on regeneration coefficient in the trial was calculated for 56%, but for factor B (the place the donor material growing and conditions of its storage) – only 14%. Intercommunication of both factors was 29%.

Table 1. Influence of plant donor stage, conditions of donor material growing and storage on regeneration frequency of onion gynogenic plants

Circle of used buds (factor A)	Place of donor material selection (factor B)	Quantity of planted ovaries	Quantity of ovaries, which manifested regenerative response	% of sprouts regeneration from ovaries
1 <sup>st</sup> circle	Film green-house	536	12	2.30
2 <sup>nd</sup> circle	Field	512	6	1.18
3 <sup>rd</sup> circle	Culture inflorescences in water	540	5	0.93
1 <sup>st</sup> circle	Film green-house	526	2	0.36
2 <sup>nd</sup> circle	Field	528	1	0.18
3 <sup>rd</sup> circle	Culture inflorescences in water	522	0	0
1 <sup>st</sup> circle	Film green-house	522	0	0
2 <sup>nd</sup> circle	Field	528	0	0
3 <sup>rd</sup> circle	Culture inflorescences in water	526	0	0.76
LSD <sub>0,05</sub> A*between variants		0.96		
LSD <sub>0,05</sub> B*between variants		0.50		

\* - Difference is significant at P=0.95

When comparing influence of different terms of donor material selection, we can come to the conclusion, that when selecting plant material from a film green – house and from field the best results are ensured by unpollinated ovaries from buds of the first circle inflorescences of donor plants (Fig. 1).

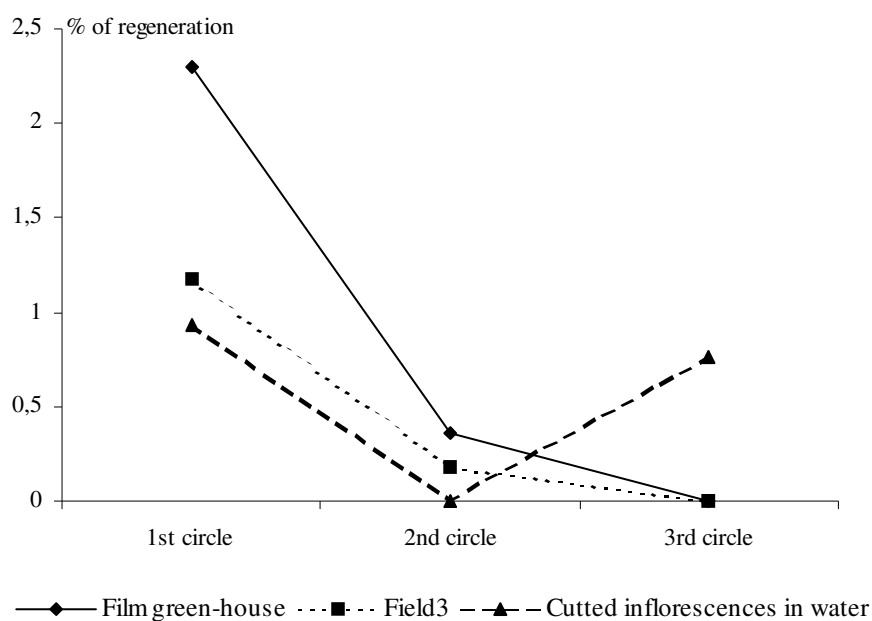


Fig. 1. Dynamics of change of tissues regenerative ability, depending on conditions of donor material growing and storage

In the trial there was observed natural reduction of regeneration coefficient, when using buds from the 2<sup>nd</sup> and 3<sup>rd</sup> circles. Somewhat other picture was fixed, when using donor material from cut inflorescences. In this case the minimum percent of regeneration (0 %) was marked not in the last, but in the second term of selection. Though it was maximum also in the first term of selection (the 1<sup>st</sup> circle of buds). When using material from the 3<sup>rd</sup> circle of inflorescences, regeneration was received only from those inflorescences, which were cut and kept in water during 3 weeks.

As for the influence of the place of donor material selection on regeneration of gynogenic sprouts the following regularity was observed: when using the buds explantant from 1<sup>st</sup> and 2<sup>nd</sup> circle of onion inflorescences, the usage of material from greenhouses ensured higher regeneration coefficient than material which was grown in field conditions.

## DISCUSSION

It is known, that a generative organ of first (low) circle is in particular condition of forming. Thus, it was shown on tomato that by the character of nutrients distribution between buds, situated on different inflorescences, but developed in approximately identical condition of external environment the considerable differences were revealed. This effect is also determined for synchronous developing generative organs within the limits of a separate inflorescences and is explained by existence of genetically programmed functional and physiological differentiation in the process of ontogenesis, which, in its turn, is provoked by evolutionally worked out succession of assimilators entrance (Zhuchenko 1990). Besides, there exist variability of xylem hydraulic conductivity (Sellin 1990) and of transpiration in different parts of a crown. It is also necessary to take into account presence of phytohormones gradients within the limits of a plant and its reproductive organs (Goroshkevich 1996). Flowers of maize, situated on the main stem, receive a larger volume of nutrients, and in tomato a separate leaf – donor supplies separate fruits with assimilators. Presence of sectorial carrying forward is confirmed on other objects – soybean, phaseolus, tobacco, cotton, sunflower (Zhuchenko 1990). A hypothesis is suggested, that in extreme conditions processes of hormone and fermentative regulation in fruits take place in such ways, that only in some of them a big attracting ability (concerning carried from leaves and other organs assimilators) is preserved. This is possible, that under „positive” genic control there are for a first time fruits, which is their development are most closely to production of mature seeds. The most viable pollen in maize and woody plants is produced namely by generative organs of the first circle, with this they are characterized by the largest quantities of recombination indices, such as frequency of chiasma and crossing-over, which results in formation of considerable genetic diversity in the next generation (Zhuchenko 1990, Montvid & Samovol 2002).



It is necessary also to take into account that this fruit is set earlier than others and ripens with the largest probability, ensuring with this the possibility of viable progenies formation. Thus, it is not excepted that the particular position of the first circle generative organ is the result of evolutionally worked mechanism action, directed at raising survival rate of populations of vegetational species, especially in unfavorable environment (Montvid & Samovol 2002).

### CONCLUSION

For the increase of regeneration quantity of union gynogenic plants it is advisable to grow donor plants in greenhouses conditions. It is desirable to plant seed bulbs in several terms in order to have possibilities during 2-3 weeks to introduce in culture of isolated tissues initial explants, which can induce haploid plants.

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### WPŁYW WARUNKÓW UPRAWOWYCH I GENOTYPU ROŚLIN DONOROWYCH (*ALLIUM CEPA* L.) NA POZIOM INDUKЦИИ ROŚLIN GYNOGENETYCZNYCH

#### Streszczenie

Warunki uprawy roślin donorowych do indukcji haploidów przy wykorzystaniu gynogenezy mają istotny wpływ na wskaźnik regeneracji początkowych eksplantatów. Wykazano, że najwyższy wskaźnik regeneracji z niezapylonej zalążni i zalążków można osiągnąć przy wykorzystaniu pąków z pierwszego okółka kwiatostanu cebuli. Rośliny donorowe, które były uprawiane w warunkach szklarniowych miały również wyższy

wskaźnik współczynnika regeneracji roślin gynogenetycznych. Proponowana jest hipoteza, że szczegółowe położenie organu generatywnego pierwszego okółka jest efektem mechanizmu wypracowanego na drodze ewolucyjnej, ukierunkowanego na wzrost możliwości przeżycia populacji gatunków wegetatywnych, zwłaszcza w niekorzystnych warunkach środowiskowych.

## **ONION SEED TREATMENT FOR INCREASE OF FIELD EMERGENCE FROM DIRECT SOWING IN SLOVAKIA**

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### Summary

In three year experiment onion seed variety Zlatava was characterized by some parameters: laboratory germination, 1000 seeds weight and field emergence. Seeds were treated with chemical against soil fungicides and coated by film coating technique. It was calculated the seed value, plant necessity number, seed necessity amount and actual seed necessity. Results during cultivated years in trials were not statistically significant. Field emergence was lower by 13.24% than laboratory germination, because of soil pathogens at the beginning of emergence period. Onion seeds treated by thiram, coated or pelleted by special powder combined with liquid were characterized by better - statistically highly significant - laboratory germination and field emergence in comparison to control treatment.

key words: onion seeds, chemical treatment, coating, pelleting, laboratory germination, field emergence

### INTRODUCTION

According to Statistical Office of Slovak Republic onion was cultivated during several years on area of 3 000 - 4 000 ha with production 30 000-50 000 tons per a year. The averaged yields of onion were approximately 10 t ha<sup>-1</sup> in individual years. Growing of onion includes all types of cultivation methods:

- one year early spring cultivation from onion sets (seedlings) under plastic house,
- one year early spring cultivation from seeds by precise direct seed sowing technology,
- precise direct sowing in September or first half of October,
- two years cultivation for onion sets and seed production.

Two onion growing methods are being used: the precise direct sowing seeds and cultivation from sets. The ratio between mentioned growing methods is approximately 80-85% to 15-20%. Number of 850 000 harvested plants on hectare are expected. At weight 3.5 g per 1000 seeds and laboratory germination of 85% it needs 5-7 kg of seeds per hectare for sowing.

It is expected, that quality of seed expressed by laboratory germination, 1000 seeds weight and field emergence are very important parameters for defining good agriculture practice for guarantee of required density of harvested plants. One of the steps is to treat seeds by film coating technique.

### MATERIAL AND METHODS

Onion seed variety Zlatava was characterized by parameters such as laboratory germination, 1000 seeds weight and field emergence, and seeds were treated with chemical against soil fungicides and coated by film coating technique. It was calculated the seed value, plant necessity number, seed necessity amount and actual seed necessity.

Precise direct sowing with 1 row hand machine was applied in the trials at the third decade of March in 2003-2005.

### RESULTS AND DISCUSSION

Analysis of 1000 seeds weight resulted from trials during 2003-2005 has shown non significant differences between grown years and non significant differences between replications which declares normal trial conditions.

Onion seeds treatment by thiram and coating by coloured liquid and pelleting by special powder combined with liquid means better laboratory germination and field emergence statistically highly significant. Field trials during three years (2003-2005) resulted differences statistically as high significant. Results allow to state establishing good trials conditions due to non significant differences in repetitions.

According the least significant differences on both levels – 0.05 and 0.01 (Fig. 1) it can be compared the obtained results with onion seed treatment.

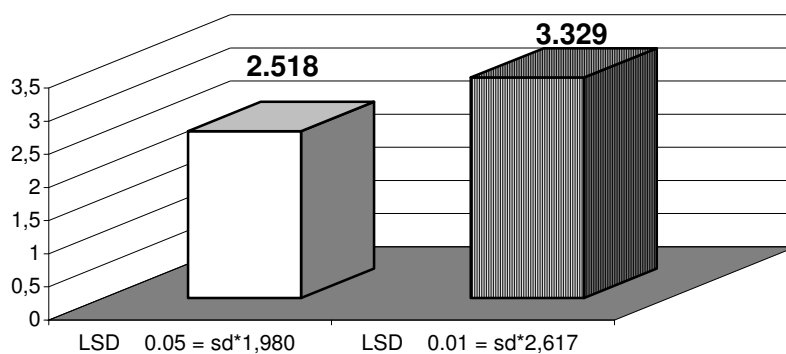
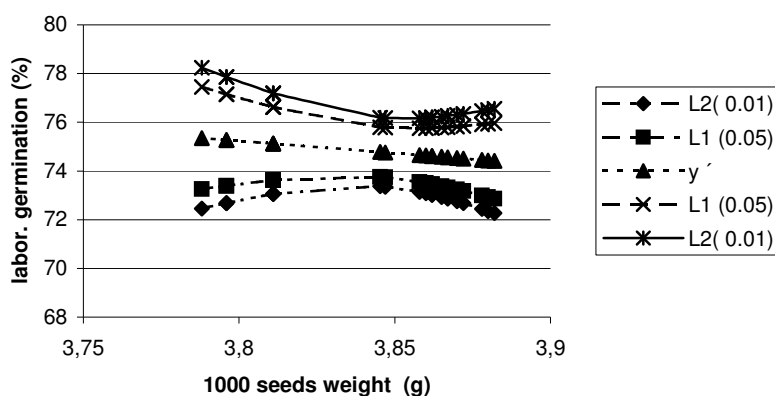


Fig. 1. LSD for onion seed treatment at 0.05 and 0.01 level

Results during cultivated years in trials were not statistically significant. Field emergence was lower by 13.24% than laboratory germination, because of soil pathogens at the beginning of emergence period. Interesting is that pelleted seeds were though higher in laboratory germination and statistically significant (2.7222), but in case of field emergence statistically non significant (1.9444).

In practice there are problems in Slovakia when some producers use pelleted onion seeds for cultivation having been persuaded about good steps for plant density after direct precise sowing. At the middle or late of March in optimal sowing time it happens due to dry soil, weather conditions short of rainfall or it is too early for irrigation possibilities. Pelleted seeds, ready for direct sowing, are 3-5 times expensive than coated seeds and needs earlier watering for the right emergence more than standard treated or coated seeds. That is why the decision for sowing coated seeds seems better solution than pelleted seeds. In case of results for coated seeds the correlations between 1000 seeds weight, laboratory germination and field emergence were observed (Fig. 2,3,4).

In connection with onion seed necessity for direct precise sowing it was decided that coated seeds are the best results because of comparatively high laboratory germination - 75% (standard EU STN - 70%), acceptable field emergence - 65% and counting real seed necessity - 9.6 kg·ha<sup>-1</sup> (Fig 5).



Note:  $y'$  – equation of regression; L2 and L1 - coefficients of regression

Fig. 2. Correlation between 1000 seeds weight and coated seeds laboratory germination at 0.05 and 0.01 level (variety Zlatava)

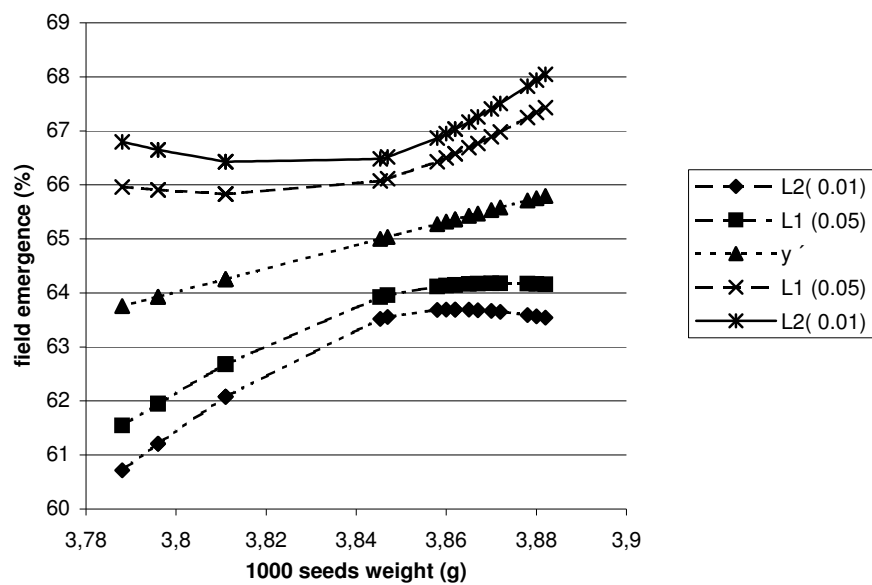


Fig. 3. Correlation between 1000 seeds weight and coated seeds field emergence at 0.05 and 0.01 level (variety Zlatava)

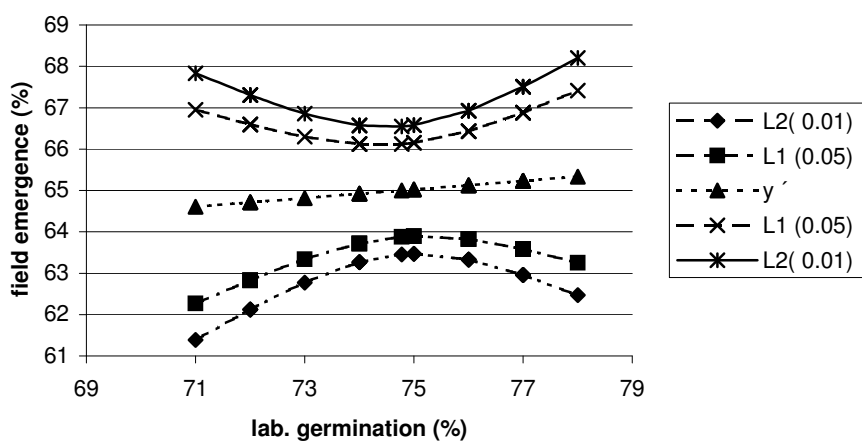


Fig. 4. Correlation between coated seeds field emergence and coated seeds laboratory germination at 0.05 and 0.01 level (variety Zlatava)

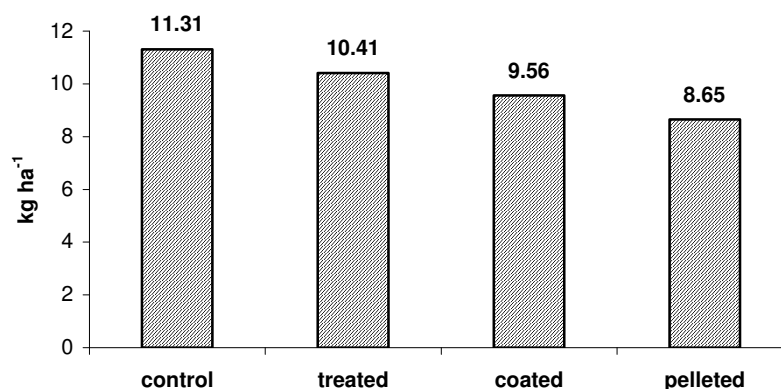


Fig. 5. Real onion seed necessity (kg·ha<sup>-1</sup>)

The main aim of presented material was integrated condition of germination and field emergence by fungicidal treatment onion seeds to improve stand and stabilized plant establishment and finally the yield as given by Khan *et al.* (1992). Duan *et al.* (1997) examined cultivar and lot variation in beet seed germination response to polymer film coating and identified the seed factors associated with the germination sensitivity to film coating.

Since 2004 the three years project is developed by seven EU partners to examine the potential of a range of physical and biological seed treatment for the control of seed-borne fungi and bacteria on a number of different vegetable crops (Lennartsson 2004).

## CONCLUSION

Onion seed variety Zlatava was characterized by parameters such as laboratory germination, 1000 seeds weight and field emergence, and seeds were treated with chemical (thiram) against soil fungicides and coated by film coating technique. It was calculated the seed value, plant necessity number, seed necessity amount and actual seed necessity.

Precise direct sowing with 1 row hand machine was applied in the trials at the third decade of March in 2003-2005.

Results during cultivated years in trials were not statistically significant. Field emergence was lower by 13.24% than laboratory germination, because of soil pathogens at the beginning of emergence period.

Pelleted seeds were though higher in laboratory germination statistically significant (2.7222), but in case of field emergence statistically non significant (only 1.9444).

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WPLYW ZAPRAWIANIA NASION NA WSCHODY CEBULI  
UPAWIANEJ Z SIEWU BEZPOŚREDNIEGO NA SŁOWACJI

Streszczenie

W trzyletnim badaniach testowano nasiona cebuli odm. Zlatava pod kątem ich zdolności kiełkowania w testach laboratoryjnych, zdolności wschodów w warunkach polowych oraz masy 1000 nasion. Nasiona były otoczkowane, zaprawiane metodą inkrustacji oraz zaprawiane preparatem Pomarasol Forte (tiuram) przeciwko grzybom odglebowym. Określono wartość siewną nasion oraz zalecaną liczbę nasion na jednostkę powierzchni w warunkach polowych. Stwierdzono m.in. że wschody cebuli w polu były o 13,24% niższe w porównaniu z testami laboratoryjnymi, ze względu na porażenie kiełkujących nasion przez grzyby odglebowe. Wykazano, że nasiona cebuli zaprawiane metodą inkrustacji, zaprawiane preparatem Pomarasol Forte (tiuram) oraz otoczkowane odznaczały się wyższą zdolnością wschodów polowych (63,4-66,9%) i lepszą zdolnością kiełkowaniem w testach laboratoryjnych (72,5-77,5%) w porównaniu z kontrolą – odpowiednio 61,1% i 70,9%.



## EFFECTIVENESS OF INVESTMENT IN APPLIED HORTICULTURAL RESEARCH

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### Summary

A study on the cost benefit analysis of applied horticultural research was carried out in two EU Member States: the Netherlands and Poland. Four crops were selected for the study; two fruit crops – apple and pear and two vegetable crops – carrot and onion. A developed spreadsheet model was applied to calculate the effectiveness of applied research and the returns to society. Important indicators for return are the Net Present Value (NPV) and the Internal Rate of Return (IRR). The returns to society were mostly high. IRR's outcomes ranged from 81 to 14,113%. The NPV's ranged from 1 million € for the least profitable project to 464 million € for the most profitable project. The results confirm that governments should continue and not abandon applied horticultural research because it contributes substantially to society. The agriculture and food production sector are subject to strong dynamics to which the research system must be able to adapt. This will require an effective set-up of a system of applied research in horticultural crops on at least four elements: purpose, priority setting, organisational structure and funding strategies.

key words: applied horticultural research, economic impact, funding sources

### INTRODUCTION

The data shown in literature illustrates the large benefits of agricultural research (Fuglie *et al.* 1996, Alston *et al.* 2000, Masters 2000, Wustman *et al.* 2004). National governments have traditionally provided most funding for agricultural research, however during recent years, there has been a shift in priorities. Privatisation and restructuring of agricultural research in new EU Member States put additional pressure on the continuity of applied agricultural research in these countries. Improvements in technology by application of scientific re-

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search to practical problems are the main source of economic growth and development.

In order to assess the costs and the benefits of applied horticultural research we carried out a study with four horticultural crops<sup>A</sup>, including two fruit crops: apple and pear, and two vegetable crops: carrot and onion. Important indicators for return are the Net Present Value (NPV) and the Internal Rate of Return (IRR), which has been calculated according to Masters (2000).

The NPV is a balance of all costs and benefits that will flow from the research activity in the future, discounted to one point in time. The IRR can be compared to any other return rate. For example: the cost of borrowing funds from a bank, the returns earned in other investments or the interest earned from a bank saving account (Masters 2000). An example to explain IRR is: an initial investment of € 1 at an IRR of 435% will generate € 4.35 after one year.

The Net Present Value represents the net gains to society from different kinds of research. The Internal Rate of Return is used to assess the economic attractiveness of investments in infrastructural development projects but can also be used for ranking research projects.

#### MATERIAL AND METHODS

Data from seven research projects: integrated control of carrot fly in the Netherlands, seed treatment of carrots in Poland, seed treatment of onions in the Netherlands, seed treatment of onions in Poland, chemical thinning of apples in Netherlands and Poland and root cutting of pears in Netherlands have been collected and run through the Masters economic surplus model (Masters 2000).

Carrot fly (*Psila rosae*) reduce marketability of the product which eventually leads to reduction of financial returns per area of land. The damage occurs when larvae of the carrot fly start to feed on the carrot roots. The principle of the integrated control system developed in the Netherlands is to spray an insecticide when a threshold of yellow sticky traps with caught carrot flies is reached in order to reduce the carrot fly population. This approach will prevent oviposition of the carrot fly at the stem base of the carrots plants. The research was conducted during 1993-1994. Carrot plants can be protected against carrot fly also through a seed dressing with an insecticide. The research was conducted in Poland during 1994-1995 with the use of a number of chemicals including Zaprawa Marshal 250 DS.

Seed coating of onions used in the Netherlands reduces the incidence of rot caused by *Botrytis alli* and *Botrytis aclada* and improves thereby the post-harvest life of the onions. Experiments were carried out in the years 1969-1971. Data from experiments carried out in Poland during 1998-2000 on seed dressing of onions with an insecticide (Zaprawa Marshal 250 DS) to reduce the incid-

ence of damage caused by the onion fly (*Delia antiqua*) were taken for our calculations.

## RESULTS AND DISCUSSION

Table 1 summaries the observations and findings of the applied research on fruit and vegetable crops from both countries. Integrated control of carrot fly in the Netherlands had the lowest NPV value only 16 million € and third highest IRR 1,987%. Reasons for the limited NPV are the limited size of the acreage and limited adoption rate as well as high cost of adoption. Seed dressing of carrot in Poland had the highest IRR 12,663% and a high NPV of 320 million €. It was caused by a high adoption rate and low adoption costs as well as by large acreage of carrot production.

Seed treatments of onions in the Netherlands had a moderate NPV but a high IRR. This case is characterised by high adoption rate (100%) and very low adoption cost 2.3 € per ha in comparison to seed treatment in Poland where adoption rate reached only 80% and adoption cost increase up to 11 € per ha.

Table 1. The Internal Rate of Return (IRR) and Net Present Value (NPV), adoption rate and changes in yield levels

Project	IRR %	NPV mln €	Adoption			Yield (t·ha <sup>-1</sup> )	
			rate in years	level in %	cost in €·ha <sup>-1</sup> in 2002	at start research	in 2002
Integrated control if carrot fly (NL)	1,987	16	1	50	220	55	44
Seed treatment of carrot (PL)	12,663	320	3	90	15	20	22
Seed treatment of onions (NL)	599	125	2	100	2.3	37	56
Seed treatment of onions (PL)	3,366	179	2	80	11	21	20
Chemical thinning apples in NL	435	464	4	100	- 2,051 <sup>1)</sup>	11.4	34.2
Chemical thinning apples in PL	81	1	7	15	- 180 <sup>1)</sup>	12.2	14.3
Root cutting pears in NL	14,113	35	1	50	- 1,100 <sup>1)</sup>	23	24

<sup>1)</sup> Adoption of research results lead to a cost reduction due to savings on needed labour hours instead of increased expenses for introduction of a new technique

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The returns to society were usually high. IRR outcomes ranged from 81% (chemical thinning of apples in Poland) to 14,113% (root cutting of pears in the Netherlands). The NPVs ranged from € 1 million for the least profitable project to € 464 million for the most profitable project. While results are probably an overestimated, even if the true gains to society would be a factor 10 lower, the conclusion that applied horticultural research is a profitable investment remains firm. High NPV values were found in cases with high adoption rates, substantial acreage's, and significant yield increases. High IRR values were found in cases with a short adoption period.

## CONCLUSIONS

This study yielded the following main conclusions:

1. Applied agricultural research provides large returns to society. An evaluation of five applied research projects in horticulture, three in Poland, two in the Netherlands, confirms this pattern. There were large returns for seed treatment research in Poland. Carrot research produced a return of over four thousand %, onion research returned over 700%. A third project, on chemical thinning of apples, returned modest losses. These three projects alone generated a total NPV of over € 450 million. Results have been adjusted downwards for the bias of evaluations at project level instead of at programme level. Although the results are probably an overestimated, even if the true gains to society would be a factor 10 lower, the conclusion that applied horticultural research is a profitable investment remains firm.
2. The scale of applied research in Polish horticulture is small. Relative to production volume, R&D expenses in the fruit sector in Poland are at least 3 to 4 times smaller than in the Netherlands. In order to remain competitive in the EU market agricultural research in Poland may have to expand substantially.
3. Impact assessment is hampered by data problems. The evaluation of agricultural research in the new EU Member States in Central and Eastern Europe and in the Netherlands is hampered by a lack of data on costs and benefits of agricultural R&D. The research structure in Poland and in the Netherlands has no routine of assessment (ex-ante or ex-post) of the impact of the research programmes in these countries.
4. Continued (or even expanded) public agricultural research in the new EU Member States is justified but the policy incentives for private R&D must be favourable. Concerns regarding rural development and the evolution of public concerns on agriculture - such as food safety, animal health and environmental protection - provide strong justification for continued public involvement in agricultural research. In other areas of research, especially in plant breeding, governments must provide a favourable context for private

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research by defining and enforcing intellectual property rights (IPR) and by providing the conditions for effective linkages between basic research and applied research. Thus, governments can play a significant role in stimulating private investment in agricultural R&D.

#### Public responsibilities

While exceptions exist, in emerging economies agricultural development is the key to poverty alleviation and rural development, and to transformation of the economical structure. And when emerging economies do develop, the demands on agriculture change: consumers shift their diet towards higher quality products, and governments increasingly seek to satisfy public expectations concerning consumer health hazards and environmental degradation. Many of the new EU Member States in Central and Eastern Europe are in such a phase of agricultural transformation. An effective agricultural research system is a critical support factor in the process of change, as important as competitive markets for input and output, and proper incentives for entrepreneurship. The public sector holds several responsibilities in supporting an effective agricultural research system.

#### Incentives for private research

Over recent decades the research orientation of the public sector and of private companies has changed in response to changes in global food markets and public priorities, especially in developing countries. Private sector of research has increasingly ventured beyond traditional areas such as production mechanisation and the use of chemicals for yield improvements.

In plant breeding, private companies have taken over the dominant position from the governmental research system. Growth prospects in variety development (breeding) and the seed industry are positive. The world-wide decline in food prices that has been continuing for several decades pushes the need for ongoing productivity gains. In addition, maturing consumer markets around the world demand an increasing variety of products and product qualities.

With such obvious outlet opportunities for improved seed, the fact whether private companies will actually invest in R&D depends to a large extent on government policies.

1. The policy on Intellectual Property Rights (IPR) will provide incentives (or disincentives) for private investment. The more companies can be sure that they will reap the exclusive benefits from R&D, the more they will be inclined to invest.
2. Insights from basic agricultural research must be made available for applied research and technology transfer. Productivity of the total research system depends to a large extent on the interaction between the basic-applied-technology components and the required technology transfer to end users and

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the implementation by these users. By setting up a system to make the results from basic research and applied research (either done in the home country or imported from abroad) accessible within the country, government provides critical support and favourable incentives to private sector investment. As Fuglie notes "...effective linkages between public and private research laboratories can increase the productivity of both parts of the system" (Fuglie *et al.* 1996).

Governments are found to have a direct impact on the profit potential of private R&D in breeding, and thereby on the scale of private agricultural R&D.

#### Public research in case of private under investment

Even when policies, like a policy on IPR, and the options for interaction between research subsystems are favourable, it cannot be guaranteed that private firms will actually invest in R&D up to the desired levels. Then, governments may want to step in and provide public research. This is justified for at least two fields that are relevant to the new EU Member States in Central and Eastern Europe.

##### 1. Rural development

Poverty and unemployment in Central and Eastern Europe is concentrated in the rural areas. For most rural regions, the very kernel of economic growth lies with increased agricultural productivity (Timmer 2002). Private firms, however, may well under invest in regions with the strongest need for productivity growth. There are several elements why rural R&D might fail to deliver.

(a) Typically, it will take a long time before the benefits of research can be reaped. As shown above, the returns under gradual development (or slow adoption rates of new technology) are much lower than under rapid technological change and quick adoption. Private firms are generally less patient.

(b) The institutional setting in poorer regions is typically less favourable to investment than more developed regions: remoteness reduces the links with basic research and applied research. IPR policies are enforced less, so that firms experience difficulties in securing the exclusive returns on their investment due to a lack of law-enforced intellectual property rights.

(c) The local demand for improved varieties is low.

##### 2. Evolving public concerns regarding agriculture

The accession to the EU has boosted regulations on public concerns relating to agricultural production and the food supply chain. Such concerns include food safety, animal health, animal welfare and environmental degradation, and have been implemented in requirements regarding food products and the process of production, processing, handling and transport. The process of change requires support from research, especially in support of smaller companies. Business strategies to comply with new regulations differ across

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firms (Reardon *et al.* 2001). Large (often international) "agribusiness" companies will use the change in policy to differentiate from competitors by raising standards above mandatory levels. Small and medium sized companies will often respond to changes in regulations by asking government support. While agribusiness dwells on the insights from global product development and product quality control, the small and medium-sized companies will turn to the agricultural research system for guidance in complying with evolving public concerns.

#### Elements of an effective applied research system

In our view, the system for applied agricultural research should support agricultural development by enabling:

- production of quality food commodities,
- the development of new concepts for production, handling and marketing,
- contributions from agriculture to nature conservation and biodiversity.

The system should be able to deal with the present dynamics in agriculture and food production. We argue in our report that society's demands on the agricultural research system are evolving from preoccupation with yields and costs of individual products to concerns regarding safety, quality and variety on the one hand and environmental implications of production processes on the other. The driving forces behind such changes include globalisation (outsourcing of raw materials, supply of primary products), market liberalisation, technological advances, and the changing role of national governments. Additional challenges are presented by the increasing desire for sustainable production systems.

The objective of the applied research system is to incorporate such dynamics and to translate relevant basic research into custom-made solutions in the green chain and/or in the food chain.

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#### OPŁACALNOŚĆ NAKŁADÓW FINANSOWYCH PONIESIONYCH NA BADANIA W ZAKRESIE OGRODNICTWA

##### Streszczenie

Badano poniesione koszty i uzyskane dochody związane z prowadzonymi badaniami aplikacyjnymi w ogrodnictwie w dwóch krajach Unii Europejskiej, tj. Holandii i Polsce. Do badań wybrano cztery najważniejsze dla obu krajów gatunki roślin ogrodniczych: z zakresu sadownictwa – jabłonie i grusze, z zakresu warzywnictwa – cebulę i marchew. Do kalkulacji opłacalności badań aplikacyjnych w ogrodnictwie wykorzystano model opracowany przez Masters'a i in. 2000. Głównymi wskaźnikami opłacalności badań są wartości zysku netto i stopy zwrotu kapitału. Stwierdzono, że zwrot poniesionych nakładów był bardzo opłacalny dla społeczeństwa. Stopa zwrotu wahała się od 81 do 14,113% zależnie od gatunku, a zysk netto wyniósł od 1 mln € dla najmniej dochodowego projektu do 464 mln € dla projektu najbardziej dochodowego. Uzyskane wyniki potwierdzają, że państwo nie powinno rezygnować z finansowania badań aplikacyjnych w ogrodnictwie, gdyż przynosi to straty dla ogółu społeczeństwa. Sektor rolnictwa i przemysłu spożywczego wykazują dużą dynamikę rozwoju i do niego musi być ściśle dostosowany system badań aplikacyjnych. Dla efektywnego wykorzystania badań aplikacyjnych w ogrodnictwie, należy uwzględnić przynajmniej cztery elementy przy ich planowaniu: cele, priorytety, strukturę organizacyjną i strategię finansowania.



**SIZE OF FLOWER BUDS IN CARROT (*DAUCUS CAROTA* L.)  
AS AN INDICATOR OF A STAGE OF MICROSPOROGENESIS  
AND ITS SUITABILITY FOR INDUCTION OF ANDROGENESIS**

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Summary

A research on microsporogenesis of carrot was carried out in order to find the optimal stage for androgenesis initiation in anther culture and establish a correlation between this stage and a bud size as its external marker.

In the presented paper percentage of different development stages of microspores in 3 tested bud size ranges, i.e. 0.7-0.9 mm, 1.0-1.3 mm, 1.5-1.8 mm, was evaluated for 7 carrot cultivars: Feria F<sub>1</sub>, HCM, Nerac F<sub>1</sub>, Perfekcja, Monanta, Berjo and Splendid F<sub>1</sub>. Fresh anthers, without initial maceration, were stained with acetocarmine and examined under light microscope (120x). To evaluate an effect of microsporogenesis stage on androgenesis, anthers of two cultivars, which in introductory experiments proved to have the highest embryogenetic ability, were, after separation according to set size ranges, laid down on a medium in order to form embryos.

In cv. Feria F<sub>1</sub> uninucleate microspores comprised above 50% of total number of microspores in all tested bud size ranges. For the other cultivars microspore development stage depended on bud size.

Comparing microsporogenesis in buds obtained from 2 donor plants of cv. Feria F<sub>1</sub> differences in percentage content of particular development stages for the same size range were found for the tested plants. In 1.0-1.3 mm buds, percentage of uninucleate microspores was 48.1% for the plant no. 13 and only 10% for the plant no. 17. Microspores in an early binucleate stage comprised 25.4% and 65%, respectively, in the tested size range.

In cvs. Feria F<sub>1</sub> and HCM, the highest number of embryos per 100 anthers was obtained in cultures of anthers taken from 0.7-0.9 mm buds.

key words: androgenesis, anther culture, carrot, microspore

INTRODUCTION

Research work on deriving domestic F<sub>1</sub> hybrid cultivars of carrot is economically justified. To obtain homozygotic lines, intended as components of F<sub>1</sub>

hybrid cultivars, inbreeding is carried out, which in carrots is associated with strong depression. Therefore a huge amount of plant material is necessary for breeding. The inbreeding in carrot typically takes from 6 to 8 years. Use of *in vitro* anther culture enables to obtain completely homozygous plants in just a few months.

Androgenesis is a process of plant development directly from male gametophyte in which haploid microspore divides to produce an embryo and later a haploid plant (Wang *et al.* 2000). In higher plants this process is induced by subjecting anthers to stress in *in vitro* culture. Many factors affect androgenesis in *in vitro* cultures, including genotype, conditions of chilling and growth of donor plants, flowering period, time of buds sampling, medium composition, type and duration of stress affecting anthers after taking from an inflorescence (Bajaj 1990, Górecka 1998). Dunwell (1985) stresses that a stage of pollen microsporogenesis is one of the main criteria affecting efficiency of anther culture. According to Bajaj (1990) the most suitable stage for producing androgenetic embryos is that of closed flower buds in which microspores are in uninucleate or early binucleate stage, depending on plant species. The indicators of optimal microsporogenesis stage for anther culture are bud size and a ratio of petals length to anther length (Bajaj 1990, Górecka 1998). Poliakov *et al.* (1995), working with flax, showed that developmental stage of microspores is correlated in this plant with flower bud length only. While for many plants, mainly crucifers, where androgenetic embryos had been obtained the optimal bud lengths were established (Dore & Boulidard 1988, Nałęczńska 1991, Górecka 1998), no such data is available for carrot.

The research works on microsporogenesis of carrot were carried out in order to establish the optimal stage for androgenesis induction in anther culture and to find out the relation between this stage and bud length as its external indicator.

#### MATERIAL AND METHODS

The following cultivars of carrot were used in the research: Feria F<sub>1</sub>, HCM, Nerac F<sub>1</sub>, Perfekcja, Monanta, Berjo, Splendid F<sub>1</sub>. Roots of these cultivars were placed after harvest in a cold room at +4°C and stored for 3 months. Next, the roots were planted in 10 L containers into a mixture of sand and peat (2:1 v/v) amended with chalk (8.0 kg·m<sup>-3</sup>) and Azofoska (13.6% N, 1.9% P, 16.0% K + microelements Mg, Cu, Zn, Mn, B and Mo) at the rate of 1.25 kg·m<sup>-3</sup>. The containers were placed into a greenhouse at the temperature +20°C. Every two weeks plants were fertigated with liquid fertilizer Hydrovit 300 (concentration 0.3% v/v) containing 2.2% N, 0.45% P, 2.65% K, 0.49% Mg and microelements Fe, Mn, Cu, Zn, B and Mo.

Prior to starting anther culture after taking buds from outside whorl of inflorescence on main stem of donor plants, observations on the stage of microsporogenesis were carried out in order to establish the optimal size of buds which are a source of anthers for starting anther culture. Based on introductory observations 3 ranges of flower bud size were set: 0.7-0.9 mm, 1.0-1.3 mm, 1.5-1.8 mm, in which microspores with characteristics typical for subsequent stages of microsporogenesis were observed. Percentage share of particular development stages in the set ranges

of bud size was established. 5 buds were examined for size ranges 0.7-0.9 mm and 1.0-1.3 mm and for some cultivars from 1.5 to 1.8 mm. This depended on distribution of percentage microspore content. When in two lower ranges of bud size sufficient number of microspores in appropriate development stages were found, to obtain acceptable results of androgenesis, time-consuming observations in 1.5-1.8 mm buds were not conducted. Anthers were taken off the buds with preparation needle. One anther was placed on each microscope slide and without previous maceration a drop of acetocarmine was added. Acetocarmine was prepared by dissolving 0.5 g carmine in 100 ml of 45% acetic acid. The solution was boiled for 30 min under return cooler and then filtered. The anthers with acetocarmine were squashed and covered with coverslip. The observations were carried out under light microscope with immersion at 120-fold magnification. For cv. Feria F<sub>1</sub> observations on two donor plants were conducted while for the other cultivars on one plant only. Also, for this cultivar observations were done in two consecutive years while for the rest only in one year.

To evaluate effect of microspore development stage on efficacy of embryogenesis in anther culture, anthers from buds of different length, containing microspores at different stages of microsporogenesis, of two cultivars Feria F<sub>1</sub> and HCM were placed on a medium for induction of androgenesis. The cultivars were selected after introductory experiments due to their capability for embryogenesis. The anthers were placed in 100 ml Erlenmeyer flasks (40 pcs in each) and kept in a dark incubator at +27°C. The B5 medium (Gamborg *et al.* 1968) containing 0.1 mg·L<sup>-1</sup> 2,4-D, 0.1 mg·L<sup>-1</sup> NAA, 500 mg·L<sup>-1</sup> glutamine, 100 mg·L<sup>-1</sup> L-serine, 750 mg·L<sup>-1</sup> CaCl<sub>2</sub>·6H<sub>2</sub>O and 100 g·L<sup>-1</sup> sucrose was used. When embryos occurred, the flasks were transferred to continuous fluorescence light (30 μmol·m<sup>-2</sup>·sec<sup>-1</sup>) with no change in temperature. Efficacy of androgenesis was assessed as a ratio of obtained embryos per 100 anthers placed.

## RESULTS

The following development stages of microspores were distinguished: 1) tetrad stage i.e. 4 identical microspores developed after meiotic division of mother cell, separated by callose walls (Photo 1); 2) uninucleate microspore with distinction of an early stage, when a nucleus is located centrally in a dense cytoplasm (Photo 2) and a late stage, when a nucleus is in central part of microspore, by sporoderm in vacuolised cytoplasm (Photo 3); 3) binucleate microspore with distinction of an early stage, when two nuclei are situated in the central part of microspore (Photo 4) and a late stage, when two cells can be distinguished, a small generative cell and big vegetative one (Photo 5).

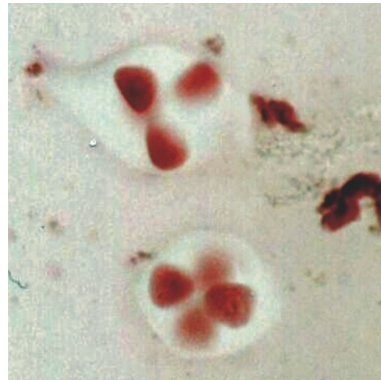


Photo 1. Tetrad of microspores of carrot cv. FERIA F<sub>1</sub>

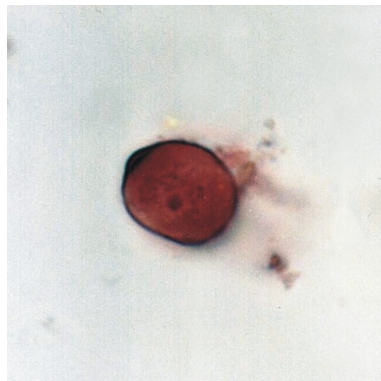


Photo 2. A microspore of carrot cv. FERIA F<sub>1</sub> in an early uninucleate stage



Photo 3. A microspore of carrot cv. FERIA F<sub>1</sub> in a late uninucleate stage

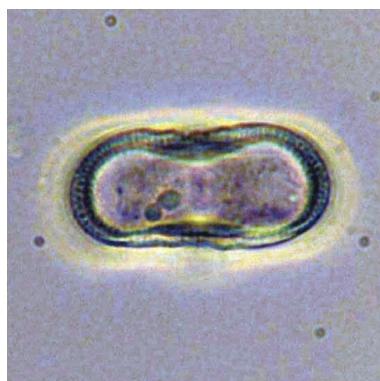


Photo 4. A microspore of carrot cv. Feria F<sub>1</sub> in an early binucleate stage



Photo 5. A microspore of carrot cv. Feria F<sub>1</sub> in a late binucleate stage

In cv. Feria F<sub>1</sub>, in all size ranges of buds, uninucleate microspores, believed to be the most suitable for androgenesis induction, comprises over 50% of microspores (Table 1). In the other cultivars microspore development stage depended on bud size. The highest number of uninucleate microspores was found 1-1.3 mm buds of cvs. Perfekcja, Berio and Splendid F<sub>1</sub>. In contrast, for cvs. HCM and Nerac F<sub>1</sub> majority of uninucleate microspores was noted in 0.7-0.9 mm buds, and for cv. Monanta in 1.5-1.8 mm buds.

When microsporogenesis in buds sampled from two donor plants of cv. Feria F<sub>1</sub> was compared, there were noted differences in percentage of particular development stages in the same bud size range of both tested plants (Table 2). The most evident differences occurred for 1.0-1.3 mm bud size range. For the plant no. 13 uninucleate microspores comprises 48.1% while for the plant no. 17 only 10%. Mi-

crosspores in an early binucleate stage were, respectively, 25.4% and 65% of all microspores in this range of bud size.

Table 1. Percentage content of microspore development stages of tested carrot cultivars in buds of different size

Cultivar	Microspore development stage in anther (%)	Bud size (mm)		
		0.7-0.9	1-1.3	1.5-1.8
Feria F <sub>1</sub>	Tetrads	25	4	0
	Uninucleate	64	71	53
	Early binucleate	3	19	6
	Late binucleate	8	6	44
	Unidentified	0	0	1
HCM	Tetrads	0	3	0
	Uninucleate	47	31	0
	Early binucleate	41	41	30
	Late binucleate	10	25	70
	Unidentified	2	0	0
Nerac F <sub>1</sub>	Tetrads	0	0	- <sup>1)</sup>
	Uninucleate	100	72	-
	Early binucleate	0	37	-
	Late binucleate	0	0	-
	Unidentified	0	0	-
Perfekcja	Tetrads	0	0	-
	Uninucleate	73	79	-
	Early binucleate	0	2	-
	Late binucleate	0	19	-
	Unidentified	27	0	-
Monanta	Tetrads	75	28	0
	Uninucleate	25	48	50
	Early binucleate	0	0	50
	Late binucleate	0	24	0
	Unidentified	0	0	0
Berjo	Tetrads	100	0	-
	Uninucleate	0	69	-
	Early binucleate	0	0	-
	Late binucleate	0	31	-
	Unidentified	0	0	-
Splendid F <sub>1</sub>	Tetrads	100	20	-
	Uninucleate	0	67	-
	Early binucleate	0	0	-
	Late binucleate	0	13	-
	Unidentified	0	0	-

Description: -<sup>1)</sup> no data

Table 2. Microspore development stages in buds of different size from two donor plants of carrot cv. Feria F<sub>1</sub>

Microspore development stage in anther expressed in %	Donor plant no. 13			Donor plant no. 17		
	Size ranges for buds (mm)			Size ranges for buds (mm)		
	0.7-0.9	1-1.3	1.5-1.8	0.7-0.9	1-1.3	1.5-1.8
Tetrads	10.2	0.6	0	28.6	0.3	1.4
Uninucleate	50.8	48.1	10.5	46.8	10.6	1.9
Early binucleate	12.4	25.4	59.9	21.5	65	47
Late binucleate	4.2	4.7	19.9	1.4	15.5	35.1
Unidentified	12.4	11.2	9.6	7.6	8.6	4.6

After comparison of percentage distribution of microspores in particular stages of development in cv. Feria F<sub>1</sub> buds of the same size for each year of experiments, the variation between the years 2002 and 2003 was found in percentage of microspores at a given development stage for the same bud size ranges (Table 3). In 2002, tetrads comprised 25% and uninucleate microspores 64% of all microspores in the first tested bud size range 0.7-0.9 mm. In contrast in 2003 tetrads were the only microspore stage noted in this size range. In the next bud size range i.e. 1.0-1.3 mm the differences were smaller. In 2002 there were 4% tetrads, 71% uninucleate and 19% binucleate microspores in buds of this size range. In 2003 tetrads were not found while uninucleate and early binucleate microspores comprised 42.4% and 30%, respectively.

Table 3. Microspore development stages in buds of different size from carrot cv. Feria F<sub>1</sub> in 2002 and 2003

Microspore development stage in anther expressed in %	Feria F <sub>1</sub> – 2002 year			Feria F <sub>1</sub> – 2003 year		
	Size ranges for buds (mm)			Size ranges for buds (mm)		
	0.7-0.9	1-1.3	1.5-1.8	0.7-0.9	1-1.3	1.5-1.8
Tetrads	25	4	0	100	0	0
Uninucleate	64	71	53	0	42.4	0
Early binucleate	3	19	2	0	30	0
Late binucleate	8	6	44	0	27.5	0
Unidentified	0	0	1	0	0	100

For both tested cultivars, the highest number of embryos per 100 cultured anthers was obtained from the anthers taken from 0.7-0.9 mm long buds, though the

cultivars differed significantly in their ability for androgenesis. In the next size range of buds less embryos were obtained and for both cultivars the numbers were several-fold lower than for the shortest buds. In cv. HCM the lowest number of embryos was obtained from the longest buds while for cv. Feria F<sub>1</sub> the number was similar to one obtained from buds from the previous size range (Table 4).

Table 4. Number of obtained embryos per 100 anthers of cvs. Feria F<sub>1</sub> and HCM

Feria F <sub>1</sub>		HCM	
Length of bud (mm)	Number of obtained embryos per 100 anthers	Length of bud (mm)	Number of obtained embryos per 100 anthers
0.7-0.9	63.1	0.7-0.9	6.9
1.0-1.3	10.2	1.0-1.3	2.5
1.5-1.8	17.5	1.5-1.8	0.3

#### DISCUSSION

Working on microsporogenesis of carrot Tyukavin *et al.* (1999) distinguished 4 stages of microspore development i.e. a tetrad, an early uninucleate microspore with centrally located nucleus, a late uninucleate microspore with two big vacuoles, a binucleate microspore. In our work we divided microsporogenesis into 5 stages separating binucleate stage into two phases.

Many authors stress that efficacy of androgenesis depends mainly on a genotype. Siebel & Pauls (1989), Nałęczyńska (1991), Ockendon & McClenaghan (1993), Górecka (1998) point out great variation in androgenesis ability between species and cultivars. Arnison *et al.* (1990) noted differences in efficacy of androgenesis not only among broccoli cultivars but also between individual donor plants. Górecka (1998) in a research work on androgenesis of cabbage found that cultivars and even clones derived from one mother plant in a given cultivar differ strongly in androgenesis efficacy. She observed also that optimal bud size for androgenesis induction was different for particular cultivars and clones. In the presented experiment not only cultivars of carrot differed in microsporogenesis but also differences for a given bud size range in individual plants were noted. The observations suggest that genotype is a factor determining also microsporogenesis. It may be supposed that in addition to genetic ability for androgenesis also differences in microsporogenesis between individual plants are the reason for variation in a number of embryos derived from their anthers. This, in turn, necessitate establishing optimal stage of microsporogenesis for individual plants within a cultivar. Defining general tendencies of the discussed process on a cultivar level only, a number of obtained embryos in anther culture may be expected not to be an optimal one.

Andersen *et al.* (1990) found that buds of carrot cvs. Feonia Nobo and Nantes Topschoor of the same length differed in particular years in percentage content of microspores in optimal stage for androgenesis induction. The results obtained in the



presented experiment support those findings. In 2002, microspores in the anthers from 0.7-0.9 mm buds of cv. Feria F<sub>1</sub> were in the stages of tetrad, uninucleate and early binucleate microspore. In contrast, in 2003 all microspores from this bud size range were in tetrad stage. This variation may result from different distribution of external factors affecting vernalization, growth and development of plants in individual years.

Andersen *et al.* (1990) conducted the experiments in which they proved that late uni-nucleate and early binucleate stages of microspore development are the most suitable for obtaining the maximal number androgenetic embryos of *Daucus carota*. According to Reynolds (1990), microsporogenesis and later pollen formation is regulated by two gene groups. The first gene group is active during meiotic divisions of pollen mother cells in an anther and it is responsible for proper pollen initiation. The second one is activated during mitotic divisions of a microspore and regulates pollen maturation and later germination of pollen tube. This author suggests that the moment of switching the activity of the two gene groups is a critical moment of microsporogenesis and at the same time very important for androgenesis induction. The results of our experiment support these observations. The best effects of androgenesis were obtained with anthers which contained microspores mainly in late uninucleate and early binucleate stages that is in the time of switching activity of the described gene groups.

#### CONCLUSIONS

1. Microspore development stage in carrot is closely correlated with a bud size and depends on a genotype, which determines microsporogenesis.
2. To obtain maximal number of embryos in anther culture of carrot the buds which contain the highest percentage of microspores in uninucleate stage should be used.

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WIELKOŚĆ PĄKÓW KWIATOWYCH U MARCHWI (*DAUCUS CAROTA* L.)  
JAKO KRYTERIUM STADIUM MIKROSPOROGENEZY  
I PRZYDATNOŚCI DLA INDUKOWANIA ANDROGENEZY

Streszczenie

Badano stadium mikrosporoogenezy marchwi w celu określenia optymalnego jej stadium dla pobudzenia androgenyzy w kulturach pylnikowych i znalezienia związku tego stadium z długością pąka, jako jego zewnętrznego markera.

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Określano procentowy udział poszczególnych faz rozwojowych mikrospor w badanych 3 przedziałach wielkości pąka: 0,7-0,9 mm, 1,0-1,3 mm, 1,5-1,8 mm, dla 7 odmian marchwi: Feria F<sub>1</sub>, HCM, Nerac F<sub>1</sub>, Perfekcja, Monanta, Berjo, Splendid F<sub>1</sub>. Świeże pylniki, bez wstępnej maceracji, wybarwiano acetokarminem i obserwowano pod mikroskopem (pow. 120x). Dla określenia wpływu fazy mikrosporogenezy na androgenezę pylniki dwóch odmian, które we wstępnych badaniach okazały się najbardziej embriogenne, wyłożono na pożywkę w celu uzyskania zarodków, dzieląc je według uprzednio wyznaczonych przedziałów wielkości.

U odmiany Feria F<sub>1</sub> we wszystkich badanych przedziałach wielkości pąka mikrospory jednojądrowe stanowiły ponad 50%. U pozostałych odmian faza rozwoju mikrospory była uzależniona od wielkości pąka.

Przy porównaniu przebiegu mikrosporogenezy w pąkach pochodzących od dwóch roślin donorowych odmiany Feria F<sub>1</sub> zauważono różnice w procentowej zrztości poszczególnych faz rozwojowych dla tego samego przedziału wielkości u badanych roślin. W przedziale długości pąka 1,0-1,3 mm u rośliny nr 13 mikrospory jednojądrowe stanowiły 48,1%, a u rośliny nr 17 tylko 10%. Mikrospory w stadium wczesnym dwujądrowym stanowiły, w badanym przedziale długości pąka, z-wiednio 25,4% i 65%.

U odmian Feria F<sub>1</sub> i HCM najwięcej zarodków na 100 wyłożonych pylników otrzymano w kulturach pylników wypreparowanych z pąków o długości 0,7-0,9 mm.

**TECHNOLOGICAL CHARACTERISTIC OF THE LINES  
SELECTED OUT FROM INTERSPECIFIC HYBRIDS  
*CAPSICUM ANNUUM* L. X *CAPSICUM CHINENSE* JACQ.**

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Summary

The plant material constituting the summary of eight years of research were the lines being the generation F<sub>6</sub> of hybrids created as a result of crossing annual pepper (*Capsicum annuum* L.) and chinese pepper (*C. chinense* Jacq.). The evaluated lines were homozygotic in a high degree. The volume of commercial yield of ripe fruit varied from 4.66 to 6.48 kg·m<sup>-2</sup> and the average fruit weight from 25 to 130 g. A technological performance understood as part of pericarp obtained as a result of preparing the fruit for preservation in relation to the whole fruit weight reached 91%, whereas a biological performance meaning part of edible part in the whole fruit weight reached 95%. The maximum thickness of pericarp reached the level of 6.6 mm. A comprehensive analysis of average values of tested lines makes it possible to distinguish three of them. It was indicated that they could be used as components of hybrids F<sub>1</sub>.

key words: biological performance, *Capsicum annuum* L., *Capsicum chinense* Jacq., hybrids, technological performance

INTRODUCTION

It is estimated that 10 million tonnes of pepper are produced yearly. One fifth of the yield comes from China. As far as the regions where pepper has its origin are concerned, pepper plays a significant part among foodstuffs in, among others, Mexico. In Brazil, where pepper consumption per person is similar to that in Poland, about 280 thousand tonnes are produced yearly (Greenleaf 1986, Carvalho *et al.* 2003).

*Capsicum annuum* L. is the most important species. It includes almost all cultivated varieties. Some cultivars are represented by other species of which *C. frutescens* L., *C. chinense* Jacq. and *C. baccatum* L. have economic significance. There is some difficulty in determining the significance of the species due to the fact that in many regions of the world, especially in Latin America and South America, wild forms of the above-mentioned species are cultivated.

*Capsicum chinense* Jacq., similarly to the other species of *Capsicum*, originates from America. Its varieties with sweet fruit are especially popular in Venezuela (Castelano 2001). It is closely related to annual pepper, which makes it possible to create hybrids as a result of crossing the two species (Greenleaf 1986, Zewdie & Bosland 2000). The hybridization makes possible a transfer of resistance genes characteristic for *C. chinense* Jacq., described by Grube *et al.* (2000). The recent research (Buso *et al.* 2003) has confirmed that there is similarity of both species with respect to genetics on the molecular level. Due to difficulties in crossing the species, is impossible to use hybrids F<sub>1</sub> in practice. It is only selection of hybrid materials that creates opportunities to obtain a new genetic variation, which might be popular in vegetable production. For the above reasons, hybrid materials were subject to individual selection with progeny evaluation, which was carried out for six years. The selection results in homozygous lines being created and presenting interesting characteristics of the fruit. The results of the research presented in this study refer to F<sub>5</sub> hybrids and homozygous generations of F<sub>6</sub>. The study contains the critical evaluation of the employed method of increasing the genetic variation being the main objective of the research.

### MATERIAL AND METHODS

The research material consisted of generation F<sub>6</sub> of hybrids created as a result of crossing annual pepper (*Capsicum annuum* L.) and chinese pepper (*C. chinense* Jacq.). The research, of which the results are presented in this study, started in 1997 with the crossing of species. Annual pepper, which was employed as a maternal form, was represented by ATZ 1 line with sweet fruit. ATZ 1 line is a registered initial component of heterosis hybrid 'Stanola F<sub>1</sub>'. Genotype *C. chinense* Jacq. selected among materials rich in capsaicin which were studied in 1996 was a pollinator. The general characteristics of initial forms are given in Table 1. In 1998 the evaluation of hybrids F<sub>1</sub> was carried out and starting from the next vegetative period, an individual selection with pedigree evaluation oriented on varieties with sweet fruit was carried out. The material subject to research in 2003 was characterized by a high level of balance of phenotypes. Among the genotypes at our disposal for the purposes of this study we chose five genotypes marked with symbols 25, 26, 27, 28 and 31 and analysed them in detail with respect to the volume and quality of yield.

Table 1. General characteristics of hybrids initial forms

Species	Yield of fruit (kg·plant <sup>-1</sup> )	Mean fruit weight (g)	Fruit performance (%)		Wall thickness (mm)
			technological	biological	
<i>C. annuum</i> L. ATZ 1	1.50	105	78	82	4.20
<i>C. chinense</i> Jacq.	0.15	6	80	86	1.10

During each of the seasons of selection the plants were grown under unheated film tents according to the rules governing annual pepper growing with the density of 4 plants per 1 m<sup>2</sup> of the general area. No pesticides were applied. The lines being the subject of this study were represented by 16 plants each. In the previous year (generation F<sub>5</sub>) each of lines was represented by 20 plants. In the Table 2 the range of traits variation of five selected plants each of group this generation were presented. The crop was collected once and the part of commercial yield of ripe fruit was determined. The average weight of the fruit and a level of other features under research were determined on the basis of three consecutive measurements of 10 fruit each, in accordance with the instructions contained in Descriptors for *Capsicum* (1995). A technological weight of the fruit was assumed as part of pericarp obtained according to the rules of the process of processing in the weight of the whole fruit. A biological weight was understood as the edible part in the weight of the whole fruit. The thickness of a pericarp of the fruit was presented as the mean of the three measurements carried out in the part of, apex middle and stem. The obtained results were subject to statistical analysis. The value of significant difference was determined by means of Tukey's test with P = 95%. As shown in the figures the data marked with the same letter symbols were statistically similar.

## RESULTS AND DISCUSSION

In practice two methods may be applied to expand the useful biological diversity. One of them is selection within populations of new and unknown plants. The other is a selection of hybrid materials created as a result of crossing wild and cultivated forms or species. This solution is more effective with regard to the higher biological level of cultivated varieties and thus it is easier to obtain materials useful in practice. However, the basic condition must be fulfilled and it is that of a lack of obstacles of prezygotic and postzygotic nature found in remote crossing. The condition in question was fulfilled for the species used by us. It was possible to obtain not only hybrid F<sub>1</sub> seeds (Nowaczyk & Olszewska 1999) but facilitated the selection among highly fertile offspring. The selection made it possible to obtain interesting hybrids. It is worth noting that the lines under research in 2003 were homozygous in a high degree. They presented such a level of uniformity as is indispensable in the procedure of registration of cultivars.

As it was stressed in the previous chapter the discussion about the volume of yield was limited to the ripe fruit of the commercial yield. It was diversified and attained a maximum level in line No 26 (Table 2). The yield derived from cultivations of breeding character carried out without pesticides. It was assumed that new cultivated varieties, which can be the result of the research carried out, would be created in the conditions as close to ecology as possible and adjusted to the production in such conditions. From such a perspective, the volume of yield being over 5 kg of ripe fruit per 1 m<sup>2</sup> can be regarded as interesting from the practical point of view. In experiments carried out by Sunil & Rasheed (1998) the interspecific hybrids of *C. annuum* L. and *C. chinense*

Jacq., characterized by the yield about 0.2 kg per plant, were recognized as the most promising as a source of colour for improving the chilli cultivars.

Table 2. The yield traits of F<sub>5</sub> and F<sub>6</sub> generation of hybrids

Traits	Genotypes				
	25	26	27	28	31
Mature fruit yield in kg·m <sup>-2</sup>					
2002	4.98-5.40	5.75-6.20	4.83-5.57	4.92-5.25	3.72-4.35
2003	5.22 a	6.48 b	5.49 ab	5.31 a	4.66 a
Mean fruit weight (g)					
2002	122-137	20-25	58-70	88-105	29-33
2003	130 d	25 a	72 b	98 c	31 a
Technological performance of fruit (%)					
2002	79-82	88-90	82-87	86-90	70-76
2003	82 b	91 d	86 c	89 cd	78 a
Biological performance of fruit (%)					
2002	87-91	90-95	87-90	87-90	83-87
2003	90 b	95 c	91 b	92 b	85 a
Wall thickness (mm)					
2002	4.02-4.66	4.10-5.05	4.70-5.35	4.78-6.50	4.00-4.82
2003	4.51 a	4.93 ab	5.40 b	6.66 c	4.46 a
Seed weight per fruit (g)					
2002	1.96-2.60	0.49-0.72	1.10-1.53	0.91-1.38	1.50-2.05
2003	3.42 a	0.63 a	2.10 a	1.28 a	1.65 a

The result of the selection was to obtain lines showing considerable differences in fruit weight (Table 2). The fruits were especially large in the line No 25. The fruit with large weight, and as a consequence, big size have the greatest market value. However, there are no clear-cut requirements with regard to this. Fruit with a mass of a few grams can also be found in the world market. Each of the potential solutions can be justified by the necessity to diversify offers in the market. Even the tiniest fruit cultivars can be marketable, especially if they differ in the contents of capsaicin which determines the level of spiciness.

Technological performance fluctuating in the tested lines within a wide range (Table 2) is undoubtedly the most objective criterion of fruit evaluation. The line No 26 was confirmed to have the highest level of technological performance. Obtaining raw material in typical conditions for a technological process is always connected with some loss of the edible part. The smaller parts of the placenta with seeds, the smaller are the edible parts. They also depend on the shape and size of fruit. A similar diversification also related to biological performance. In three of the lines tested it exceeded 90% (Table 2). Genotype No 26 particularly stands out in the lines. In the research and breeding works (Nowaczyk & Nowaczyk 2001) which have been carried out so far, the maximum biological yield was as high as 90%. The genotype obtained can thus be regarded as a new step on the way of biological progress. It is worth noting

that the difference in relation to the yield observed in commercial hybrids (Cebula 1989) is as big as the one tenth of the net yield. The maximum share of the edible part of fruit weight did not exceed the level of 86% also in spicy forms and varieties (Wang & Wang 1996). It was very interesting that the highest level of biological performance was accompanied by the lowest seed weighting fruit.

A very valuable selective criterion, which can be especially decisive with respect to the selection, is the thickness of pericarp. It is regarded as an especially important quality. The analysis of data presented in Table 2 makes it possible to carry out a clear-cut selection of materials which fulfil the basic requirements. The lines numbered as 26, 27 and 28 can be the subject of further breeding works as cultivars or as initial components of the hybrids. The high heterosis effects observed in *C. chinense* Jacq. (Sousa & Maluf 2000) let to expect the good combining ability of the lines selected out of interspecific hybrids. The other potential is contingent upon the selection of the other parental partner.

### CONCLUSION

The selection within of interspecific hybrids *C. annuum* L. x *C. chinense* Jacq. resulted of obtaining the homozygous lines characterized with good quality of fruits particularly of high technological and biological performance.

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CHARAKTERYSTYKA TECHNOLOGICZNA LINII  
WYSELEKJONOWANYCH Z MIĘDZYGATUNKOWYCH MIESZAŃCÓW  
*CAPSICUM ANNUUM* L. i *CAPSICUM CHINENSE* JACQ.

Streszczenie

Materiałem badawczym było pokolenie F<sub>6</sub> międzygatunkowych mieszańców między papryką roczną (*Capsicum annuum* L.) i papryką chińską (*C. chinense* Jacq.). Oceniane linie wykazywały wysoki poziom homozygotyczności. Wielkość plonu handlowego owoców dojrzałych wahała się w granicach od 4,66 do 6,48 kg·m<sup>-2</sup>, a średnia masa owocu w granicach od 25 do 130 g. Wydajność technologiczna, rozumiana jako udział owocni pozyskiwanej przy przygotowaniu owoców do konserwowania do masy całego owocu, osiągnęła poziom 91%, a wydajność biologiczna, oznaczająca udział części jadalnej w masie całego owocu, poziom 95%. Maksymalna grubość ścian owocu sięgała poziomu 6,6 mm. Całościowa analiza wartości średnich badanych linii pozwala na wyróżnienie trzech z nich. Wskazano na możliwość ich wykorzystania, jako składników pierwotnych mieszańców F<sub>1</sub>.

## **CHANGES OF MACRO AND MICRONUTRIENTS CONCENTRATIONS IN ROOT MEDIUM AND DRAINAGE WATER DURING TOMATO CULTIVATION IN ROCKWOOL**

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### Summary

The aim of the work conducted in 2002-2003 was monitoring of changes of macro and micronutrients content in nutrient solution, root-zone and drainage water in tomato cultivation in rockwool (Grodan) with nutrient solution recirculation. The changes are described by simple mathematical models useful in development of fertilization program for this kind of culture. The content of the nutrients in root-zone and drainage water during cultivation of tomato was depended on a kind of nutrient and plants growth stage. The highest increase of the content of most nutrients in root-zone and drainage water (except of Na, Cl, and Zn) occurred at peak of yielding during summer months. Nutrient solution in root-zone and drainage water was richer in nutrient elements than the solution supplied to plants. The time course of pH and content of N-NO<sub>3</sub>, P-PO<sub>4</sub>, K, Mn, and Cu ions in the root medium and drainage water were similar and their course did not differ significantly.

key words: rockwool, soilless culture, nutrient solution, tomato

### INTRODUCTION

In the recent years, modern tomato cultures are carried out at medium amount reduced to minimum, most often in rockwool (Sonneveld 1991, Komosa 2002). Such systems require systematic and precise supply of appropriate amounts of nutrient solution with proper composition to the zone of root growth. The role of growing medium is reduced to mechanical holding of the roots and provide proper air-water conditions, conducive to uptake of easily-available nutrients. In the research of Vaughan (1990) it was found that in rockwool only ca. 2% of supplied nutrients may become bound and unavailable. Lack of sorption complex makes necessary to keep proper pH, concentration and proportion of elements in the root-zone (Michałowicz & Nurzyński 2002). Root-zone solution is modified by developing root system, selective ions uptake, varied intensity of nutrients uptake and transpiration as well as by interaction of elements in nutrient solutions. The elements which affect each other in combination with pH are mainly phosphorus, calcium, iron and manganese.

Interaction of the other components is insignificant and has no negative effect on their availability and plant nutrition (Kowalczyk 2003). In Poland, greenhouse production of tomato in soilless cultures is almost in 100% carried out in open nutrition systems i.e. where the excess of nutrient solution drained from root-zone is discharged without any control into a ground of the greenhouse (Komosa 2002). In order to maintain set parameters of nutrient solution in cultivation slabs it is necessary to ensure a proper outflow of drainage water (Uronen 1995). The nutrient solution draining from slabs is richer in nutrient elements than the one supplied to plants. From 1 ha tomato culture, at 20% outflow of drainage water, 5 tons of high-quality fertilizers, including microelements mainly in chelated form, are introduced to greenhouse soil and surrounding environments (Benoit & Ceustermans 1995). Insufficient outflow of drainage water results in poor development of root system, as well as improper root respiration. The consequences of bad drainage include also difficulties in control of solution EC in slabs, reduced uptake of nutrient elements and worse plants development (Alarcòn *et al.* 1997).

The aim of the research was to assess the dynamics of changes in macro and microelements content in the nutrient solution supplied to plants, root-zone (slabs) and in the drainage water and their description by simple mathematical models useful in development of fertilization program for tomato plants grown in rockwool (Grodan) with nutrient solution recirculation.

#### MATERIAL AND METHODS

The experiments were carried out in the years 2002-2003, in the greenhouse of Research Institute of Vegetable Crops in Skierniewice. A system of collecting and redistribution of nutrient solution was created. Cultivation slabs of rockwool from Grodan company, size 1.0 x 0.2 x 0.075 m, were placed in metal gutters mounted with 1% slope in the greenhouse. Excess nutrient solution draining from the slabs by the system of cultivation and collection gutters was collected in 300 dm<sup>3</sup> tank. From this tank the solution was pumped to a measurement tank, where amount of drainage water was measured daily and samples for analysis were taken at weekly intervals. In cultivation gutters, the slabs were placed in poly-bags, cut slantwise at the bottom up to 2 cm high in order to drain the surplus of nutrient solution. Prior to planting, the rockwool slabs were soaked with nutrient solution at pH = 5.3 and EC = 3.0 mS·cm<sup>-1</sup>. Since planting, a systematic drip-fertigation was applied accordingly to climatic conditions and plant growth stage. Standard concentrations of nutrients were used: N-NO<sub>3</sub> - 220, P - 60, K - 320, Ca - 210, Mg - 60, Fe - 2.1, Mn - 0.8, Cu - 0.15, Zn - 1.9, B - 0.3, Mo - 0.07 mg·dm<sup>-3</sup>. The nutrient solution was prepared on the base of fertilizers N:P:K:Mg - 9:4.5:30:3.5, N:P:K:Mg - 10:4:25:4.4, microelement solution contained: Fe - 1.42%, Mn - 0.54%, Cu - 0.1%, B - 0.20%, Mo - 0.03%, chelated iron 2.7%, calcium nitrate, potassium sulfate, magnesium sulfate and nitric acid. Irrigation water contained: HCO<sub>3</sub> - 349, N-NO<sub>3</sub> - 0.25, N-NH<sub>4</sub> - 0.05, P - 0.05, K - 2.72, Ca - 101, Mg - 15.0, Na - 10.5, Cl - 12.9, S-SO<sub>4</sub> - 33.5, Fe - 0.042, Mn - 0.022, Cu - 0.020, Zn - 1.680, B - 0.025 mg·dm<sup>-3</sup>, EC - 0.56 mS·cm<sup>-1</sup>,

pH - 7.2, total hardness 17.6°dH. Total consumption of nutrient solution per one plant was 365 dm<sup>3</sup>, and outflow of the drainage water was 110 dm<sup>3</sup> (i.e. 30%). The experiment consisted of 74 plants planted in the beginning of April and grown until 15<sup>th</sup> of October. Tomato plants cv. Raissa F<sub>1</sub> were planted at the density of 2.8 plant per m<sup>2</sup>.

Chemical analysis of the water sampled from drippers, cultivation slabs and drainage water were conducted once a week in four replications. Nutrient solution from slabs was sampled with a syringe from 10 places between two plants, from the middle layer of the slab, half an hour after the second irrigation cycle.

Mineral components were measured with the following methods: N-NO<sub>3</sub>, P-PO<sub>4</sub> – colorimetrically with flow-autoanalyzer Sanplus (Skalar); K, Ca, Na, Mg, Mn, Zn, Cu, B – with plasma spectrometer ICP, Atom Scan (Thermo Jarrel Ash); Cl<sup>-</sup> - potentiometrically with ion-selective electrode; SO<sub>4</sub> – colorimetrically with BaCl<sub>2</sub>; EC – conductometrically directly in nutrient solution; pH – potentiometrically.

Changes in the concentrations of elements, pH and content of elements in nutrient solution supplied to the plants, in slabs and drainage water were compared basing on correlation analysis as well as linear and parabolic regression.

## RESULTS AND DISCUSSION

For proper plant nutrition an analysis of the elements content in nutrient solution supplied to plants, in root-zone and drainage water drained from slabs is necessary. The results of chemical analysis of solutions sampled from drippers, root-zone and drainage water are shown in Figures 1–15 (averages from two years). It was found that nutrient solution in root zone and drainage water was richer in the elements than the solution supplied to the plants. These findings agree with the data presented by Komosa & Olech (1996 a, b) and Alarcón *et al.* (1997). In inert media proper uptake of nutrients is related to the proper pH of the solution. Nutrient solution for fertigation of tomato should have pH 5.5–5.8. Weekly chemical analysis revealed that pH root zone changed during cultivation. Course of pH is showed in the Fig. 1. Dynamics of these changes were described by parabolic regression and presented in figures as mathematical functions. The pH of root zone (slabs) and drainage water did not differ significantly, and therefore it was presented as one regression curve. The regression proved significant dependence ( $P=0.01$ ) the of root-zone pH and drainage water on the growth stage of the plants. During the initial period of the cultivation (first 6 weeks) as well as during the final one (15–17 week of cultivation) the solution in slabs and drainage water became alkalinized. In contrast, during peak of yielding the pH of solution in slabs and drainage water was similar to pH of nutrient solution supplied to the plants. Increase in pH of solution in cultivation slabs of rockwool were observed also in other studies (Komosa & Olech 1996 a, Michajłójć & Nurzyński 2002, Kowalczyk 2003).

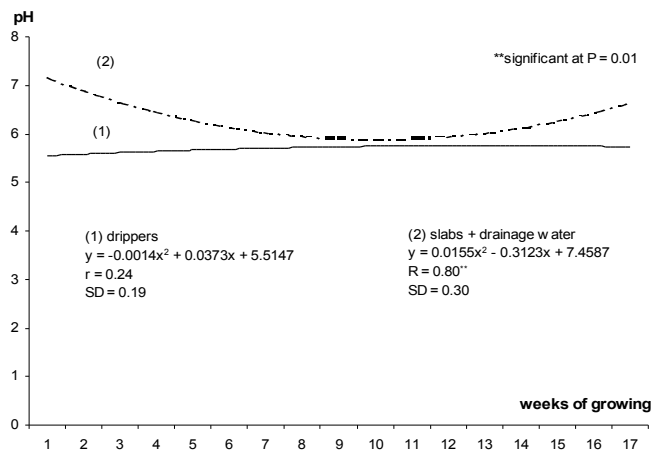


Fig. 1. Course of pH changes in the nutrient solution collected from drippers, root medium and drainage water

Electrical conductivity (EC) is a basic physical indicator of concentration of all mineral components of nutrient solution. The nutrient solution supplied to plants had stable EC value, ranged from 2.8 to 3.0  $\text{mS}\cdot\text{cm}^{-1}$ , during entire cultivation period. The highest concentration of nutrients occurred in root-zone and was slightly lower in drainage water. Course of EC changes during cultivation of tomato plants is presented in the Fig. 2. Until the 10<sup>th</sup> week of cultivation the concentration of nutrients in root-medium and drainage water increased and in the following weeks it decreased till the end of the cultivation. EC values in the slabs and drainage water were similar. Courses of these values were described by two parabolas shifted by 0.5  $\text{mS}\cdot\text{cm}^{-1}$ . These curves had significant correlation coefficients, at 5% confidence interval for root-zone and at 1% confidence interval for the drainage water. A increase the nutrients concentration in the slabs and drainage water resulted from increased water transpiration of plants during summer months, with good light and temperature conditions, and selective ions uptake.

Course of  $\text{N-NO}_3^-$  concentration in monitored solutions is presented in the Fig. 3. The nutrient solution supplied to the plants contained from 220 mg  $\text{N-NO}_3^-$  to 300 mg  $\text{N-NO}_3^-$ . During the initial period of cultivation, at vegetative growth of the plants the solution with increased nitrogen content was used, while during generative phase  $\text{N-NO}_3^-$  content was reduced. Changes of nitrogen content in the solution supplied to the plants depending on cultivation period, were described by linear regression, significant at  $P=0.01$ . Course of  $\text{N-NO}_3^-$  content in root-zone and drainage water was similar to the course of EC level. Similar as EC, the highest  $\text{N-NO}_3^-$  content in the slabs and drainage water was noted during 9–11 cultivation weeks. Dependence of

N-NO<sub>3</sub><sup>-</sup> concentration on cultivation period was described by parabolic regressions which did not differ significantly.

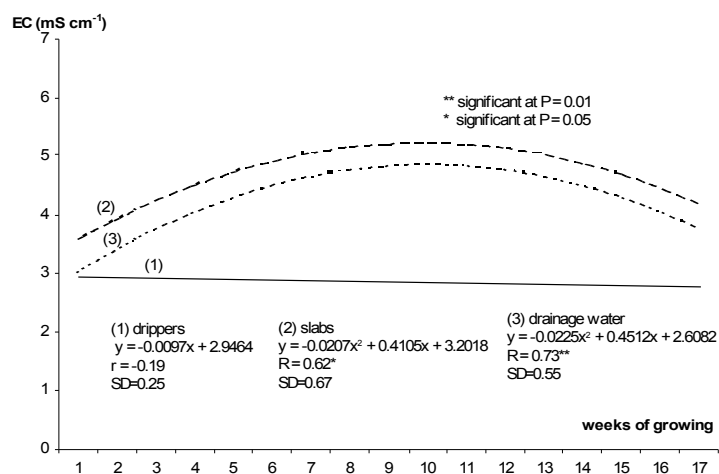


Fig. 2. Electrical conductivity (EC) of the nutrient solution collected from drippers, root medium and drainage water

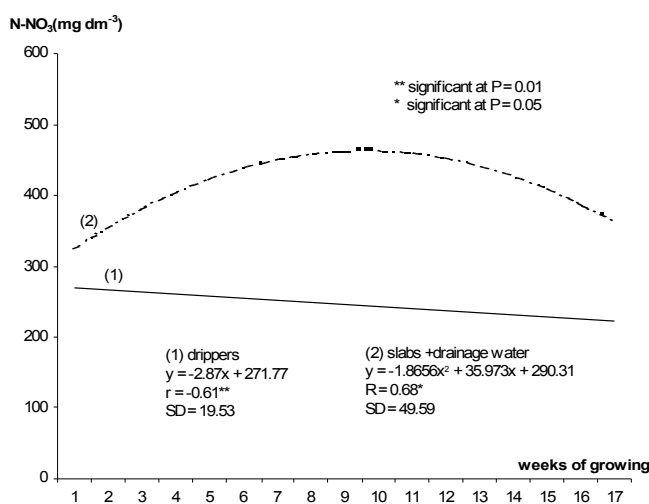


Fig. 3. Course of changes of N-NO<sub>3</sub> content in the nutrient solution collected from drippers, root medium and drainage water

Concentration of phosphorus in supplied solution was at the same level ( $60 \text{ mg P-PO}_4\cdot\text{dm}^{-3}$ ), for the entire cultivation period (Fig. 4). A content of available P in the root-zone and drainage water was closely correlated with pH of the solution. During the first three weeks of cultivation, P content in slabs and drainage water was lower than in the solution supplied to the plants and in the first week it was only  $20 \text{ mg P-PO}_4\cdot\text{dm}^{-3}$  i.e. at the minimal level for tomato. The pH of solution sampled at that time from slabs and drainage water was above the optimum and exceeded  $\text{pH} = 7.0$ , similarly as in the experiments of Michałojć & Nurzyński (2002) and Kowalczyk (2003). Starting from the 4<sup>th</sup> week of cultivation, P content in the root-zone and drainage water began to increase. The highest P level in the root-zone and drainage water occurred between the week 9 and 13. Course of P content in the slabs and drainage water was statistically identical and is presented by one regression curve of the second degree. In the research of Komosa & Olech (1996 a) pH was between 7.0 and 7.5 at a low content of phosphorus in the root-zone (below  $20 \text{ mg P-PO}_4\cdot\text{dm}^{-3}$ ).

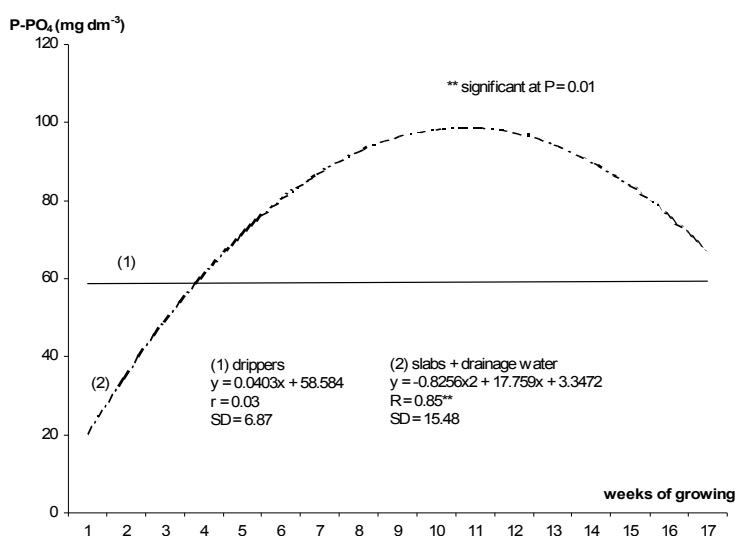


Fig. 4. Course of changes of  $\text{P-PO}_4$  content in the nutrient solution collected from drippers, root medium and drainage water

Demand of plants due to potassium varied during cultivation (Fig. 5). Concentration of K in the solution supplied to the plants ranged from  $250$  to  $400 \text{ mg K}\cdot\text{dm}^{-3}$ . Potassium content in root-zone and drainage water showed an upward trend. During initial period of the cultivation, during the first two weeks, the level of K ions, noted in the slabs and drainage water was lower than in the used solution. The highest concentration of available K in the slabs and drainage water was occurred during summer months (weeks 10–15). Courses of K concentration in both media were similar and they were described by parabolic curves which did not differ signi-

ificantly. According to Alarcón *et al.* (1997), K content in the root-zone and drainage water increased and reached maximum on 120<sup>th</sup> day of tomato cultivation.

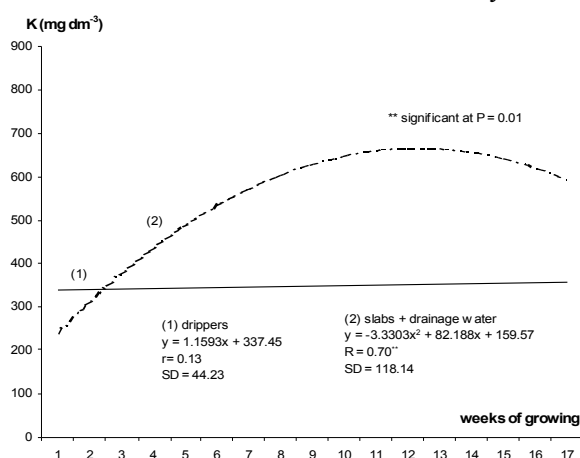


Fig. 5. Course of changes of K content in the nutrient solution collected from drippers, root medium and drainage water

A trend of Ca concentration in the solution, root-zone and drainage water is presented in the Fig. 6. Course of Ca concentration in drainage water can be described by parabolic curve with highly significant ( $P=0.01$ ). In the slabs this course was also described by parabolic curve but shifted to higher values on an average 70  $\text{mg Ca}\cdot\text{dm}^{-3}$ . Course of Ca concentration in the slabs was not proven statistically.

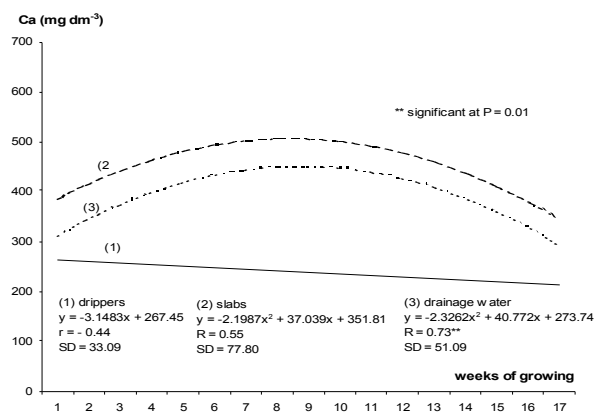


Fig. 6. Course of changes of Ca content in the nutrient solution collected from drippers, root medium and drainage water



Concentration of Mg had similar course to the trend of Ca content (Fig. 7). The lowest level of this element was in the solution supplied to the plants, higher in drainage waters and the highest in the slabs. The highest content of Mg in the root-zone and drainage water was noted during peak of yielding, and thus during the highest absorption of the solution by plants. Changes of Mg content in the slabs and drainage water can be described by two parallel parabolas, one shifted from another by the value of 40 mg Mg·dm<sup>-3</sup>. Similar to the trend of Ca concentration, the significance of regression of Mg concentration changes in time was not proven for the root-zone, while for the drainage water the regression was significant at P=0.05.

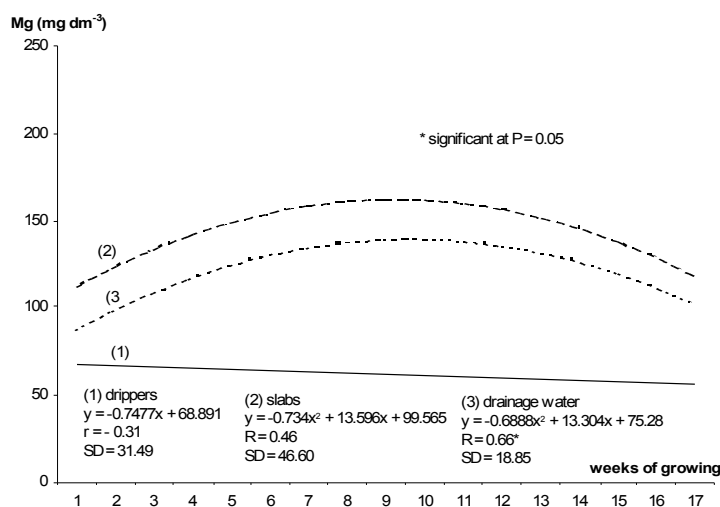


Fig. 7. Course of changes of Mg content in the nutrient solution collected from drippers, root medium and drainage water

During the entire cultivation period, a content of Na in the solution supplied to plants was stable, and it was on average 17 mg Na·dm<sup>-3</sup> (Fig. 8). Also in drainage water Na level was similar during the whole experiment, on an average 37 mg Na·dm<sup>-3</sup>. In the root-zone Na concentration was the highest at the beginning of the cultivation (ca. 50 mg Na·dm<sup>-3</sup>) and showed the downward trend in course of time. However, no significant changes in Na content were proven. A little amount of Na is taken by plants and therefore concentration of this element in the root-zone was very high (264% as compared to the supplied solution). Due to the extent of concentration increase, some authors see Na as a factor limiting the use of nutrient solution in recirculation system (Breš 2002, Sonneveld 1991).

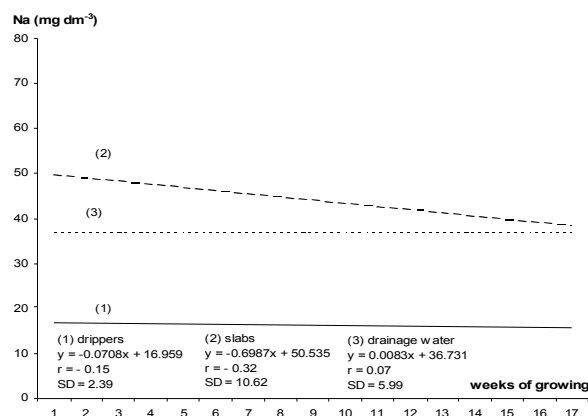


Fig. 8. Course of changes of Na content in the nutrient solution collected from drippers, root medium and drainage water

Chloride was not added to nutrient solution. Its content in tested solutions, resulted from its presence in water used for irrigation. Moreover amounts of Cl might contaminated the fertilizers used in hydroponic cultures. Cl content in the solution supplied to plants was the lowest at the beginning of the culture and increased linearly during the experiments. In the initial period of the cultivation Cl concentration in the slabs and drainage water was lower then its content in supplied solution. After 10 weeks, Cl concentration in the root-zone was higher.

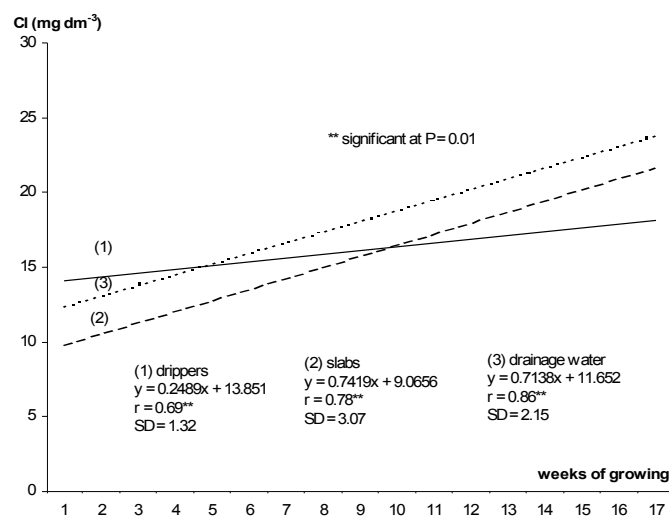


Fig. 9. Course of changes of Cl content in the nutrient solution collected from drippers, root medium and drainage water

Concentration of Cl in the slabs and solution draining from the slabs is presented in the Fig. 9 as regression lines shifted from each other. Change of the concentration of Cl ions with time was highly significant, as it was showed by high values of obtained correlation coefficients.

Sulfates were introduced with sulfate fertilizers, where they are a carrier of macro and microelements, and a component of water. Content of sulfates in the solution supplied to the plants was at similar level during the entire cultivation period (Fig. 10). Their concentration in the root-zone and drainage water gradually increased during cultivation. However, this increase was not proven statistically. According to Lopez *et al.* (1996) chlorides and sulfates may easily accumulate in the root-zone are reaching toxic contents for plants. In open systems, thanks to solution outflow partial leaching of accumulated ions occurs, including sulfate and chloride anions.

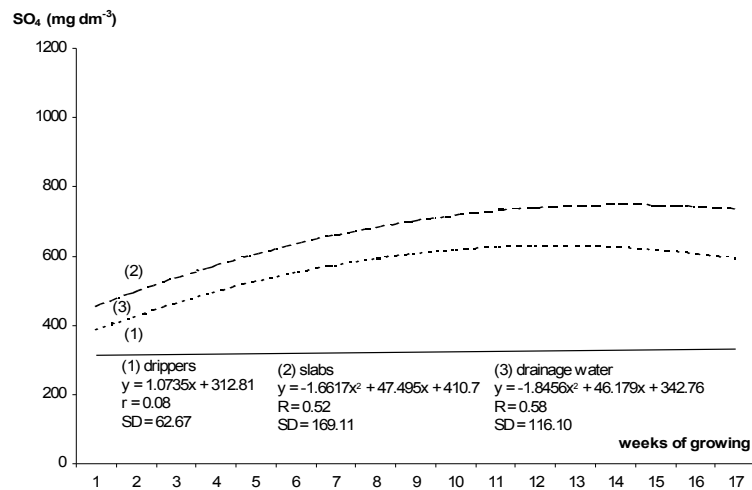


Fig. 10. Course of changes of  $\text{SO}_4$  content in the nutrient solution collected from drippers, root medium and drainage water

Microelements content in tested solutions also varied during tomato cultivation. Course of Fe concentration was similar in all three solutions (from drippers, slabs and drainage water) (Fig. 11). In the first part of cultivation period Fe concentration increased, while in the second part it decreased. The changes can be described with high probability ( $P=0.01$  for drainage water and  $P=0.05$  for supplied solution and slabs) by three parabolic curves, significantly different. Similar changes in Fe content in root-zone were showed by Kowalczyk (2003) in cucumber cultivation at three pH levels (pH 5.0, pH 5.5, pH 6.5).

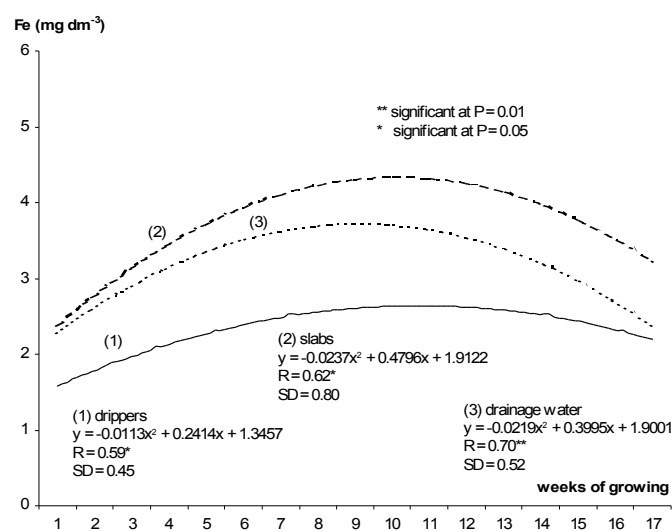


Fig. 11. Course of changes of Fe content in the nutrient solution collected from drippers, root medium and drainage water

Concentration of available forms of manganese in three monitored solutions (from drippers, slabs and drainage water) varied significantly during tomato growth (Fig. 12). Changes of Mn content in the root medium and drainage water are described by parabolic regressions with no significant differences between each other, they were replaced with one curve. During the first 4 weeks of cultivation, Mn content in the root-zone and drainage water was lower than in the supplied solution. After 5 weeks its level was higher and after 13 weeks decreased again. Content of available Mn forms depended on solution pH. It decreased in the periods when higher pH was noted. Sonneveld & Voogt (1980) were observed reduced concentration of Mn in the root-zone of tomato plants grown in closed system at high pH of solution (pH 6.5–7.0). With 2 mg Mn·dm<sup>-3</sup> in supplied solution, at pH 6.5–7.0, they found less than 0.05 mg Mn·dm<sup>-3</sup> in the root – zone, while at pH 5.0–5.5 the concentration of Mn increased to 2.31 mg·dm<sup>-3</sup>.

In the middle of the cultivation period copper content in the root-zone and drainage water was twice as high as in supplied solution (Fig. 13). In that time (week 8 – 9) Cu concentration in the solutions sampled from slabs and drainage water increased and then till the end of the cultivation it decreased. Course of Cu content in the slabs and drainage water did not differ significantly.

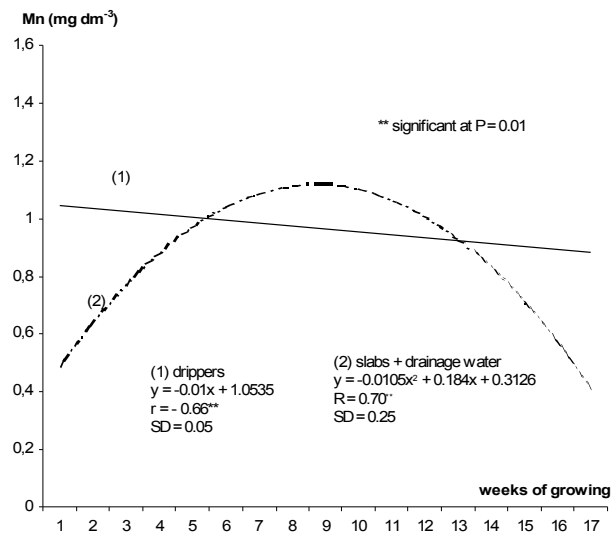


Fig. 12. Course of changes of Mn content in the nutrient solution collected from drippers, root medium and drainage water

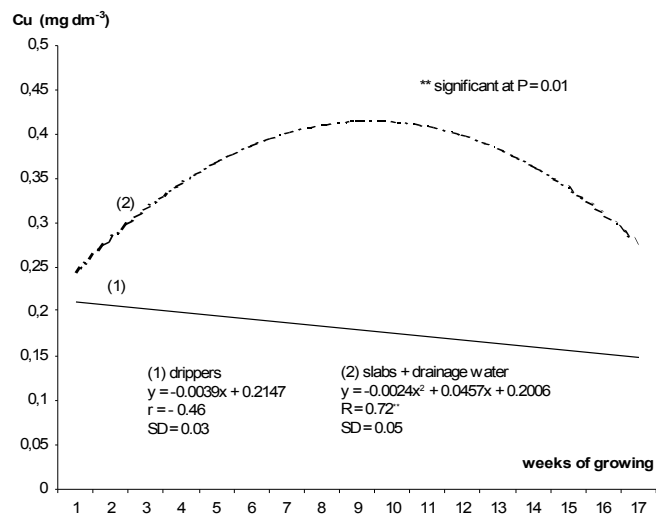


Fig. 13. Course of changes of Cu content in the nutrient solution collected from drippers, root medium and drainage water

High Zn content in supplied solution and changes of its concentration during cultivation resulted from high Zn level in fertigation water. Dynamics of zinc con-

tent in the root-zone and drainage water was described by linear regression and presented in the figures as  $y = ax + b$  lines (Fig. 14). In both, slabs and drainage water the level of Zn was higher at the beginning of the cultivation and it decreased with time. In root-medium it was only a trend and the changes were statistically not significant.

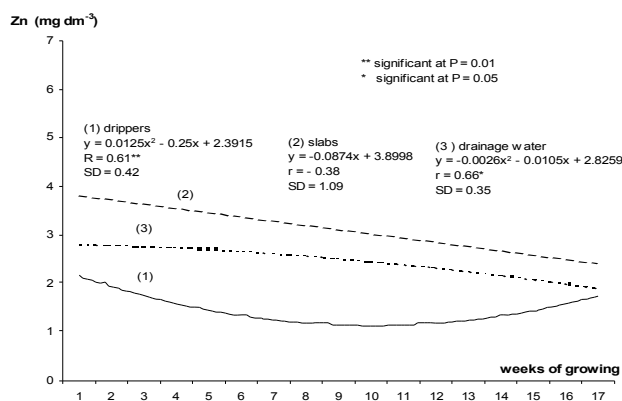


Fig. 14. Course of changes of Zn content in the nutrient solution collected from drippers, root medium and drainage water

Concentration of boron in solutions supplied to the plants was similar during entire cultivation period, and it is presented as a straight line in the Fig. 15. The content of B in the in the root-zone and drainage water are represented by two parallel parabolas.

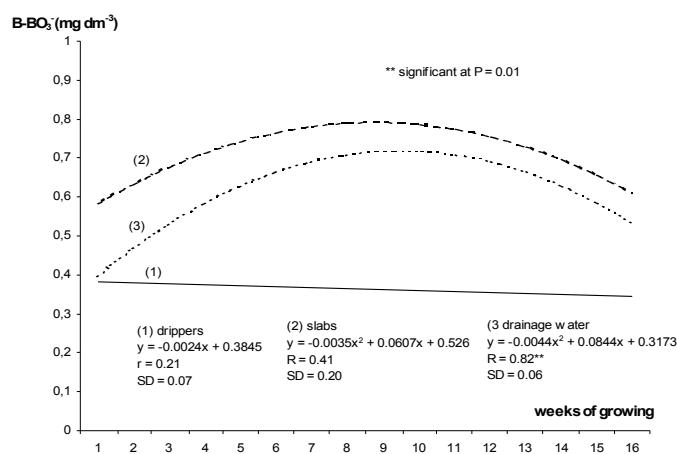


Fig. 15. Course of changes of B-BO<sub>3</sub> content in the nutrient solution collected from drippers, root medium and drainage water

Higher level of B occurred in the root-zone and was slightly lower in drainage water. Boron concentration in drainage water varied significantly during cultivation and was indicated by high correlation coefficient at 1% confidence interval. Content of boron in root-zone changed similarly as in the drainage water but the changes were not significant.

Similar results on microelements were obtained by Komosa & Olech (1996 b) during cultivation of tomato plants in polyurethane foam. In their research, manganese content in the root-zone and drainage water was lower than in the supplied solution, while concentration of iron, zinc and copper was higher in drainage water it was the highest in the slabs.

Root-zone is not an easy environment to describe and to explain precisely the processes that occur in it. This zone as well as absorption of nutrient elements by plants is very dynamically affected by climatic conditions (temperature, humidity, sunlight) and CO<sub>2</sub> content in greenhouse air. A sample of the solution (at the same frequency, composition and dosage of fertigation) may show a great differences in the content of elements as compared to the sample taken at the same time a day before. Concentrations of elements in drainage water is a result of the changes occurring in root-zone and therefore is less variable. The standard aberrations of regression calculated for the majority elements presented in drainage water were low.

#### CONCLUSIONS

1. In closed fertigation system of greenhouse tomato cv. Raissa F<sub>1</sub> grown in rockwool, the concentration levels of elements in the root-zone and drainage water were significantly different and depended on element and plant growth stage.
2. Increase in content of most elements in the root-zone and drainage water (with exception of Na, Cl, and Zn) was strongest during peak of yielding in summer months.
3. The solution in the root-zone and drainage water was richer in nutrients than the solution supplied to the plants.
4. Trends of changes in pH and N-NO<sub>3</sub>, P-PO<sub>4</sub>, K, Mn and Cu content in the root-zone and drainage water were similar and they did not differ significantly.

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#### ZMIANY STEŻEŃ SKŁADNIKÓW POKARMOWYCH W ŚRODOWISKU KORZENIOWYM I WODACH DRENARSKICH W UPRAWIE POMIDORA SZKLARNIOWEGO W WEŁNIE MINERALNEJ

##### Streszczenie

Celem badań przeprowadzonych w latach 2002 – 2003 było określenie zmian zawartości makro i mikrośladników w dostarczanej roślinom pożywce, strefie korzeniowej i wodach drenarskich, opisanie ich za pomocą równań regresji przydatnych do opracowania nawożenia pomidora na wełnie mineralnej (Grodan) w układzie zamkniętym z recyrkulacją pożywki. Przebieg zmian zawartości składników w strefie korzeniowej i w wodach drenarskich w okresie uprawy uzależniony był od rodzaju składnika i fazy wzrostu roślin. Wzrost zawartości większości składników w strefie korzeniowej i wodach drenarskich (z wyjątkiem Na, Cl, i Zn) był największy w okresie intensywnego plonowania. Pożywka w strefie korzeniowej i wodach drenarskich była bardziej zasobna w składniki pokarmowe w porównaniu z pożywką dostarczaną roślinom. Zmiany odczynu oraz zawartości jonów N-NO<sub>3</sub>, P-PO<sub>4</sub>, K,



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Mn i Cu w strefie wzrostu korzeni i wodach drenarskich miały podobny, nie różniący się istotnie przebieg.

## NITROGEN REQUIREMENTS AND FERTILIZATION OF BRUSSELS SPROUTS

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### Summary

Nitrogen requirements of Brussels sprouts were studied in field experiments. In applied nitrogen rates of 100, 200, 400 and 600 kg N ha<sup>-1</sup> the amount of residual nitrogen in the soil layer of 0-60 cm has been included. Nitrogen rates of 200, 400 and 600 kg N ha<sup>-1</sup> were applied either as single preplant only or as a split application, while the rate of 100 kg N ha<sup>-1</sup> as preplant only. The yield, content of nitrate nitrogen in the soil and plant tissue (leaf petioles) in different stages of Brussels sprout growth were recorded. Content of nitrate nitrogen in leaf petioles increased due to increase of nitrogen rates and decreased along with plant age. The growth stage called stem formation was better time for determination the range of N-NO<sub>3</sub> content in petioles than phase of sprouts setting. The optimum range of this nutrient was 1.09-3.34% d.w. for single preplant fertilization and 0.90-2.35% for split application. Optimum range of nitrate nitrogen content in the soil amounted to 51-78 mg L<sup>-1</sup> for preplant fertilization. For split application only the upper limit of the optimum range was lower – 71 mg L<sup>-1</sup>.

key words: Brussels sprouts, nitrogen requirements, fertilization

### INTRODUCTION

Nutrition requirements of Brussels sprouts, described as an amount of nutrients actually taken up during vegetation period, are high due to large biomass production. Inadequate fertilization for nutrient requirements of Brussels sprouts may result in yield decrease or, in the case of over-fertilization, excessive growth of vegetative organs, delay in sprouts development and losses of nutrient elements due to leaching.

According to Sady (2000) to produce average marketable yield Brussels sprouts take from the soil, on average, 423 kg N, 60 kg P, 460 kg K and 22 kg Mg per 1 ha. As reported Kołota & Biesiada (1990) nitrogen rate increase, irrespectively of the form of this element, strongly stimulated its intake both during the phase of intensive vegetative growth and in the initial phase of sprouts setting. If fertilization is adequate for plants requirements, Brussels sprouts take nitrogen from the soil in a relatively short period (from June to mid-August).

Brussels sprouts leave soil depleted from nitrogen reserves, though considerable amount of this element is left in plants residues. At the fertilization rate of 300 kg N ha<sup>-1</sup> ca. 200 kg N per ha was contained in crop residues (Booij *et al.* 1993). Nitrogen amount left in the field as plants residues grows with increasing nitrogen fertilization, due to greater plant weight and higher nitrogen content in plants (Neeteson *et al.* 2003). Fink & Scharpf (1993) showed that amount of mineral nitrogen left in the soil after cultivation of vegetables depends on plant species and fertilization applied, ranging from 50 to 850 kg N ha<sup>-1</sup>. On average, at planting time 30-60 kg N ha<sup>-1</sup> is found in soil which makes 10-20% of total nitrogen fertilization recommended for cole crops (Everaarts 1993). Significant reduction of nitrogen amount left in the soil after cultivation period occurs when residual nitrogen, available in spring in the soil, is included in calculation of fertilization rate (Hähndel & Iserman 1993)

Nowosielski (1988) suggests that pre-plant fertilization rate can be precisely calculated based on soil content of available nitrogen. In his opinion, soil content of 50-120 mg N-NO<sub>3</sub> per 1 L of soil is satisfactory. According to Sady (2000), standard soil content of available nitrogen before planting of Brussels sprouts is 105-120 mg N L<sup>-1</sup>.

Nutrient status of plants is assessed by content of both total and nitrate nitrogen. As indicator parts, leaf petioles, veins or entire healthy, the youngest but fully developed leaves from the middle of stem are sampled (Biernacki *et al.* 1995). Kołota & Biesiada (1990) reported that optimal yield of Brussels sprouts was correlated with N-NO<sub>3</sub> content in indicator parts in the range of 18000-18400 mg·kg<sup>-1</sup> (i.e. 1.80-1.84% d.w. – author's note) during intensive growth of plants and 4600-5300 mg·kg<sup>-1</sup> (0.46-0.53% d.w. – author's note) at the beginning of sprouts setting. Booij *et al.* (1996) obtained maximal dry matter yield of Brussels sprouts when total nitrogen content in plants was between 2.8 and 3.1% d.w. Minimal nitrogen content which enabled further growth of plants was 1.2-1.5% d.w.

The results published in literature are not consistent as to the usefulness and efficiency of split application of nitrogen fertilizers (preplant and top dressing) in cultivation of cole crops (Tremblay *et al.* 2001). Some authors stress positive effect of top dressing fertilization on yield of Brussels sprouts (Neuvel 1990) while others did not obtain such result (Burghardt & Ellering 1987).

The objective of the experiment was to determine optimal range of N-NO<sub>3</sub> content in the soil and plant tissue securing satisfactory yield of Brussels sprouts and establish the most suitable phase of plant development for diagnostic purposes in which correction of fertilization will be still effective.

## MATERIAL AND METHODS

The experiments were carried out in Institute of Vegetable Crops in Skierniewice during 1992-1994, on sandy loam soil with 1.2-1.3% of organic matter content and pH ca. 6.5. Brussels sprouts was grown from transplants produced in seedling bed. Transplants were planted to the field in the end of May at the density

of 33 000 of plants per 1 hectare. Plot area was 10 m<sup>2</sup>. Fertilization was based on chemical analysis of soil. Soil nutrient content was supplemented to 100 mg P and 200 mg K per 1 L of soil. Nitrogen fertilization was one of the experimental factors. The experiment was laid out in two-factorial split-plot design with 3 replicates. It encompassed nitrogen fertilization level and method of its application as well as two cultivars - an early Ottoline F<sub>1</sub> (Huizer) and late Adonis F<sub>1</sub> (S&G).

The nitrogen rates applied in the experiment 100, 200, 400, and 600 kg N·ha<sup>-1</sup> included nitrate nitrogen (N-NO<sub>3</sub>) present in soil layer of 0-60 cm in spring. The nitrogen necessary to reach the level of 100 kg N·ha<sup>-1</sup> was given only as preplant application, while the levels of 200, 400 and 600 kg N·ha<sup>-1</sup> were reached either by single preplant or split application. In split application 100 kg N·ha<sup>-1</sup> was given as top dressing at the beginning of sprouts setting. The mentioned treatments for nitrogen fertilization are presented in the Table 1.

Table 1. Rates and method of nitrogen fertilization and treatment codes

Rate and method of nitrogen fertilization	Treatment code
1. 100 kg N·ha <sup>-1</sup> preplant	(100)
2. 200 kg N·ha <sup>-1</sup> preplant	(200)
3. 100 kg N·ha <sup>-1</sup> preplant + 100 kg N·ha <sup>-1</sup> top dressing	(100 + 100)
4. 400 kg N·ha <sup>-1</sup> preplant	(400)
5. 300 kg N·ha <sup>-1</sup> preplant + 100 kg N·ha <sup>-1</sup> top dressing	(300 + 100)
6. 600 kg N·ha <sup>-1</sup> preplant	(600)
7. 500 kg N·ha <sup>-1</sup> preplant + 100 kg N·ha <sup>-1</sup> top dressing	(500 + 100)

For preplant fertilization urea was used while top dressing was done with ammonium nitrate. During drought periods, crop was irrigated after seedlings planting and at the stage of sprouts setting. Single harvest was performed when sprouts reached proper maturity. Entire plants were cut off, taken from a field and sprouts were picked manually. The early cultivar Ottoline F<sub>1</sub> was harvested at the end of October or beginning of November while mid-late Adonis F<sub>1</sub> on the beginning of December. For each plot, total yield, processing yield (sprouts with ø 15-30 mm), yield of large sprouts (ø >30 mm), small sprouts (ø <15 mm) and yield of unmarketable sprouts (loose, soft, injured by diseases or pests) was recorded. During vegetation period samples of soil and plant material were taken for chemical analysis (Table 2).

Table 2. Dates of sampling of soil and plant material for chemical analysis

Period of sampling	Date of sampling
Preplant (soil only)	1 <sup>st</sup> decade of May
(FI) – Stage of stem growth (period of intensive vegetative growth and stem formation). Before top dressing.	3 <sup>rd</sup> decade of July
(FII) – Stage of sprouts setting (initial phase of sprouts setting, sprouts in the lower part of stem with dia. 5-10 mm)	1 <sup>st</sup> decade of September
(FIII) – Harvest time: early cultivar	3 <sup>rd</sup> decade of October – beginning of November
mid-late cultivar	3 <sup>rd</sup> decade of November – beginning of December
After harvest (soil only)	End of November – beginning of December

Soil for analysis was sampled from two layers of soil profile 0-20 cm and 20-60 cm. Chemical analysis of plant material were conducted on indicatory parts (petioles of healthy fully developed leaves in the middle of stem) and sprouts (from the fraction of 20-30 mm in diameter). To assess nutrient status of soil and plant material Universal method was used (extraction of soil with 0.03 N acetic acid and of plant material with 2% acetic acid). Nitrogen content in soil samples was measured by potentiometric method with ion-selective electrode while in plant samples by emission spectrometry with argon plasma.

The data on yield and nutrient content were subjected to analysis of variance. The means were compared with Newman-Keul's test at  $P=0.05$ . Correlation analysis was used to evaluate the relationship between compared parameters. The correlation was regarded significant when significance coefficient ( $p$ ) was equal or lower than 0.01.

## RESULTS AND DISCUSSION

The experimental factors tested in the research (level of nitrogen fertilization and cultivar) affected growth and yielding of plants and quality parameters of sprouts. These aspects were already published (Babik *et al.* 1996).

### Nitrate nitrogen soil content and nitrogen fertilization level

Depending on a forecrop and previous nitrogen fertilization  $N-NO_3$  present in the soil layer of 0-60 cm varied in different years (Fig. 1). After two-year leek cultivation, amount of nitrate nitrogen in the soil in spring, before Brussels sprouts cultivation, was the highest ( $147 \text{ kg N ha}^{-1}$ ), what confirms the results of Booij *et al.* (1993), Van der Werf *et al.* (1996) and Smit *et al.* (1995) who classify leek as a plant leaving high amounts of nitrogen in soil. After Brussels sprouts and following it buckwheat cultivation, amount of nitrate nitrogen in soil was the lowest ( $46 \text{ kg}$

$\text{N ha}^{-1}$ ) as, according to Fink & Sharpf (1993), Booij *et al.* (1996), Brussels sprouts use up all available nitrogen in soil in relatively short time. It is regarded as a plant strongly depleting soil nitrogen reserves but at the same time leaving large amounts of this element in crop residues (Booij *et al.* 1993). In the presented experiments, Brussels sprouts cultivation did not increase mineral N content in soil because entire plants were cut out and removed from the plots. Nitrate nitrogen content in deeper soil layer (20-60 cm) was two to five times higher than in upper soil layer (0-20 cm) (Fig. 1). Including nitrate nitrogen present in 0-60 cm soil layer into fertilization program allowed for a reduction of nitrogen supplied with fertilizers by 8-32%. This fertilization method is believed to be the most economic and environment-friendly (Händel & Iserman 1993, Booij *et al.* 1993).

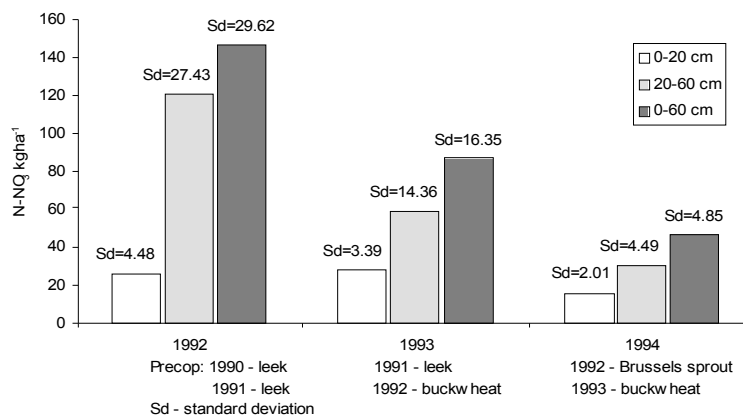


Fig.1. Average content of nitrate nitrogen in soil profile (0-60 cm) in spring, before Brussels sprouts planting

Nitrate nitrogen content in the soil increased with increasing nitrogen rates in all growth stages of plants. On average, during three years of experiments,  $\text{N-NO}_3$  content in soil at the stage of stem growth (F I) varied from  $26.1 \text{ mg L}^{-1}$  with the lowest level of nitrogen fertilization ( $100 \text{ kg N ha}^{-1}$ ) to  $80.2 \text{ mg L}^{-1}$  for the highest fertilization ( $600 \text{ kg N ha}^{-1}$ ). At the stage of sprouts setting (F II)  $\text{N-NO}_3$  content in the soil strongly decreased with single pre-plant application of nitrogen and the decrease was stronger the higher nitrogen rates applied. With split application, significant effect of top dressing applied in August was visible in this stage of plant growth, as higher content of  $\text{N-NO}_3$  in soil was observed compare to previous stage (F I). In the final stage of plant growth i.e. during harvest (F III) nitrate nitrogen content decreased further, irrespectively of nitrogen fertilization method, and ranged from  $19.5 \text{ mg L}^{-1}$  at the lowest nitrogen dose ( $100 \text{ kg N ha}^{-1}$ ) up to  $49.6$  at the

highest rate of nitrogen fertilization (600 kg N ha<sup>-1</sup>). At this stage the N content was still slightly higher after split application (Fig. 2).

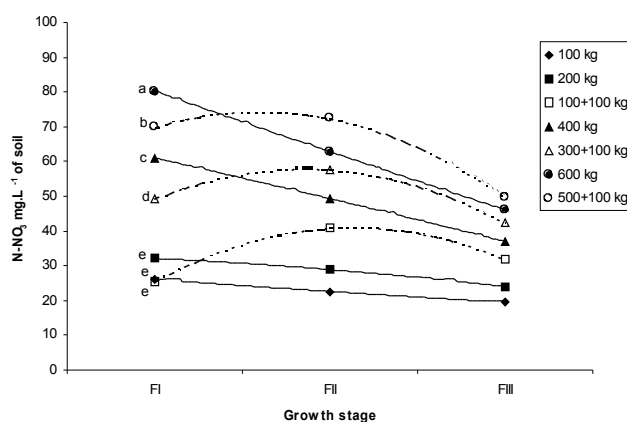
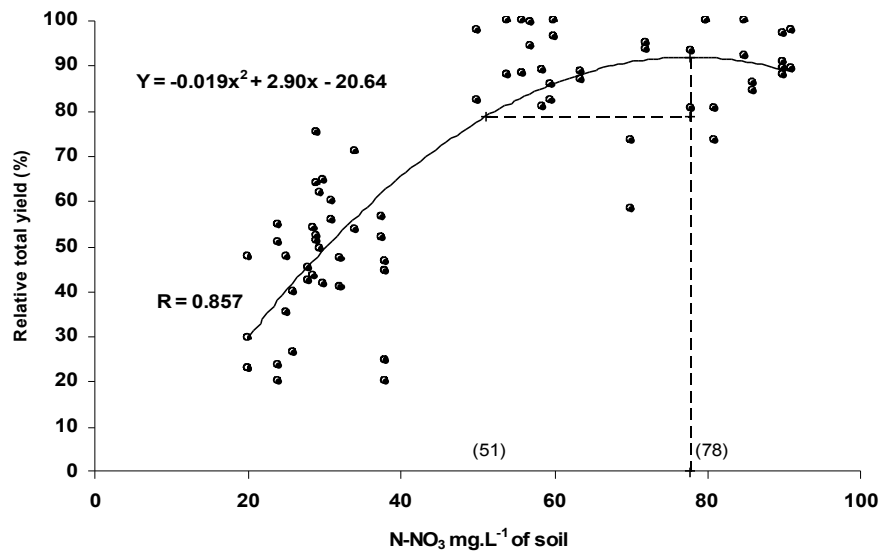


Fig. 2. The influence of nitrogen fertilization on nitrate nitrogen content in soil (0-20 cm) in different stages of Brussels sprouts growth (N-NO<sub>3</sub> in mgL<sup>-1</sup> of soil)

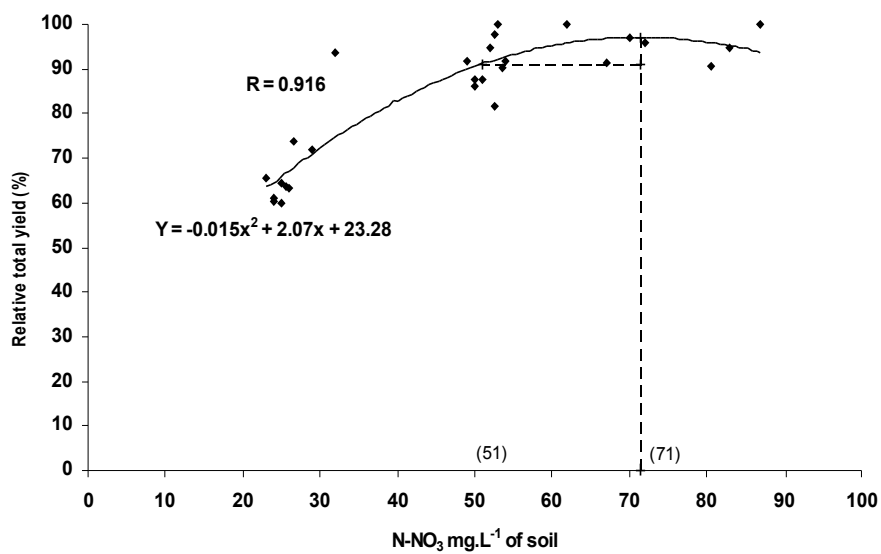
(For explanation of growth stages see Table 2)

Nitrogen fertilization had considerable effect on mineral nitrogen content in soil during stem growth stage and therefore for this stage of plant growth correlation between yield and nitrate nitrogen content in soil was assessed. This relationship was established separately for single pre-plant fertilization and split application. Determined N-NO<sub>3</sub> content in soil was compared to relative total yield expressed in percentage of maximal yield obtained in a given year for each cultivar.

Correlation and regression analysis revealed significant correlation between N-NO<sub>3</sub> content in soil and Brussels sprouts yield ( $R = 0.857$  for pre-plant fertilization and  $R = 0.915$  for split application) at the stage of stem growth. The relationship was expressed as quadratic function (Fig. 3). For pre-plant fertilization, the curve shape (more convex parabola) suggests higher increase in yield with increasing N-NO<sub>3</sub> content than with split fertilization. Calculation of coordinates of parabolas peaks and considering of standard variation enabled to find optimal N-NO<sub>3</sub> soil content for Brussels sprouts. The range was very similar for both fertilization methods. Lower critical N-NO<sub>3</sub> content was the same (51 mgL<sup>-1</sup>) irrespective whether nitrogen was supplied in a single dose or in split application, while the upper one differed slightly and equaled 78 mgL<sup>-1</sup> for pre-plant fertilization and 71 mgL<sup>-1</sup> for split application (Fig 3a & 3b). Slight difference in upper limit of optimal content for split and single pre-plant application confirms the findings of Biemond *et al.* (1995) and Booij *et al.* (1996) that for yielding of Brussels sprouts the most important is supply of sufficient amount of nitrogen during production of plant mass, before sprouts setting. Fertilization in the later period has small effect on yield.



a. Preplant fertilization



b. Split fertilization

Fig. 3. Relationship between relative yield of Brussels sprouts and N-NO<sub>3</sub> content in the soil (0-20 cm) in the growth stage of stem formation



### N-NO<sub>3</sub> content in leaf petioles during various stages of plants growth

Varied nitrogen fertilization significantly affected N-NO<sub>3</sub> content in leaves of Brussels sprouts in all growth stages and years of experiment. The lowest N-NO<sub>3</sub> content in Brussels sprouts leaf petioles occurred with the lowest nitrogen fertilization rate (100 kg N ha<sup>-1</sup>) and it increased with higher nitrogen fertilization reaching the highest value for the highest nitrogen dose (600 kg N ha<sup>-1</sup>). The greatest variation of nitrate nitrogen content in leaves was observed at the stage of stem formation and it decreased at the stage of sprouts setting. In the latter growth stage strong effect of nitrogen applied as top dressing with nitrogen fertilizer was visible. In the final growth stage – during harvest – the content was lowest, almost not dependant on application method and only slightly dependant on nitrogen fertilization rate (Fig. 4). This agrees with the results obtained by Kolota & Biesiada (1990) as well as Williams & Maier (1996).

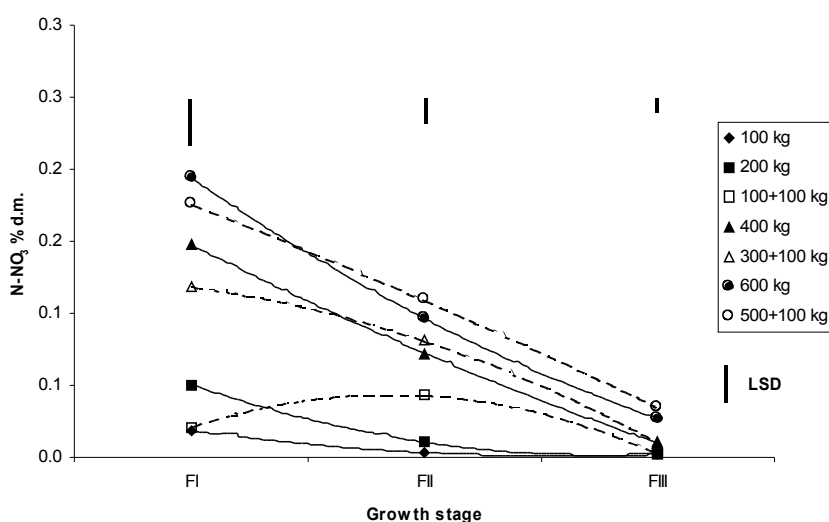


Fig. 4. Effect of rates and application methods of nitrogen fertilization on N-NO<sub>3</sub> contents in leaf petioles in different growth stages of Brussels sprouts (For explanation of growth stages see Table 2)

### Nutrient status of plants

To evaluate the relationship between Brussels sprouts yield and nitrate nitrogen content in leaf petioles and plants nutrient status the obtained results were subjected to correlation and regression analysis. The analysis was carried out for two developmental stages described as a stage of stem formation and a stage of sprouts setting, when the differences in N-NO<sub>3</sub> content in leaf petioles were the greatest and statistically proven. The calculations were conducted separately for single pre-plant as well as split fertilization for both cultivars. Content of N-NO<sub>3</sub> in leaf petioles were compared to sprouts yield expressed as percentage of maximal yield obtained for each cultivar in a given year.

The relation between compared parameters i.e. yield and N-NO<sub>3</sub> content in indicative parts, expressed by coefficient of quadratic function, depended on developmental stage of Brussels sprouts and nitrogen fertilization method (Table 3).

Table 3. Relationship between N-NO<sub>3</sub> content in leaf petiols and yield of Brussels sprouts. Value of correlation coefficient R for parabolic regression

Period of analysis	Cultivar		Comparison of parabolas
	Ottoline F <sub>1</sub>	Adonis F <sub>1</sub>	
Nitrogen applied as pre-plant application only			
(FI) Stage of stem growth	0.911**	0.927**	Different
(FII) Stage of sprouts setting	0.722**	0.808**	Parallel
Nitrogen applied as split application (pre-plant application and top dressing)			
(FI) Stage of stem growth	0.897**	0.820**	Parallel
(FII) Stage of sprouts setting	0.880**	0.902**	Identical <sup>1)</sup>

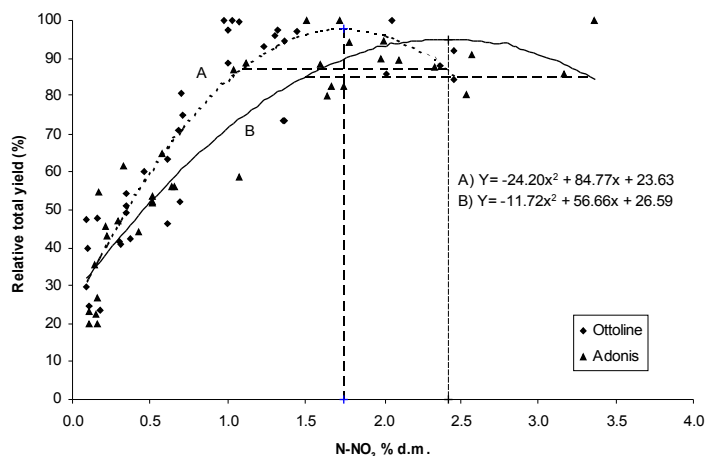
\*\* correlation significant for P=0.01

<sup>1)</sup> - parabolas identical may be replaced by one general parabola

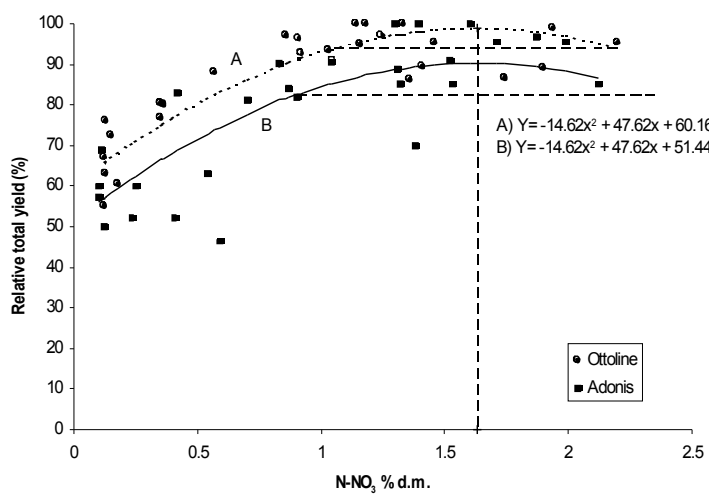
The highest correlation coefficient, and thus the strongest correlation was found for the stage of stem growth after pre-plant nitrogen application. For the cultivar Ottoline F<sub>1</sub> the coefficient R was 0.911 while for the cultivar Adonis F<sub>1</sub> R = 0.927. In the later growth stage (sprouts setting) the correlation was weaker because calculated values of the coefficients are slightly lower and equals respectively, R = 0.722 and R = 0.808. For split application of nitrogen the differences in correlation coefficients for the stages of stem growth and sprouts setting was lower than for pre-plant fertilization only. With this method of nitrogen application, N-NO<sub>3</sub> content in leaves, at the stage of stem growth, was an effect of pre-plant rates only (reduced by the amount for top dressing), whereas yield resulted from application of both nitrogen rates (pre-plant and top-dressed). The obtained correlation is slightly weaker than with pre-plant fertilization only as correlation coefficient is lower for both cultivars (Ottoline F<sub>1</sub> R = 0.897, Adonis F<sub>1</sub> R = 0.820). For the stage of sprouts setting the calculated correlation coefficient for split application is slightly higher only for the late cultivar Adonis F<sub>1</sub> (R = 0.920) (Table 3).

The relationship between N-NO<sub>3</sub> content in leaf petiols and relative total yield of Brussels sprouts, for both growth stages and nitrogen application methods, was expressed by quadratic function (Fig. 5). With pre-plant fertilization, the relations obtained for stem growth stage are different for both cultivars and so are the parabolas. For an early cultivar the parabola is more convex which indicates greater increase in yield already for lower N-NO<sub>3</sub> content in leaves. For later cultivar, yield increase with growing N-NO<sub>3</sub> content in leaf petioles is lower; also yield reduction begins later, what indicates higher fertilization requirements of this cultivar. Establishing coordinates of parabolas peaks, and considering standard variation, enabled to evaluate optimal range of N-NO<sub>3</sub> content in leaf petiols of both cultivars. For the

early cultivar (Ottoline F<sub>1</sub>) the range was 1.09-2.41% d.w. and for the late cultivar (Adonis F<sub>1</sub>) 1.50-3.34% d.w. (Fig. 5a). For split fertilization the relation was similar for both cultivars. It is described by two parallel but shifted parabolas. A range of optimal N-NO<sub>3</sub> content in leaf petiols was lower than for pre-plant fertilization and amounted to 1.05-2.21 for the early cultivar and 0.90-2.35% d.w. for the late cultivar (Fig 5b).



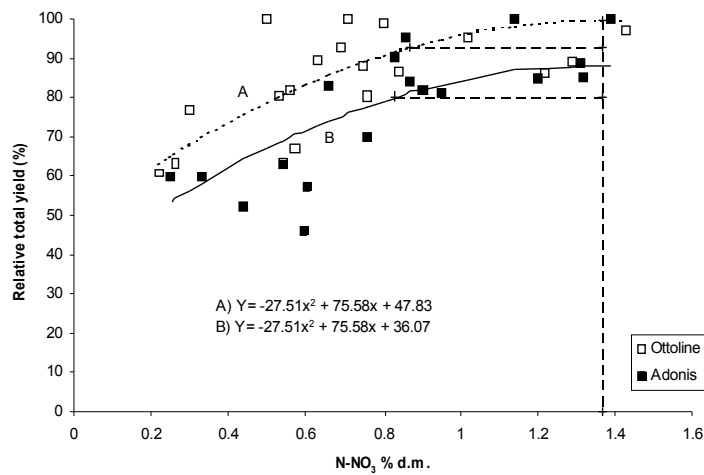
#### a. Preplant fertilization



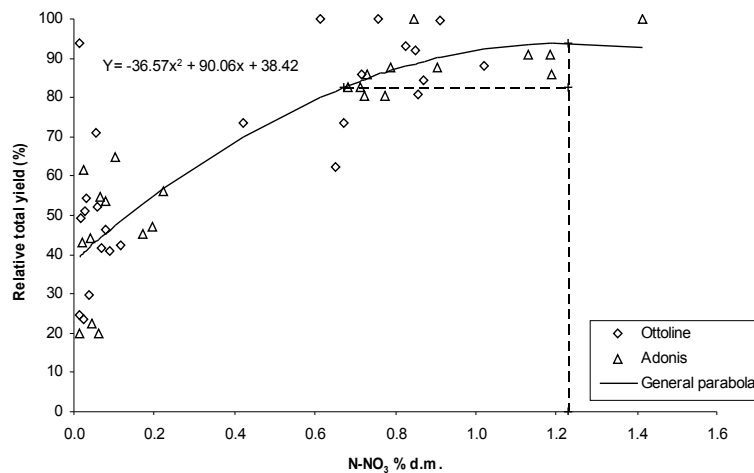
#### b. Split fertilization

Fig. 5. Relationship between Brussels sprouts yield and N-NO<sub>3</sub> content in leaf petioles in the growth stage of stem formation (F I)

The optimal N-NO<sub>3</sub> content in leaf petiols of Brussels sprouts, ranging for both cultivars and fertilization methods from 0.9 to 3.34% d.w., is lower than, reported by Nowosielski (1988), standard nitrate nitrogen content for head cabbage 30 000 – 40 000 mg kg<sup>-1</sup> (3-4% d.w.) and much wider than the range of optimal content obtained by Kołota & Dobromilska (1992) which was 18 000 – 18 400 mg kg<sup>-1</sup> (1.80-1.84% d.w.).



#### a. Preplant fertilization



#### b. Split fertilization

Fig.6. Relationship between Brussels sprouts yield and N-NO<sub>3</sub> content in leaf petiols in the growth stage of sprouts setting

In the stage of sprouts setting, N-NO<sub>3</sub> content in leaves was for both fertilization methods much lower than during the stage of stem growth, which may be explained by the fact that part of the nutrient was moved from leaves and used up for sprouts formation. In leaf petioles, no such high N-NO<sub>3</sub> levels occurred that yield would decrease and therefore parabolic regression has different characteristic and does not enable to assess maximal range of N-NO<sub>3</sub> content in indicator parts (Fig. 6a & b).

Due to relatively low correlation coefficient and reduced N-NO<sub>3</sub> content in indicator parts at the stage of sprouts setting as well as inability to establish full range of N-NO<sub>3</sub> content in leaf petioles it was concluded that the stage of sprouts setting is too late to assess N-NO<sub>3</sub> content in indicator parts for the purpose of correction of nitrogen fertilization. Final period of stem growth stage gives much better representation of N-NO<sub>3</sub> content in leaf petioles for diagnostic purposes and possible application of top dress fertilization to correct deficiency of nitrogen, than an initial stage of sprouts setting. The importance of proper period of analysis for correct interpretation of results was stressed by Williams & Maier (1996) who found significant correlation between N-NO<sub>3</sub> content in leaf petioles and relative total yield only for 8, 10 and 14 weeks after Brussels sprouts planting. Selection of stem growth stage as good period for evaluation of plant nutrient status was supported by further research of other authors (Biemond *et al.* 1995, Van der Werf *et al.* 1996) who found that stage of stem growth is an important period of Brussels sprouts development as amount of biomass produced and stored in plant during this time is a crucial factor affecting future yield.

#### CONCLUSIONS

1. Content of N-NO<sub>3</sub> in leaf petioles and in the soil increased with growing amount of nitrogen fertilization and decreased with plant age.
2. Stage of intensive vegetative growth, called stage of stem formation, was better period to assess N-NO<sub>3</sub> content in leaf petioles for diagnostic purposes than initial stage of sprouts setting.
3. Bottom critical content of N-NO<sub>3</sub> in leaf petioles varied, depending on cultivar, from 0.90 to 1.50% d.w. while upper limit of optimal range was 2.35-3.34 d.w.
4. For Brussels sprouts, optimal content of nitrate nitrogen in soil ranged from 51 to 71 mg N·L<sup>-1</sup> for split fertilization and to 78 mg N·L<sup>-1</sup> for single preplant nitrogen application.

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## WYMAGANIA POKARMOWE I NAWOŻENIE AZOTEM KAPUSTY BRUKSELSKIEJ

### Streszczenie

Potrzeby pokarmowe kapusty brukselskiej w stosunku do azotu określano w doświadczeniu polowym. Założone dawki azotu: 100, 200, 400 i 600 kg N ha<sup>-1</sup>, uwzględniały ilość tego składnika znajdującą się wiosną w glebie, w warstwie 0-60 cm. Azot w dawkach 200, 400 i 600 kg N ha<sup>-1</sup> stosowano jako nawożenie wyłącznie przedwegetacyjne oraz jako podzielone na przedwegetacyjne i pogłównne (100 kg N ha<sup>-1</sup>). Dawkę 100 kg N ha<sup>-1</sup> stosowano wyłącznie przedwegetacyjnie. Określono wysokość plonu oraz zawartość azotu azotanowego w glebie i częściach wskaźnikowych brukselki, w różnych fazach jej rozwoju, dla obydwu sposobów zżycia. Zawartość azotu azotanowego w ogonkach liściowych zwiększała się wraz ze wzrostem dawek azotu, a obniżała wraz z wiekiem rośliny. Faza formowania łodygi była lepszym terminem oceny zawartości N-NO<sub>3</sub> w częściach wskaźnikowych niż faza wiązania główek. Optymalny zakres zawartości tego składnika dla jednorazowego nawożenia przedwegetacyjnego wynosił 1,09-3,34% s.m., a dla nawożenia dzielonego 0,90-2,35% s.m. Optymalna zawartość azotu azotanowego w glebie wynosiła dla nawożenia przedwegetacyjnego 51-78 mg L<sup>-1</sup>. Dla nawożenia dzielonego górna wartość zakresu optymalnego była niższa i wynosiła 71 mg L<sup>-1</sup>.

## **SULFORAPHANE AND FLAVONOID CONTENTS IN CHOSEN BROCCOLI CULTIVARS**

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### Summary

Broccoli is a vegetable of high dietary value, due to presence of several important bioactive constituents, like ascorbic acid, carotenoids, glucosinolates, flavonoids and other phenolic compounds. Heads of eight broccoli cultivars: Marathon F<sub>1</sub>, Lucky F<sub>1</sub>, Griffen F<sub>1</sub>, Lord F<sub>1</sub>, Milady F<sub>1</sub>, Chevalier F<sub>1</sub>, Monaco F<sub>1</sub> and Monopoly F<sub>1</sub> were analyzed to determine contents of sulforaphane, flavonoids and total phenolic compounds. Among studied broccoli cultivars Monaco F<sub>1</sub> and Chevalier F<sub>1</sub> had higher sulforaphane content than the other cultivars in 2002, but during 2003 season the sulforaphane level was highest in four cultivars: Griffen F<sub>1</sub>, Monaco F<sub>1</sub>, Marathon F<sub>1</sub> and Milady F<sub>1</sub>. In all investigated broccoli cultivars the kaempferol was predominant flavonoid, and its content was around 60% higher than the quercetin. The largest content of total flavonoids was found in head of broccoli cv. Chevalier F<sub>1</sub>, Monaco F<sub>1</sub> and Lucky F<sub>1</sub> (season 2002), and in cv. Marathon F<sub>1</sub>, Lord F<sub>1</sub>, Milady F<sub>1</sub> and Lucky F<sub>1</sub> (season 2003). Analysed flavonoids are accumulated mainly in flower buds, and only traces occurs in stem. Highest level of total phenolics was noted in broccoli cv. Monaco F<sub>1</sub> and Chevalier F<sub>1</sub>, and the lowest in cv. Monopoly F<sub>1</sub>.

key words: broccoli, cultivars, sulforaphane, flavonoids, total phenolics, quercetin, kaempferol, apigenin

### INTRODUCTION

Broccoli is a vegetable of high dietary value, due to presence of several important bioactive constituents: carotenoids, ascorbic acid, glucosinolates, flavonoids and phenolics (Price *et al.* 1998, Rice-Evans & Miller 1995, Rosa & Rodrigues 2001, Vallejo *et al.* 2001, 2002).

The idea that the preventive action of fruits and vegetables towards chronic disease which has been observed in many epidemiological studies was caused by the high levels of antioxidants in these kinds of food (Block *et al.* 1992, Ness & Powles 1997, Williamson 1996). Among highly bioactive compounds naturally occurring in common vegetables are: glucosinolates (and products of their enzymatic breakdown - isothiocyanates), as well as flavonoids.



More than 100 glucosinolates occur in nature (Fahey *et al.* 2001). They are sulphur-containing glycosides differing in their side chain R-groups. Glucosinolates are found in all *Brassica* vegetables but the composition and the amount of the single glucosinolates vary. On average ca. 10-15 glucosinolates occur in a certain species but only between one and four glucosinolates are found in high concentrations. These compounds also vary between different parts of the plants (Kushad *et al.* 1999). Food preparation like chopping or short-time blanching, cause enzymatic breakdown (by myrosinase) of the glucosinolates to a mixture of volatile components - thiocyanates, isothiocyanates, nitriles and oxazolidinethiones. They are responsible for the special flavour and aroma of the *Brassica* vegetables. Some of them are goitrogenic, but another also the best proven cancer preventing principles in vegetables (Hecht 1999). Breakdown products from glucosinolates - isothiocyanates and indolyl compounds might inhibit many types of cancer, which has been shown on animals. The sulforaphane - isothiocyanate from glucoraphanin (chemical name: 4-(Methylsulfinyl) butylglucosinolate), was proven to be potent inducer of detoxication enzymes, which favour the antioxidative capacity of the cells (Fahey & Talalay 1999). Broccoli heads are best dietetic source of that compound among Cruciferous vegetables. According to Fahey *et al.* (1997) broccoli sprouts (3-days old, cv. Saga), contained around fifteen times more of sulforaphane than matured broccoli: 2900 and 190 mg·kg<sup>-1</sup>, respectively. It seems like broccoli sprouts is a richest source of sulforaphane among all plants.

Flavonoids are the large family containing over 4000 compounds. They are found in fruits, vegetables, nuts, seeds as well as in tea and wine. There is association between the intake of plant flavonoids and the incidence of some chronic diseases (Rice-Evans & Miller 1995). Bioflavonoids found in plants have free radical scavenging and metal ion chelation properties. Antibacterial, antithrombotic, vasodilatory, antiinflammatory and anticarcinogenic properties are also associated with flavonoid compounds, what was broadly described in many reviews (Block *et al.* 1992, Erlund 2004, Horbowicz 2000, Middleton *et al.* 2000, Steinmetz & Potter 1996).

Quercetin and its glucosides are the main flavonoids in our diet particularly abundant in onion and other crops of *Allium* (Hertog *et al.* 1992; Horbowicz 1999, 2000; Horbowicz & Kotlińska 2000). Another common flavonoids are kaempferol and apigenin. The kaempferol is present in leaves of *Allium* plants (Horbowicz & Kotlińska 2000), as well as in *Brassica* vegetables (Hertog *et al.* 1992). The flavonoids formation and level depends on light conditions during vegetation, so they are concentrated in the outer tissues (Bilyk & Sapers 1985, Herrmann 1988). Lettuce grown in open-field conditions had higher levels of flavonoids content than the lettuce grown in greenhouse (Romani *et al.* 2002).

The objective of this study was to determine important bioactive constituents present in head of eight broccoli cultivars grown in Poland. We

measured main isothiocyanate - sulforaphane, aglycones of main flavonoids, as well as content of total phenolic compounds and dry weight level.

## MATERIAL AND METHODS

For the experiments following cultivars were used: Marathon F<sub>1</sub>, Monaco F<sub>1</sub> and Monopoly F<sub>1</sub> (Syngenta), Lucky F<sub>1</sub> (Bejo), Griffen F<sub>1</sub> (Clause) as well as Lord F<sub>1</sub>, Milady F<sub>1</sub> and Chevalier F<sub>1</sub> (Asgrow). The plants were grown during seasons 2002 and 2003 in an experimental field trials of Research Institute of Vegetable Crops in Skierniewice. Transplants of the broccoli cultivars were planted in four field replicates on pseudopodsolic soil, containing 1.3% of organic matter, and pH 6.53 (Kaniszewski *et al.* 1999). Following mineral nutrition was used: N - 200 kg·ha<sup>-1</sup>; P - 100 kg P<sub>2</sub>O<sub>5</sub>·ha<sup>-1</sup> and K - 250 kg K<sub>2</sub>O·ha<sup>-1</sup>. Nitrogen fertilization was divided into two doses: half of N was applied before planting of seedlings, and next half was applied on beginning of heads formation. Seed of broccoli were sown on middle of June, and obtained transplants were planted in field trials in density of 42,000 pcs per 1 hectare, on middle of July. During vegetation the broccoli plants were watered as needed, and protected against diseases and pests according to recommendations for the species. Primary heads of broccoli were harvested, starting from the second week of September till first week of October. From each variety and field replications a samples of 10 heads were collected. The broccoli samples were taken to laboratory analyses in the middle of harvest period of each cultivar, when the largest number of heads reached commercial maturity. To time of analyses the broccoli samples were stored at 0°C.

Analyses of sulforaphane were carried out by compilation of methods described by Chiang *et al.* (1998) and Sultana *et al.* (2002) with some modifications. In preliminary investigations rate of sulforaphane recovery from broccoli tissue was studied (data not shown). According to the studies the time for completing of myrosinase action, and full hydrolysis of the glucoraphanine into sulforaphane, was 60 to 90 minutes.

Twenty grams of knife cut florets of broccoli were homogenized during 2 minutes with 150 mL of distilled water, and the homogenizer jar was washed with two portions of 20 mL of the water, and finally the slurry was filled up to 200 mL volume. After 1-1.5 h in ambient temperature part of the slurry was filtered through medium filter paper. Five ml of filtrate was placed in 10 mL plastic centrifuge vial, and 2 mL of dichloromethane containing 100 µg of internal standard (phenyl isothiocyanate) was added. The vial was tightly capped, and vigorous shaken during 1 minute. The mixture was then centrifuged for 5 minutes at 7000 rpm (3000 g). Separated lower organic layer was transferred into screw-capped glass vials, dried over anhydrous sodium sulfate and analyzed by gas chromatographic method.

Gas chromatography analysis: samples (1 µL) of dichloromethane extract were injected onto capillary column HP-5 (5% crosslinked methylsilicone layer

- 0.32  $\mu\text{m}$  film thickness, 30 m long, 0.25 mm i.d.) in Shimadzu GC17A gas chromatograph fitted with flame ionization detector (FID), and injector set at splitless mode. The injector and detector temperatures was 220°C and 250°C, respectively. Helium was used as a carrier gas at inlet pressure 190 kPa and flow rate 56  $\text{cm}\cdot\text{s}^{-1}$ . Separations were performed under the following temperature program: 40°C (held 1 min.) to 100°C at 6°C $\cdot\text{min}^{-1}$ , to 240°C at 10°C $\cdot\text{min}^{-1}$ , then held at 240°C during 10 minutes. Peak areas were recorded using Shimadzu computer software (Class VP Chromatography Data System, version 4.3). Concentration of sulforaphane was calculated from standard curve prepared earlier for standard solutions at range 10 to 200  $\mu\text{g}\cdot\text{ml}^{-1}$ .

The flavonoids content was determined according to modified method of Patil *et al.* (1995) described earlier for onion (Horbowicz 1999, Horbowicz & Kotlińska 2000). Before analysis the broccoli samples were dried during 24 h in oven at 50°C. Preliminary experiments shown that drying of the plant material in such conditions had no effect on flavonoids content. After pulverizing a 500 mg portions were taken to analyses. Flavonoid glycosides were extracted by homogenization of samples in mortar with 60% ethanol-water solution. Extracted glycosides were subjected to hydrolysis in 1.2 N HCl. Hydrolysis conditions were following: temperature 100°C, time - 30 min. Obtained flavonol aglycones were extracted by triplicate vigorous shaking with ethyl acetate. Each separated upper layer was withdrew and pooled. To analyses a HPLC apparatus equipped with UV detector set at 370 nm was used. The flavonoid aglycones were isocratically separated on Lichrosorb RP18 (4 x 250 mm, 10  $\mu\text{m}$ ) column, and a mobile phase was methanol: water mixture (55:45, v/v) contained 0.2% orthophosphoric acid. The flow rate was 0.8  $\text{ml}\cdot\text{min}^{-1}$ .

Total phenolics was determined by Folin–Ciocalteu method according to Kaur & Kapoor (2002). Instead the catechol the results of analyses were expressed as mg chlorogenic acid per kg of fresh weight, and absorbance was measured at 700 nm. Dry weight was determined after drying of plant material in laboratory fan dryer during 24 h at 70°C.

Results were subjected to one way analysis of variance and Newman-Keuls comparisons were carried to test for significant differences between the means ( $P = 0.05$ ). In case of sulforaphane to statistical analyses were taken four laboratory replicates, and in case of determination of flavonoids, total phenolic compounds, and dry weight means and its statistics were done for three laboratory replicates. Exception are results presented in Table 3, which are means of two laboratory replicates.

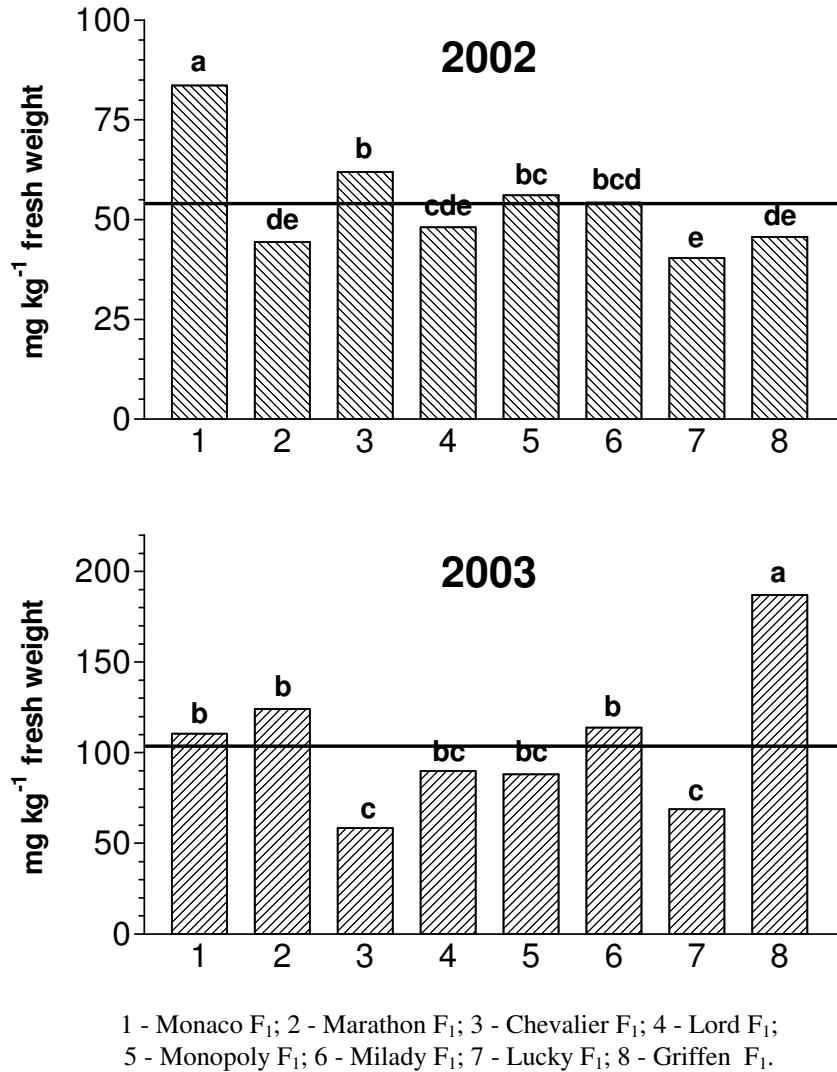
## RESULTS AND DISCUSSION

During two years studies (2002-2003) heads of some broccoli cultivars were analyzed to determine sulforaphane and flavonoids content, as well as total phenolic compounds and dry weight, and results were described in present paper.

Sulforaphane - product of glucoraphanine hydrolysis by myrosinase is a major isothiocyanate occurring in disintegrated tissue of broccoli (Carlson *et al.* 1987; Kushad *et al.* 1999; Vallejo *et al.* 2002). Content of sulforaphane in eight investigated cultivars ranged from 40 mg to 190 mg·kg<sup>-1</sup> fresh weight (Lucky, 2002 and Griffen 2003, respectively) (Fig. 1). It was found broad variation in the sulforaphane content among cultivars and year of study. Mean contents of the compound in broccoli harvested in 2003 was almost two-fold higher, than in broccoli heads harvested in 2002.

It is difficult to indicate the cultivar with highest sulforaphane content, because there were big differs among particular cultivars from both seasons of cultivation. In 2002 highest content of sulforaphane was found in Monaco F<sub>1</sub> (85 mg·kg<sup>-1</sup> fresh weight), and in 2003 season Griffen F<sub>1</sub> contained much more the isothiocyanate (190 mg·kg<sup>-1</sup> fresh weight), than the Monaco F<sub>1</sub> (108 mg·kg<sup>-1</sup> fresh weight) (Fig. 1). Among studied broccoli cultivars two of them: Monaco F<sub>1</sub> and Chevalier F<sub>1</sub> had sulforaphane level above mean of all cultivars in 2002, and during 2003 season level of sulforaphane in four cultivars: Griffen F<sub>1</sub>, Monaco F<sub>1</sub>, Marathon F<sub>1</sub> and Milady F<sub>1</sub> exceeded yearly mean of all cultivars (Fig. 1). The results presented here are similar to data obtained for another six broccoli cultivars published by Carlson *et al.* (1987). According to their studies, level of glucoraphanine ranged from 298 to 883 μmol·kg<sup>-1</sup> fresh weight, what is equivalent 57 to 167 mg of sulforaphane·kg<sup>-1</sup> fresh weight. In later studies Kushad *et al.* (1999) analyzed 51 cultivars and accessions of broccoli, and found that glucoraphanine ranged from 0.8 to 21.7 μmol·g<sup>-1</sup> dry weight, what can be recalculated as 18 to 500 mg of sulforaphane·kg<sup>-1</sup> fresh weight. Rosa & Rodrigues (2001) reported that florets of broccoli cv. Marathon F<sub>1</sub> produced during Spring and Autumn in Portugal contained 8.5 and 14.1 mmol of glucoraphanine·kg<sup>-1</sup> dry weight respectively. Recalculation of these values gives results: 190 to 335 mg of sulforaphane·kg<sup>-1</sup> fresh weight. The results are higher than obtained for the cultivar during our studies. The differences between results of both investigations can be an effect of variability of climatic and cultivation conditions, as well as differences among analytical methods used for analyses.

Discrepancies between results of sulforaphane content among broccoli cultivars from 2002 and 2003 seasons were probably caused by various weather conditions (temperature, sunlight) in mentioned cultivation periods. Ciska *et al.* (2000) have observed, that weather conditions can greatly affect the glucosinolates content in cabbage, Brussels sprouts, kale, cauliflower, kohlrabi, rape, and radish. Rosa & Rodrigues (2001) also confirmed the large variation in glucosinolate levels among broccoli produced in Spring and Autumn seasons.



Bars labelled by various letters differ significantly at  $P=0.05$  according to Newman-Keuls test.

Figure 1. Content of sulforaphane in heads of eight broccoli cultivars grown in 2002 and 2003

Broccoli heads are good source of flavonoids. According to Hollman & Katan (1999) broccoli belongs to major food sources of flavonoids among common vegetables, fruits and beverages. To the group of species with high flavonoids content (exceeded  $50 \text{ mg} \cdot \text{kg}^{-1}$  fresh weight) belong: onion, broccoli, endive, kale, French beans, celery and cranberries.

The two main flavonol glycosides present in broccoli florets were identified as quercetin 3-O-sophoroside and kaempferol 3-O-sophoroside (Price *et al.* 1998). According to their studies the levels of flavonol aglycones in broccoli florets, quercetin and kaempferol, were 43 and 94 mg·kg<sup>-1</sup> fresh weight, respectively. The results are close to values reported by Hertog *et al.* (1992) of 30 and 72 mg·kg<sup>-1</sup> fresh weight, respectively. Results of our studies of eight broccoli cultivars have indicated that level of quercetin ranged from 8.7 to 31.9 mg·kg<sup>-1</sup> fresh weight, and 17.5 to 70.3 mg·kg<sup>-1</sup> fresh weight in case of kaempferol (Table 1). The results are very close to those published by Hertog *et al.* (1992), and slightly lower than reported by Price *et al.* (1998). Besides the quercetine and kaempferol, the peak of third flavonoid was found on HPLC chromatogram (not shown), with retention time very close to apigenine. We calculated it temporary on basis of apigenine standard, although Herrmann (1988) have reported that broccoli contains isorhamnetin, and no apigenin. In later studies, carried out in Malaysia, was shown that broccoli heads contained quercetin, luteolin and myricetin (no kaempferol or apigenin) (Miean & Mohamed 2001). The cited authors reported, that among studied *Brassica* vegetables the apigenin occurred in Chinese cabbage only. Due to lack of isoramnethin standard we could not confirm the presence of the flavonoid in broccoli. Confirmation of apigenine, luteoline and/or myricytine (or their glycosides) presence in broccoli needs further studies.

Table 1. Content of flavonoid aglycones in chosen cultivars of broccoli (mg·kg<sup>-1</sup> fresh weight)

Cultivar	Quercetin		Kaempferol		Unknown <sup>(*)</sup>		Total	
	2002	2003	2002	2003	2002	2003	2002	2003
Monaco F <sub>1</sub>	22.6 b	11.6 c	33.3 b	18.6 f	6.2 cd	2.7 d	62.5 b	32.9 d
Marathon F <sub>1</sub>	8.7 e	28.5 a	17.5 c	70.3 a	2.8 e	5.2 c	29.0 d	104.0 a
Chevalier F <sub>1</sub>	31.9 a	13.2 c	41.5 a	21.0 ef	8.8 bc	5.9 c	82.2 a	40.1 d
Lord F <sub>1</sub>	15.8 cd	24.2 a	31.6 b	55.1 b	4.7 de	5.9 c	52.1 bc	87.2 b
Monopoly F <sub>1</sub>	13.1 d	15.6 c	20.6 c	21.9 ef	2.2 e	3.2 cd	35.9 d	40.7 d
Milady F <sub>1</sub>	17.4 c	28.7 a	29.2 b	38.5 c	6.8 cd	9.4 b	53.4 bc	76.6 b
Lucky F <sub>1</sub>	20.7 b	30.0 a	29.3 b	32.3 d	13.4 a	12.2 a	63.4 b	74.5 b
Griffen F <sub>1</sub>	14.6 cd	19.5 b	21.7 c	26.9 de	10.5 b	9.0 b	46.8 c	55.4 c
Mean of year	18.1	21.7	28.1	35.6	6.9	6.7	53.2	63.9

Means labelled by various letters differ significantly at P = 0.05 according to Newman - Keuls test.

Unknown<sup>(\*)</sup> was calculated on basis of apigenine standard

In broccoli cultivars much variation was found in particular flavonoid level, and their total amounts (Table 1). In all investigated broccoli cultivars the kaempferol was predominant flavonoid, exceeding the quercetin content from ca. 7% (Lucky F<sub>1</sub>) to ca. 250% (Marathon F<sub>1</sub>). For both years of studies and eight cultivars, mean content of kaempferol was by around 60% higher than

quercetin. The highest quercetin content in 2002 was noted in cv. Chevalier F<sub>1</sub> and Monaco (31.9 and 22.6 mg·kg<sup>-1</sup> fresh weight, respectively), and the lowest (8.7 mg·kg<sup>-1</sup> fresh weight) in cv. Marathon F<sub>1</sub>. In 2003 Lucky F<sub>1</sub>, Milady F<sub>1</sub> and Marathon F<sub>1</sub> contained highest level of quercetin (30.0 to 28.5 mg·kg<sup>-1</sup> fresh weight) and cv. Chevalier F<sub>1</sub> and Monaco F<sub>1</sub> the lowest (13.2 and 11.6 mg·kg<sup>-1</sup> fresh weight, respectively). Highest level of kaempferol was found in 2002 in cv. Chevalier F<sub>1</sub> (41.5 mg·kg<sup>-1</sup> fresh weight). Three other cultivars: Marathon F<sub>1</sub>, Monopoly F<sub>1</sub> and Griffen F<sub>1</sub>, harvested in 2002 contained low level of kaempferol: 17.5 mg, 20.6 mg and 21.7 mg·kg<sup>-1</sup> fresh weight, respectively. During season 2003 highest content of the flavonol was noted in Marathon F<sub>1</sub> and Lord F<sub>1</sub> (70.3 and 55.1 mg·kg<sup>-1</sup> fresh weight), and the lowest in: Monaco F<sub>1</sub>, Chevalier F<sub>1</sub> and Monopoly F<sub>1</sub> (18.6 mg, 21.0 mg and 21.9 mg·kg<sup>-1</sup> fresh weight, respectively). The largest content (82.2-63.4 mg·kg<sup>-1</sup> fresh weight) of total flavonoids was found in head of broccoli cv. Chevalier F<sub>1</sub>, Monaco F<sub>1</sub> and Lucky F<sub>1</sub> (season 2002), and in cv. Marathon F<sub>1</sub>, Lord F<sub>1</sub>, Milady F<sub>1</sub> and Lucky F<sub>1</sub> (104.0-74.5 mg·kg<sup>-1</sup> fresh weight, season 2003). In some cultivars flavonoids contents varied considerably between years of growing. In cv. Marathon F<sub>1</sub> content of flavonoids was 3-4 folds higher in 2003 than in season 2002, but in others (Monaco F<sub>1</sub>, Chevalier F<sub>1</sub>) the flavonoids level was two-folds lower in 2003, than in 2002. The mean content of total flavonoids in investigated broccoli cultivars (53-64 mg·kg<sup>-1</sup> fresh weight) was similar to those published for cv. Marathon F<sub>1</sub> and Lord F<sub>1</sub> grown in Spain (Vallejo *et al.* 2002).

In head of broccoli almost all flavonoids content were accumulated in flower buds, and in stem were only their traces (Table 3). Flower buds are exposed on direct sunlight. It is known that flavonoids are part of plant defence system against UV light damage (Hohl *et al.* 2001). Accumulation of all amounts of the flavonoids in upper part of broccoli head confirms the hypothesis.

Total phenolics in broccoli cultivars ranged from 1267 to 2280 mg·kg<sup>-1</sup> (Table 2). The content range was higher then results published by Kaur & Kapoor (2002). According to data in their paper broccoli produced in Asia had relatively low content of total phenolic compounds: 87.5 mg·100 g<sup>-1</sup> fresh weight (or 875 mg·kg<sup>-1</sup>) fresh weight. During our studies highest level of total phenolics was noted in broccoli cv. Monaco F<sub>1</sub>, and Chevalier F<sub>1</sub>, and the lowest in cv. Monopoly F<sub>1</sub>. Four cultivars: Monaco F<sub>1</sub>, Chevalier F<sub>1</sub>, Milady F<sub>1</sub> and Griffen F<sub>1</sub> had higher level of dry weight than the others (Marathon F<sub>1</sub>, Lord F<sub>1</sub>, Monopoly F<sub>1</sub> and Lucky F<sub>1</sub>) in both vegetation seasons (Table 2). The total phenolic contents varied considerably between flower buds and stem, with almost two-fold higher values obtained for buds than in comparison to stems (Table 3).

Postharvest changes in the content of bioactive compounds may be the result of different factors as weather conditions, senescence processes, genetics, structural origin of the plant part, metabolic rate, postharvest handling and preharvest factors. Broccoli is a very perishable vegetable, with a short shelflife, even under optimal storage conditions. It has a relatively high

respiration rate, and the large surface to volume ratio leads to a relatively high transpiration rate of the broccoli florets (Wills *et al.* 1998). Our studies confirms the large variation in levels of main bioactive constituents between year of production among broccoli cultivars grown in Poland. Due to high antioxidative activity a pills containing extract from broccoli are produced and commercially available. Although the pills contain basic compounds occurring in broccoli tissue: vitamin C,  $\beta$ -carotene, lutein, sulforaphane, quercetin, indolyl compounds and glutathione, the raw or minimally processed broccoli heads have an advantage, due to natural combination of the bioactive substances acting simultaneously.

Table 2. Contents of total phenolic compounds and dry weight in chosen cultivars of broccoli

Cultivar	Total phenolic compounds (mg·kg <sup>-1</sup> fresh weight)		Dry weight (%)	
	2002	2003	2002	2003
Monaco F <sub>1</sub>	1650 a	2145 a	11.89 a	12.26 a
Marathon F <sub>1</sub>	1267 c	2280 a	11.09 b	12.46 a
Chevalier F <sub>1</sub>	1651 a	2222 a	11.69 a	12.30 a
Lord F <sub>1</sub>	1409 bc	2057 ab	11.26 b	12.10 a
Monopoly F <sub>1</sub>	1382 bc	1661 c	10.93 b	10.58 c
Milady F <sub>1</sub>	1467 b	1752 bc	11.72 a	11.84 a
Lucky F <sub>1</sub>	1666 a	1746 bc	11.26 b	11.05 b
Griffen F <sub>1</sub>	1472 b	1713 bc	11.62 a	12.39 a
Mean of year	1495	1947	11.43	11.87

Means labelled by various letters differ significantly at P = 0.05 according to Newman - Keuls test.

Table 3. Comparison of flavonoids, total phenolic compounds and dry weight levels in flower buds and flower stem of broccoli (cv. Griffen F<sub>1</sub>; mean of two replicates; Tr - traces)

Analysed constituent	Flower buds	Flower stem
Quercetin (mg·kg <sup>-1</sup> fresh weight)	24.2	Tr
Kaempferol (mg·kg <sup>-1</sup> fresh weight)	47.2	Tr
Unknown <sup>(*)</sup> (mg·kg <sup>-1</sup> fresh weight)	11.0	0
Total flavonoids (mg·kg <sup>-1</sup> fresh weight)	82.4	Tr
Total phenolic compounds (mg·kg <sup>-1</sup> fresh weight)	2128	1193
Dry weight (%)	14.28	9.78

Unknown<sup>(\*)</sup> was calculated on basis of apigenine standard



## CONCLUSIONS

1. Among studied broccoli cultivars Monaco F<sub>1</sub> and Chevalier F<sub>1</sub> had higher sulforaphane content than the other cultivars in 2002, and during 2003 season the sulforaphane level was highest in four cultivars: Griffen F<sub>1</sub>, Monaco F<sub>1</sub>, Marathon F<sub>1</sub> and Milady F<sub>1</sub>.
2. In all investigated broccoli cultivars the kaempferol was predominant flavonoid, and its content was around 60% higher than the quercetin.
3. The largest content total flavonoids was found in head of broccoli cv. Chevalier F<sub>1</sub>, Monaco F<sub>1</sub> and Lucky F<sub>1</sub> (season 2002), and in cv. Marathon F<sub>1</sub>, Lord F<sub>1</sub>, Milady F<sub>1</sub> and Lucky F<sub>1</sub> (season 2003).
4. Almost all quantities of determined flavonoids are accumulated in flower buds, and only traces occurs in stem.
5. Highest level of total phenolics was noted in broccoli cv. Monaco F<sub>1</sub> and Chevalier F<sub>1</sub>, and the lowest in cv. Monopoly F<sub>1</sub>.

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#### ZAWARTOŚĆ SULFORAFANU I FLAWONOIDÓW W WYBRANYCH ODMIANACH BROKUŁÓW

##### Streszczenie

Brokuł jest warzywem o dużej wartości dietetycznej, ze względu na wysoką zawartość ważnych bioaktywnych składników, takich jak: karotenoidy, glukozynolany, flawonoidy i związki fenolowe. Analizowano główne róże, ośmiu następujących odmian brokuła: Marathon F<sub>1</sub>, Lucky F<sub>1</sub>, Griffen F<sub>1</sub>, Lord F<sub>1</sub>, Milady F<sub>1</sub>, Chevalier F<sub>1</sub>, Monaco F<sub>1</sub> i Monopoly F<sub>1</sub>. Oznaczano zawartość sulforafanu, aglikonów głównych flawonoidów, a także całkowitą zawartość związków fenolowych i poziom suchej masy. Wśród badanych odmian Monaco F<sub>1</sub> i Chevalier F<sub>1</sub> charakteryzowały się najwyższą zawartością sulforafanu w roku 2002, zaś w roku 2003 najwyższy poziom tego składnika wystąpił w odmianach Griffen F<sub>1</sub>, Monaco F<sub>1</sub>, Marathon F<sub>1</sub> i Milady F<sub>1</sub>. We wszystkich badanych odmianach brokuła kemferol był ilościowo dominującym flawonoidem, przewyższając średnio o 60% zawartość kwercetyny. Największe sumaryczne zawartości flawonoidów w roku 2002 wystąpiły w różach brokuła odm. Chevalier F<sub>1</sub>, Monaco F<sub>1</sub> i Lucky F<sub>1</sub>, natomiast w roku 2003 największymi poziomami tych związków charakteryzowały się Marathon F<sub>1</sub>, Lord F<sub>1</sub>, Milady F<sub>1</sub> i Lucky F<sub>1</sub>. Niemal całe ilości oznaczanych flawonoidów kumulują się w pąkach kwiatowych róży brokuła, zaś w mięsistych pędach występują jedynie ich ślady. Najwyższe poziomy sumarycznej zawartości związków fenolowych wystąpiły w odmianach Monaco F<sub>1</sub> i Chevalier F<sub>1</sub>, a najniższe w odmianie Monopoly F<sub>1</sub>.

## **EFFECT OF WEEDY BACKGROUND ON COLONIZATION OF RED BEET BY BLACK BEAN APHID (*APHIS FABAE* SCOP.)**

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### Summary

In 1995-2000, the author investigated the occurrence of *Aphis fabae* Scop. on red beet in relation to the degree of ground coverage by weeds. The different coverage of plots by weeds was obtained by varying the frequency of weeding on particular plots. In combination A plots were continuously kept weed-free during the whole vegetation season, in B weeds were removed three times, in C weeds were removed twice and in combination D weeds were not removed. It was found that the number of aphids and the number of red beet plants colonized by black bean aphid decreases with the lower weeding frequency i.e. with the greater coverage of the soil by weeds, reaching its minimum on the plots twice weeded and on the plots where weeds were not removed.

key words: *Aphis fabae*, black bean aphid, weeds, red beet

### INTRODUCTION

Black bean aphid (*Aphis fabae* Scop.) is one of the most dangerous pest of red beet (*Beta vulgaris* L.) (Łuczak 1991). Nowadays, the most common method of protection from these pests are chemical treatments. Because of economic reasons and necessity to protect the natural environment, the use of chemical treatments should be limited by the introduction of the integrated methods (IPM) being the key element in sustainable agriculture in the countries of European Union. The integrated methods include the competent use of natural elements of environment and the self adjustment mechanisms occurring in the nature. Without any doubts, weeds can be treated as the main, natural elements of agriculture environment (Boczek 1984, Lipa 1974). McKinlay & McCreath (1995) treat weedy culture as one of the method of cultivation of two or more species together with intercropping, undersowing or using living mulch. The research on many specialized plant pests shows that they are more numerous in monoculture than in complex systems (Altieri & Whitcomb 1980, Wnuk & Pobożniak 1999). The knowledge and appropriate use of the critical period of weed competition and customised selection of the weeding is of great importance in so called ecological vegetable production (Dobrzański 1996,

Turner 1999). In view of this, the weeds should not be treated only as the factor limiting the yields and instead of plans to completely remove the weeds, the methods to use the weeds as the means for the reduction of pest occurrence should be developed. Weed manipulation could be a practical technique to augment biological control of insects in agroecosystems.

The aim of the research was to evaluate how the weedy background influences the colonization of red beet by black bean aphid (*Aphis fabae* Scop.).

## MATERIAL AND METHODS

The experiments were carried out on red beet plots cv. Czerwona Kula from 1995 till 2000 at the Agricultural Experimental Station in Mydlniki near Cracow on a typical brown soil with pH 6.5 and  $C_{org}$  content of 1.8%. Potatoes, wheat, pea and onion were the most frequently cultivated plants in the direct vicinity of the plots.

The method of randomized blocks with four replicates was used. Each plot had area of 16 m<sup>2</sup> (4 m x 4 m). The plots were separated by paths with width of 1 m. Seeds were sown in rows spaced 0.4 m apart. No chemical treatments were applied and the weeds were removed mechanically and manually. Four combinations were included in the experiments (A, B, C and D) differing in the degree of ground coverage by weeds. The different coverage of plots by weeds was obtained by varying the frequency of weeding on particular plots. In combination A plots were weeded once a week and were kept weed-free during the whole vegetation season, in B weeds were removed three times, in C weeds were removed twice and in combination D weeds were not removed, but once per month topped to the height of red beet. Until to the end of thinning, the plots were kept weed free in order to protect the beets. The information about the dates of sowing, thinning and weeding in particular years are presented in Table 1. The heavy rains in 1996 which started 3 weeks after the sowing washed out some of the sowed plants and the plants were sowed once again in such places.

The infestation rate and population dynamics of aphids were regularly observed on 25 plants randomly selected from each plots along its diagonal. The analyses were started when the first aphids were observed and continued until the disappearance of the population of aphids. When the number of aphids was low, aphids were counted accurately, while in case of large colonies the estimation method described by Goos (1966) was used. In his approach, the following classes are distinguished: I class (no aphids): 0 aphids (the average for the class: 0); II class (single cases): 1-5 aphids (the average for the class: 3 aphids); III class (small colonies): 6-12 aphids (the average for the class: 9 aphids); IV class: (medium colonies): 13-42 aphids (the average for the class: 27 aphids); V class: (large colonies): 43-120 aphids (the average for the class: 81 aphids); VI class: (very large colonies): > 120 aphids (the average for the class: 243 aphids).

The percentage of plants infested by aphids was also determined.

The soil coverage by weeds expressed in percentage was approximately evaluated according to the method described by Rola (1964).

The Dunnegan's multiple test was used for statistical analysis of results. The correlation coefficients between the degree of the soil coverage by weeds and the number of aphids and percentage of beets infested by aphids were calculated (Elandt 1964).

Table 1. Agricultural treatments (Mydlniki 1995-2000)

Year	Date of sowing	Date of thinning	B- weeds removed three times			C- weeds removed twice	
			Date of weeding				
			I	II	III	I	II
1995	20 IV	3 VI	23 VI	7 VII	19 VII	24 VI	14 VII
1996	25 IV						
	15 V	4 VI	15 VI	3 VII	21 VII	15 VI	21 VII
1997	17 IV	26 V	18 VI	11 VII	7 VIII	4 VII	7 VIII
1998	7 IV	12 V	19 V	14 VI	10 VII	10 VI	17 VII
1999	6 IV	18 V	24 V	17 VI	12 VII	11 VI	19 VII
2000	10 IV	20 V	27 V	20 VI	19 VII	14 VI	26 VII

## RESULTS

The development and the numerousness of *A. fabae* on the red beet was varying over the years. The black bean aphid was noticed on the red beet from the third decade of May to the end of the last decade of June. Only in 1995, the first aphids were noticed in the third decade of June. The late occurrence of aphids and the not numerous colonies during the vegetation period of red beet were probably caused by the weather conditions in the early spring and later. After the period of maximum occurrence, i.e. from the half of June to the first decade of July, the number of aphids was continuously decreasing. The decrease of the population of aphids could be caused by the numerous predators and unfavourably weather conditions like too high temperatures and heavy rains can be given (Fig. 1-3).

In years 1995-2000, significant differences in the development of aphids and the degree of infestation of plants in relation to the weediness of particular combinations were found (Fig. 1-3, Table 2).

The infestation by *A. fabae* started at the same time in all analyzed combinations, excluding 1997. In the initial period, the development of black bean aphid was similar in all combination, but after a few days, differences in number of aphids on the particular plots were noticed. On combination A i.e. plots without weeds, the development of aphids was the fastest. On the plots with greater coverage of soil by weeds (weeded twice and not weeded), after the initial growth of the number of aphids, the population was at lower level (Fig. 1-3, Table 3). Only in 1995, after the first aphids were found, the number of aphids was fast growing in all combinations, except the plots not weeded

(Fig. 1). In all years, during the period of the most intensive occurrence of black bean aphid, the greatest numbers were noticed on plots without weeds (A), and the lowest numbers on the plots not weeded (D) or weeded twice (C). For example, in 1998, during the period of the most intensive occurrence of aphids, its number on plots without weeds (A) was nearly four times greater than on plots not weeded (D) (Table 2).

The periods of occurrence of aphids on plots were different in particular combinations. In years 1997-2000 *A. fabae* in combination weeded twice (C) and not weeded (D) ended the development earlier than in the remaining combinations (Fig. 1-3).

Significant statistical differences in the total number of aphids in the particular combinations were found. In years when the significant differences were noticed, the total number of aphids on plots without weeds (A) was about 1.4 to 1.9 times greater than on the plots of combination weeded three times (B) and from 1.9 to 9 times greater than on plots of combination weeded twice (C) and not weeded (D) (Table 2).

The percent of plants infested by aphids was growing gradually together with the growing number of aphids on infested plant in the particular combinations. During the whole vegetation season, the greatest number of infested plants was observed on combination without weeds and it was significantly different from the results for the remaining combinations, except the combination weeded three times in 1996-2000 (Table 2).

On the base of the calculated negative correlation coefficient it can be stated, the infestation of plants was lowering together with the growth of the soil coverage by weeds (Table 4).

In all years, the most dominant species of dicotyledonous weeds were: *Galinsoga parviflora* (Cav.), *Chenopodium album* L., *Cirsium arvense* (L.) Scop. and *Amaranthus retroflexus* L. Among the monocotyledons weeds the most dominant were: *Agropyron repens* L. and *Echinochloa crus-galli* L. The most numerous colonies of black bean aphid were observed on *Ch. album* and *C. arvense*. Less numerous were found on *G. parviflora*.

Over all years, the highest yield of beet's roots was noticed for the combination A, kept weed free, because there was no negative influence of weeds on the cultivated plants. Average yield for this combination was 2.6 kg·m<sup>-2</sup>. A bit lower yield was received for the combination weeded three times (B), which was not statistically different from the yield received from combinations without the weeds (A), except 2000 year. The lowest yield was noticed for combinations weeded twice (C) and not weeded (D). The yield from the combination weeded twice (C) was statistically different from the yield from the combinations without the weeds (A) and from the combinations weeded three times (C), except 1999 year (Table 5).

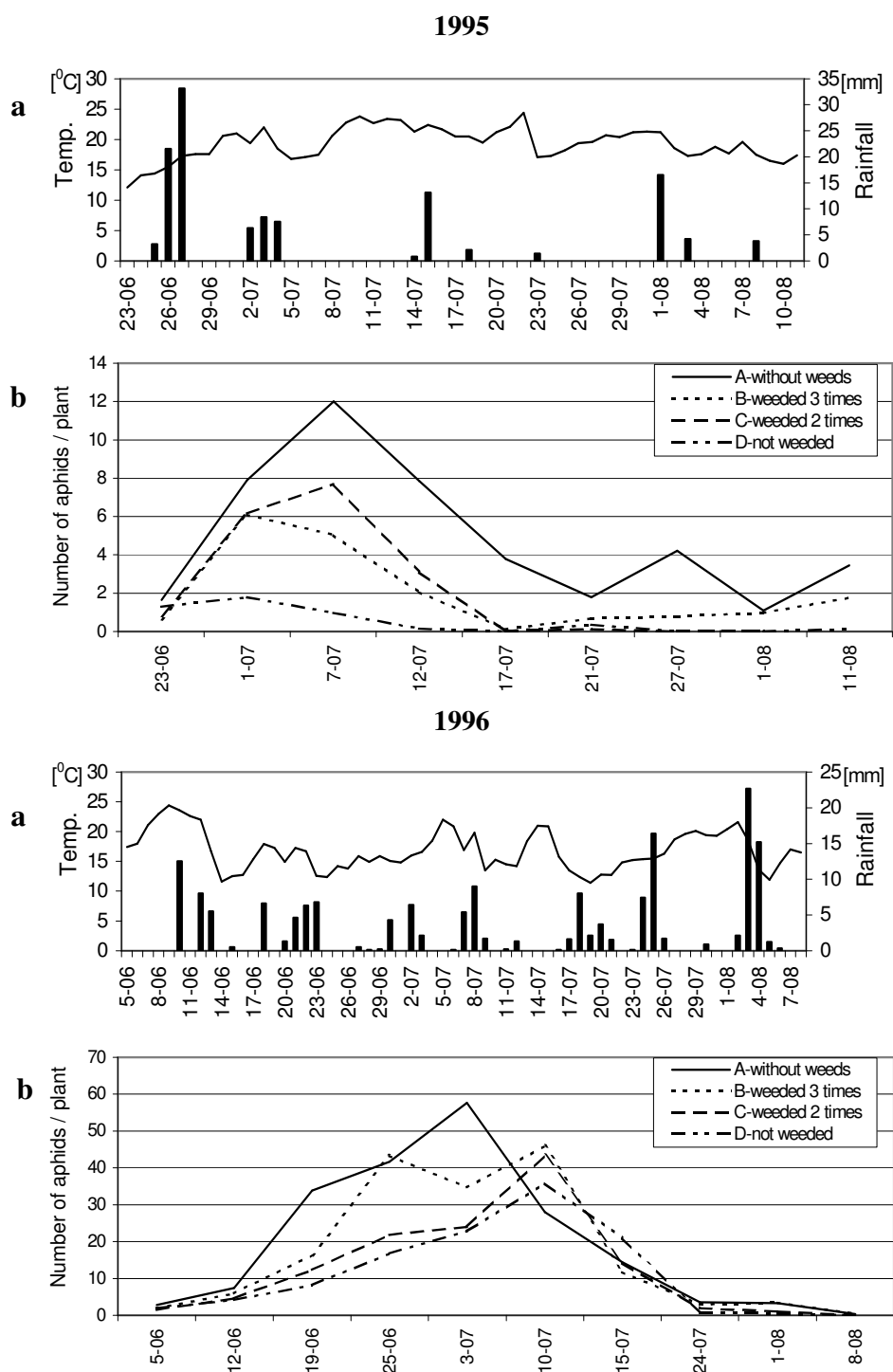


Fig. 1. The weather conditions (a) and dynamics of population of *Aphis fabae* Scop. on red beet (b) (Mydlniki 1995 – 1996)



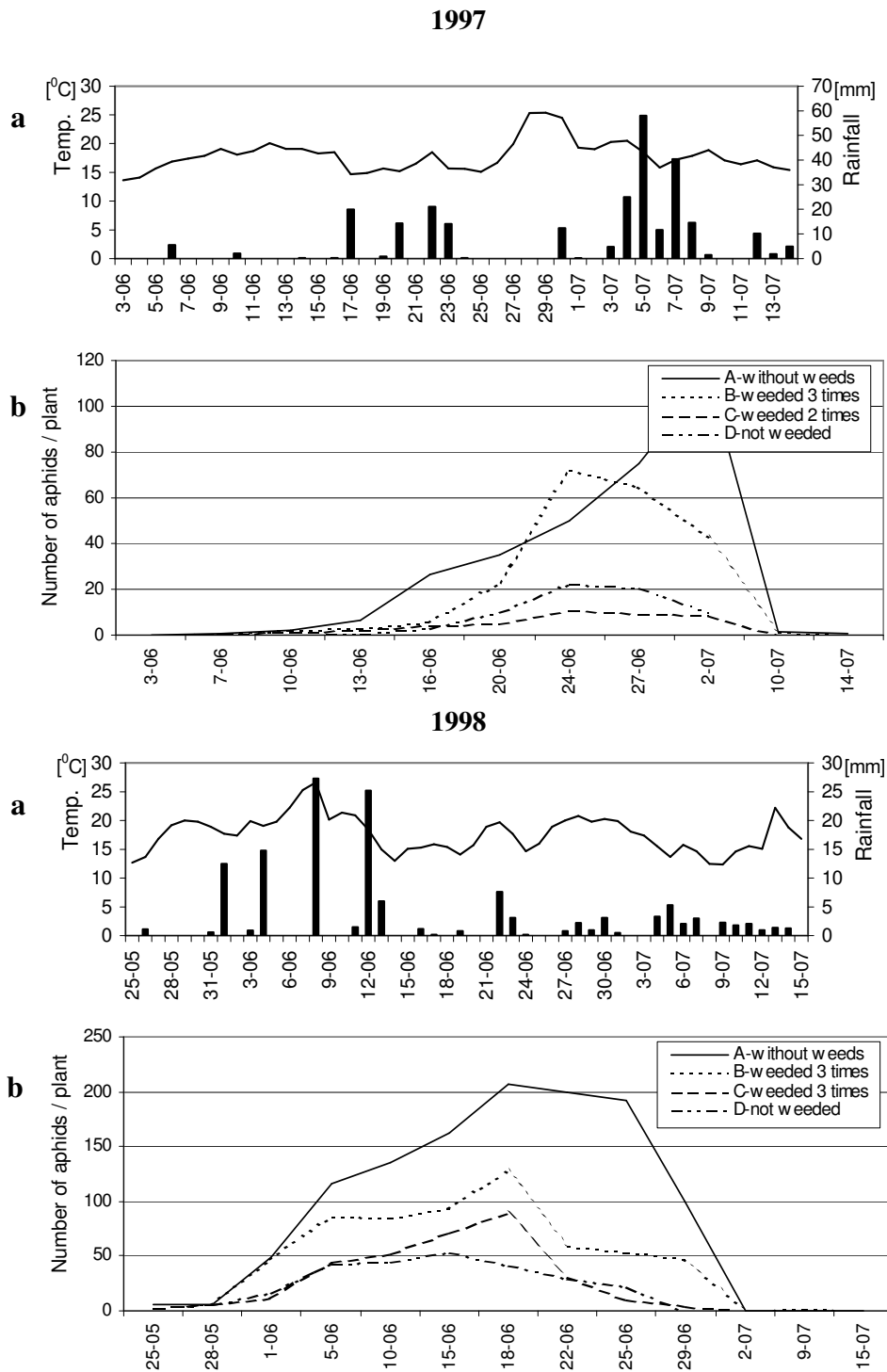


Fig. 2. The weather conditions (a) and dynamics of population of *Aphis fabae* Scop. on red beet (b) (Mydlniki 1997 – 1998)

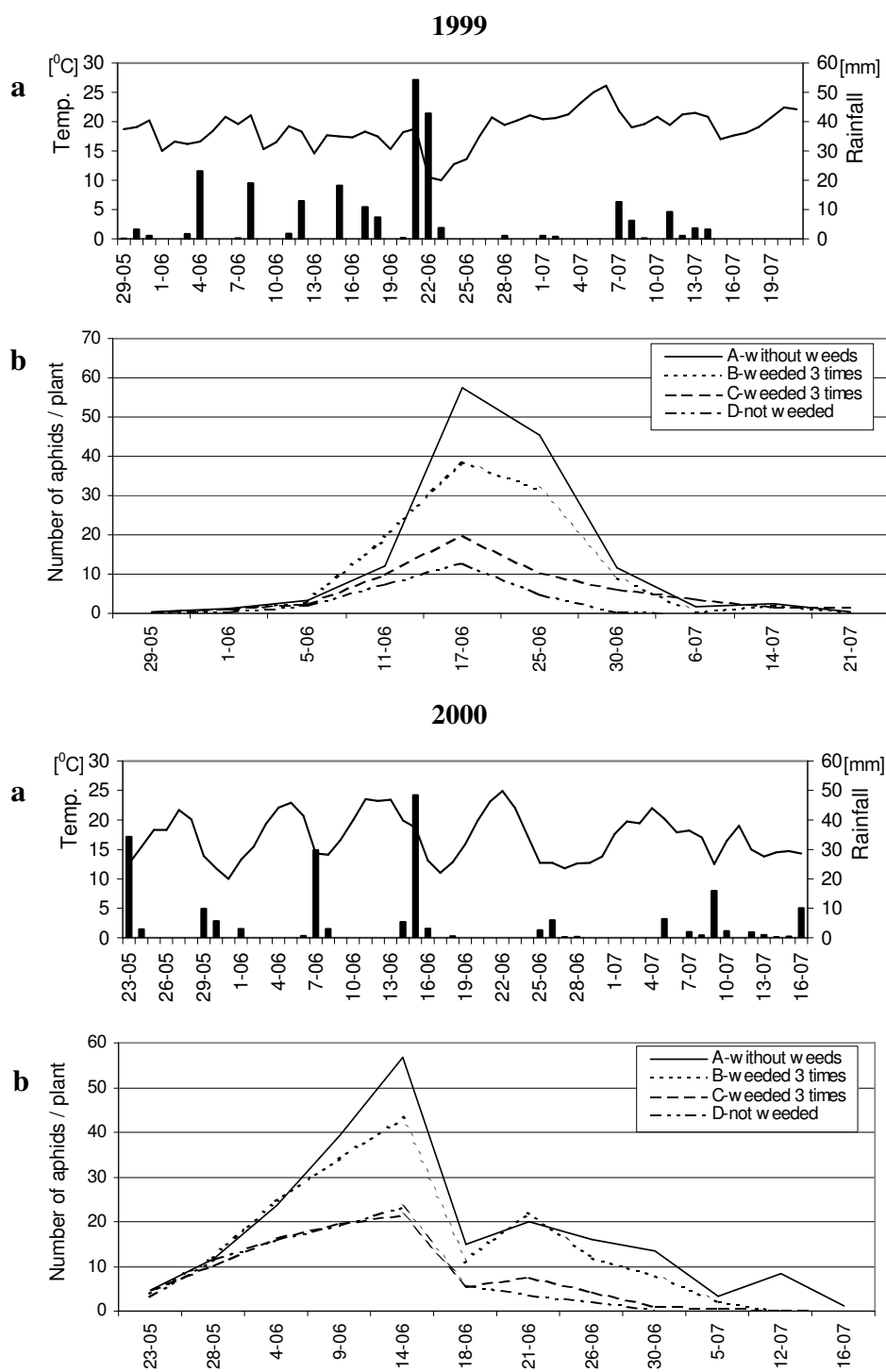


Fig. 3. The weather conditions (a) and dynamics of population of *Aphis fabae* Scop. on red beet (b) (Mydlniki 1999 – 2000)

Table 2. Selected information concerning the occurrence of *Aphis fabae* Scop. on red beet (Mydlniki 1995-2000)

Selected information	Combination			
	A	B	C	D
1995				
Mean number of aphids/plant (1)	12.0b	6.1ab	7.7ab	1.8a
Max. % of infested plants (1)	68.0c	38.0b	43.0 b	9.0a
Mean number of aphids/plant (2)	44.3b	18.5ab	18.4ab	5.0a
Mean % of infested plants (2)	44.4c	23.1b	15.4b	3.3a
1996				
Mean number of aphids/plant (1)	57.7 b	46.0ab	43.5ab	36.0a
Max. % of infested plants (1)	96.0b	86.0ab	87.0ab	67.0a
Mean number of aphids/plant (2)	202.9a	178.0a	132.1ab	116.2b
Mean % of infested plants (2)	53.8b	53.1b	50.8b	37.1a
1997				
Mean number of aphids/plant (1)	112.8c	65.0b	10.5a	22.4a
Max. % of infested plants (1)	85.0c	63.0b	33.0a	39.0a
Mean number of aphids/plant (2)	310.5c	216.0b	43.1a	67.2a
Mean % of infested plants (2)	32.5b	26.6ba	16.6a	14.1a
1998				
Mean number of aphids/plant (1)	207.3c	127.3b	89.7ba	53.9a
Max. % of infested plants (1)	94.0b	79.0a	75.0a	70.0a
Mean number of aphids/plant (2)	1177.1c	616.4b	325.7a	262.5a
Mean % of infested plants (2)	53.8b	48.0ba	34.1a	31.6a
1999				
Mean number of aphids/plant (1)	57.4c	38.8bc	20.1ba	13.1a
Max. % of infested plants (1)	64.0b	54.0b	33.0a	26.0a
Mean number of aphids/plant (2)	135.9c	106.2cb	57.7b	28.9a
Mean % of infested plants (2)	28.3c	23.9cb	16.3b	9.5a
2000				
Mean number of aphids/plant (1)	56.7b	43.1ab	21.6a	23.2a
Max. % of infested plants (1)	63.0b	50.0b	34.0a	36.0a
Mean % of aphids/plant (2)	213.4b	173.1ab	92.4a	84.6a
Mean percent of infested plants (2)	32.0b	25.9ab	16.3a	15.0a

A-without weeds, B- weeds removed three times, C-weeds removed twice, D-not weeded

Values in one row with the same letter do not differ statistically from each other (P=0.05)

(1) - period of the most intensive occurrence of aphids

(2) - all vegetation season

Table 3. Soil coverage by weeds (%) (Mydlniki 1995-2000)

Year	Date of observation	Combination			
		A without weeds	B weeds removed three times	C weeds removed twice	D not weeded
1995	23. 06	0	45	40	50
	17. 07	0	10	87	97
	27. 07	0	20	38	100
	06. 08	0	58	100	100
1996	25. 06	0	15	20	48
	10. 07	0	10	65	98
	29. 07	0	14	18	100
1997	03. 06	0	15	12	16
	20. 06	0	0	62	66
	02. 07	0	27	83	87
	14. 07	0	2	0	95
1998	05. 06	0	31	43	39
	18. 06	0	3	10	97
	25. 06	0	13	37	100
	09. 07	0	51	94	100
1999	05. 06	0	15	28	29
	17. 06	0	46	6	100
	30. 06	0	19	39	100
	14. 07	0	0	83	100
2000	04. 06	0	12	26	28
	14. 06	0	39	56	56
	21. 06	0	0	5	84
	30. 06	0	14	27	100

Table 4. Correlation coefficients (for average values 1995-2000)

Analyzed dependencies	Correlation coefficient R	Error of correlation coefficient Sr
Coverage of soil by weeds / number of aphids	-0.383*	0.087
Coverage of soil by weeds / % of plants infested by aphids	-0.58*	0.067

$r_{\text{teor. } P=0.05} = 0.2008$ ;  $r_{\text{teor. } P=0.01} = 0.2619$

\*Dependence significant at  $P=0.01$

Table 5. Yield ( $\text{kg}\cdot\text{m}^{-2}$ ) and reduction of root yield (%) of red beet in comparison to A-without weeds (Mydlniki 1995-2000)

Year	Combination							
	A-without weeds		B-weeds removed three times		C-weeds removed twice		D-not weeded	
	yield (kg)	reduction (%)	yield (kg)	reduction (%)	yield (kg)	reduction (%)	yield (kg)	reduction (%)
1995	3.9c	0.0	3.6c	7.7	2.8b	28.2	1.0a	74.3
1996	2.2c	0.0	2.0c	10.0	1.7b	22.7	1.1a	50.0
1997	2.6c	0.0	2.4c	7.7	1.8b	30.8	0.7a	73.1
1998	1.8c	0.0	1.7c	5.5	1.3b	27.8	0.6a	66.7
1999	2.2b	0.0	1.9b	13.6	1.4ba	36.4	0.6a	72.7
2000	2.7d	0.0	2.3c	14.8	1.8b	33.3	-*	-*
Mean	2.6	0.0	2.3	11.5	1.8	29.8	0.8	67.3

Values in one row with the same letter do not differ statistically from each other ( $P=0.05$ )

\* The yield from combination D not included

## DISCUSSION

Over all years, the greatest number of black bean aphid was observed in combination without weeds. The presence of weeds on the plots of the remaining combinations, including the species which are the host-plants for *Aphis fabae* (i.e. *Chenopodium album* L., *Cirsium arvense* (L.) Scop.), always lowered this number.

The best conditions for the infestation of red beet and the development of aphids during the whole development period of *A. fabae* were on combinations without weeds. The presence of weeds always limited both the percent of infested plants and the development of black bean aphid. Similar effect was observed by Smith (1976) on the weeded plots with Brussels sprouts, where despite the presence of cruciferous weeds, only a small number of *Brevicoryne brassicae* L. was found. Also Horn (1981) observed significantly lower occurrence of *Myzus persicae* Sulz. on collards cultivated with the presence of weeds. The greater number of black bean aphids on plots without weeds in comparison to the remaining plots was probably caused by the fact, that the plants with stronger contrast between the plant and soil were more often selected by aphids. The same role of contrast between the soil and cultivated plant in selection of plants by aphids, including *A. fabae* was noticed by other authors comparing the number of aphids caught in traps placed in cultivations with different density of plants (A'Brook 1973).

The lower number of plants on plots without weeds or with few number of weeds in comparison with weeded plots facilitated the infestation of red beet by aphids. The additional factor attracting the aphids could be the green color of weeds. It could increase the frequency of so called "inappropriate" landings, and lower the probability of finding the host plant. The theory of "appropriate" and

"inappropriate" landings described by Finch & Collier (2000) also can explain the reason for the lower infestation of red beet by *A. fabae* on weeded plots. Additionally, on weeded plots, where apart from red beet there were various species of other plants, *A. fabae* faced a lot of odour stimulus, which could make difficult to find the host plant. According to Pickett *et al.* (1992), aphids are flying toward the source of odours accompanying their host plants. While in the works by Nottingham & Hardie (1993) about the behavior of *A. fabae* during the flight there is the opinion, that the odour of non-host plant can change the behavior of aphids just before the landing. It should be noted, that weeds were not only covering the soil, but very often were higher than red beets, thus protecting these plants from aphids. However, it seems on the basis of the analysis of the weediness of the plots in various periods of the development of black bean aphid that this effect could be more important during the late development period of *A. fabae*, hindering the re-emigration on the neighbouring plants.

The weediness always lowered the yields in the experiments, although in combination weeded three times (B), the yield was nearly the same as on the combination without weeds (A). Additionally, in this combination, the weeds around the red beets were lowering the number of aphids during the period of their development. The decrease of the weeding frequency to the two times and the presence of the weeds during the vegetation period limit the number of pests, but also cause the significant loss of the yield. This is probably due to the critical period of the competition of weeds, which is different for various vegetables. Dobrzański (1996) classify red beet as the medium sensitive to weediness. Kołota & Osińska (1997) noticed that the critical period of the competition for the red beet lasts to the 6 weeks from the moment of the rise. The presence of weeds in May or June in the combination weeded twice (C) significantly limited the number of aphids, but also significantly reduced the yield in comparison to the combination weeded three times (B). The loss of the yield on the combinations not weeded (D) in comparison to the combination without the weeds (A) was from 50.0 to 74.3%. According to Kołota & Osińska (1997), the loss of the yield of red beet in the cultivation where the weeds were not removed is 53.4%.

Based on the comparison of the occurrence of aphids, the degree of weediness and the crops from the individual combinations it can be state that maintaining the certain level of weediness can be used as a treatment in integrated protection of red beet against the *A. fabae*.

## CONCLUSIONS

1. The presence of weeds in the red beet cultivation always reduced the number of *Aphids fabae* Scop. and the degree of infestation of plants. The lowest number of black bean aphid was noticed in combination with the greatest coverage of soil by weeds, while the plots without the weeds created the best conditions for their development.

2. The yield on combination weeded three times was nearly as high as on combination without weeds, and the weeds neighbouring the beets during the period of the development of black bean aphid lowered the total number of aphids and the average percent of infested plants.

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#### WPŁYW ZACHWASZCZENIA NA OPANOWANIE BURAKA ĆWIKŁOWEGO PRZEZ MSZYCĘ BURAKOWĄ (*APHIS FABAE* SCOP.)

##### Streszczenie

W latach 1995-2000 przeprowadzono badania nad występowaniem *Aphis fabae* Scop. na buraku ćwikłowym, w zależności od różnego stopnia pokrycia gleby przez chwasty. Zróżnicowane zachwaszczenie poletek uzyskano poprzez zastosowanie różnej częstotliwości przeprowadzonych mechanicznie zabiegów odchwaszczających w poszczególnych kombinacjach. W kombinacji A odchwaszczanie przeprowadzono systematycznie, utrzymując poletka bez chwastów, w kombinacji B odchwaszczanie przeprowadzono trzykrotnie, w kombinacji C dwukrotnie, a w kombinacji D poletek nie odchwaszczano. We wszystkich latach badań stwierdzono, że najliczniej mszyca burakowa wystąpiła na poletkach bez chwastów. W miarę jak zmniejszała się liczba zabiegów odchwaszczających, czyli wraz ze wzrostem pokrycia gleby przez chwasty, liczebność mszycy burakowej oraz zasiedlonych roślin malała. W najmniejszym nasileniu *A. fabae* występowała na poletkach dwukrotnie odchwaszczanych i nie odchwaszczanych.



**A COMPARISON OF THE OCCURRENCE  
OF THE DIAMONDBACK MOTH *PLUTELLA XYLOSTELLA* L.  
(*LEPIDOPTERA, PLUTELLIDAE*) ON DIFFERENT CABBAGE  
VEGETABLES**

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Summary

From 1993-1997 the occurrence of the diamondback moth was observed on nine different cabbage vegetables: savoy cabbage cv. Vertus, white cabbage cv. Amager, red cabbage cv. Langendijker, Brussels sprouts cv. Maczuga, cauliflower cv. Pionier, blue kohlrabi cv. Masłowa, white kohlrabi cv. Delikates, kale cv. Zielony Kędzierzawy and broccoli cv. Piast. The highest infestation of diamondback moth was observed in mid-July, while in 1997 it occurred in the beginning of August. In all the years of the study, the greatest number of caterpillars was noted on Brussels sprouts. In all the years of the research, except 1997, among the tested vegetables the least infested was kale. Heavy rainfalls may be an important factor decreasing the number of diamondback moth caterpillars on the vegetables.

key words: *Plutella xylostella* L., cabbage vegetables

INTRODUCTION

The diamondback moth (DBM), *Plutella xylostella* L., is one of the most important pests affecting cruciferous crops. It is particularly damaging to cabbage vegetables in Poland and throughout the world and can cause serious economic losses (Łagowska 1979, Kempczyński 1983, Rice & Hahr 1994). The life cycle can be completed in 12-33 days depending on the temperature (Park *et al.* 1993). In Poland the diamondback moth has 3-4 generations each year. Caterpillars feed on leaves making small holes and “windows”, but may also destroy the growing point which stops from cabbage forming heads (Kempczyński 1983). Several factors determine searching and choosing a host plant by insects including visual stimuli. In spite of the fact that cabbage vegetables are botanical varieties of one species (*Brassica oleracea* L. var. *sylvestris*), they show considerable morphological differences within the group (Peterman & Tschirner 1987). Chemical attractant become also the factors influencing the process offinding a host plant. According to many authors (Gupta & Thorsteinson 1960, Srinivasan & Moorthy 1991, Pawar & Lawande 1995, Mitchell *et al.* 1997, Pivnick *et al.* 1990), *Plutella xylostella* is stimulated

to oviposition on cabbage leaves by the secondary plant compound - allyl isothiocyanate. Therefore, although cabbage vegetables are all attacked by diamondback moth, their attractiveness for this pest varies. The aim of the study was to compare the infestation of different cabbage vegetables by the diamondback moth *Plutella xylostella* L.

## MATERIALS AND METHODS

Observations of the occurrence of *Plutella xylostella* L. were carried out in the Plant Protection Experimental Station in Mydlniki near Krakow from 1993–1997, on typical brown soil with a pH of 6.5 and  $C_{org}$  content 1.8%. The following nine late cruciferous vegetables; savoy cabbage cv. Vertus, white cabbage cv. Amager, red cabbage cv. Langendijker, Brussels sprouts cv. Maczuga, cauliflower cv. Pionier, blue kohlrabi cv. Masłowa, white kohlrabi cv. Delikates, kale cv. Zielony Kędzierzawy and broccoli cv. Piast (except 1993), were grown on plots of 30 m<sup>2</sup> each, in four replications. Plants were planted: in 1993 - on 5<sup>th</sup> of June, in 1994 - on 14<sup>th</sup> of June, in 1995 - on 30<sup>th</sup> of May. Every plot contained 90 plants (10 plants of each vegetable, 60 x 60 cm spacing), planted in such a way that plants of the same kind never adjoined. Near the experimental plots other vegetables - broad bean, tomatoes, pepper, carrot, onion and red beet were cultivated. No insecticidal treatment was applied. During the observation, every 3–4 days, 12 plants from each vegetable were inspected. Each time the larvae and pupae of the diamondback moth were counted. The Duncan multiple test ( $\alpha < 0.05$ ) was used for statistical analysis of the results.

## RESULTS AND DISCUSSION

The diamondback moth was observed in each year of the experiment and occurred on all studied vegetables, except kale in 1993 (Table 1). The first instar larvae were leaf miners, but later instars fed on the leaf surface. Caterpillars did not eat the veins on and the leaves appeared with windows or holes in them. Feeding caterpillars were observed both the upper and lower surfaces of the leaf. This corresponds with the observations of Kempczyński (1983).

The greatest infestation was observed in the last year of the study i.e. 1997, when up to 20 caterpillars were feeding simultaneously on a single plant (Fig. 5). The weakest infestation was observed in 1993 (Fig. 1) and 1996 (Fig. 4), which may have resulted from low temperatures in the spring. Females of the diamondback moth stop laying eggs when the temperature falls below 12°C, or when windforce reaches 2 m·s<sup>-1</sup> (Harcourt 1957). When the temperature drops below 7°C they cease to fly (Goodwin & Danthanarayana 1984).

Łagowska (1979), who carried out research on the population dynamics of the diamondback moth on late white cabbages (including “Amager”), observed the greatest infestation in mid-August. During my observation the biggest

infestation on white cabbage as well as other tested vegetables occurred one month earlier (Fig. 1-4). In only one instance - 1997 - was the biggest infestation observed in the beginning of August (Fig. 5).

The earliest infestation was observed on 11<sup>th</sup> of June in 1993, initially on only two of the tested vegetables, i.e. Brussels sprouts and red cabbage. Despite the early appearance, the period of occurrence was not long. The last caterpillars and pupae (the most numerous being on the Brussels sprouts) were observed on 22<sup>nd</sup> of July (Fig. 1). In 1997 the caterpillars appeared late, - on 10<sup>th</sup> of July. In spite of such a late appearance the occurrence period in this year was the longest, lasting until the beginning of September (Fig. 5).

The occurrence period of caterpillars was similar on all tested vegetables. Statistically significant differences were found mainly between the most infested and the least infested vegetables (Table 1).

Rice & Hahr (1994) found that especially the cabbage, cauliflower, Brussels sprouts, broccoli and collard were attacked by the diamondback moth. In Poland only Kempczyński (1983) compared the occurrence of the diamondback moth, but only on few cruciferous crops. According to this author the white cabbage, Brussels sprouts, cauliflower and kale are the most frequently chosen, and red cabbage is the least preferred. During the entire period of observation (except in 1994) the Brussels sprouts was the most infested vegetable. In 1994 was the red cabbage was slightly more infested only (Table 1).

Phytophagous insects locate plants for oviposition on the basis of scent and visual stimuli. Biologically active compounds called glucosinolates are feeding and oviposition stimulants for such a crucifer specialist. According to many authors (Gupta & Thorsteinson 1960, Srinivasan & Moorthy 1991, Pawar & Lawande 1995, Mitchell *et al.* 1997, Pivnick *et al.* 1990), *Plutella xylostella* is stimulated to oviposition on cabbage leaves by the secondary plant compound - allyl isothiocyanate. In the Brussels sprouts and white cabbage this compound is present in significant quantities (Carlson *et al.* 1987, Gow-Chin Yen & Que-King Wei 1993, Ciska *et al.* 1994), and this may account for the fact that females of the diamondback moth preferred these vegetables for laying eggs. This compound also occurs in quantity in the kale, and that is why Mitchell *et al.* (1997) suggest using this plant as a trap crop. However in the years 1993-1996 kale was the least infested among the tested vegetables (Table 1). Only in 1997 were there many feeding caterpillars on the kale, which may possibly have resulted from the specific weather conditions that year. Year 1997 was characterized by violent storms and long periods of rain (sometimes up to a week-long) after which many caterpillars which had been washed away were found underneath the plants. Harcourt (1957) and Carballo (1989) found also that heavy rainfalls may wash caterpillars off of plants. In such cases caterpillar mortality, especially among the first instars, may reach up to 65% (Harcourt 1957). The caterpillars feeding on kale were the least affected by the rains most likely due to the specific texture of the kale leaf, which may have provided a better grip for caterpillars.

Table 1. The occurrence of diamondback moth (*Plutella xylostella* L.) larvae and pupae on the tested cabbage vegetables (1993-1997)

Cultivar	1993			1994			1995			1996			1997		
	Mean number / plant			Mean number / plant			Mean number / plant			Mean number / plant			Mean number / plant		
	larvae	pupae	total	larvae	pupae	total	larvae	pupae	total	larvae	pupae	total	larvae	pupae	total
Savoy cabbage	0.04	0.06	0.10 ab	0.17	0.11	0.28 ab	3.05	0.3	3.35 b	0	0.33	0.33 a	6.57	2.57	9.14 c
White cabbage	0.33	0.13	0.46 bc	0.31	0.19	0.5 ab	4.7	1.6	6.3 e	0.33	0.58	0.91 ab	7.9	3.44	11.34 d
Blue cohlrabi	0.38	0.08	0.46 bc	0.67	0.01	0.68 c	5.1	0.4	5.5 cde	0.33	0.33	0.66 ab	8.73	2.6	11.33 d
Kale	0	0	0 a	0.13	0	0.13 a	1.7	0.35	2.05 a	0.08	0.17	0.25 a	8.87	4.5	13.37 e
Cauliflower	0.12	0.08	0.2 abc	0.46	0.12	0.56 bc	4.5	0.35	4.85 cd	0.33	0.4	0.73 ab	7.5	1.97	9.47 cd
Brussels sprout	0.48	0.15	0.63 c	0.7	0.1	0.8 c	6.15	0.6	6.75 e	0.67	0.58	1.25 b	10.1	4.03	14.13 e
White cohlrabi	0.33	0	0.33 abc	0.33	0	0.33 ab	4	0.4	4.4 bc	0.17	0.17	0.34 a	3.13	0.57	3.7 a
Red cabbage	0.25	0.13	0.38 abc	0.75	0.07	0.82 c	4.95	1	5.95 de	0.33	0.33	0.66 ab	3.6	1.7	5.3 ab
Broccoli	x	x	x	0.5	0.09	0.59 bc	4.38	0.15	4.53 bc	0.25	0.25	0.5 ab	5.1	0.93	6.03 b

Values followed by the same letter do not differ at 5% level of significance (Duncan's multiple test)

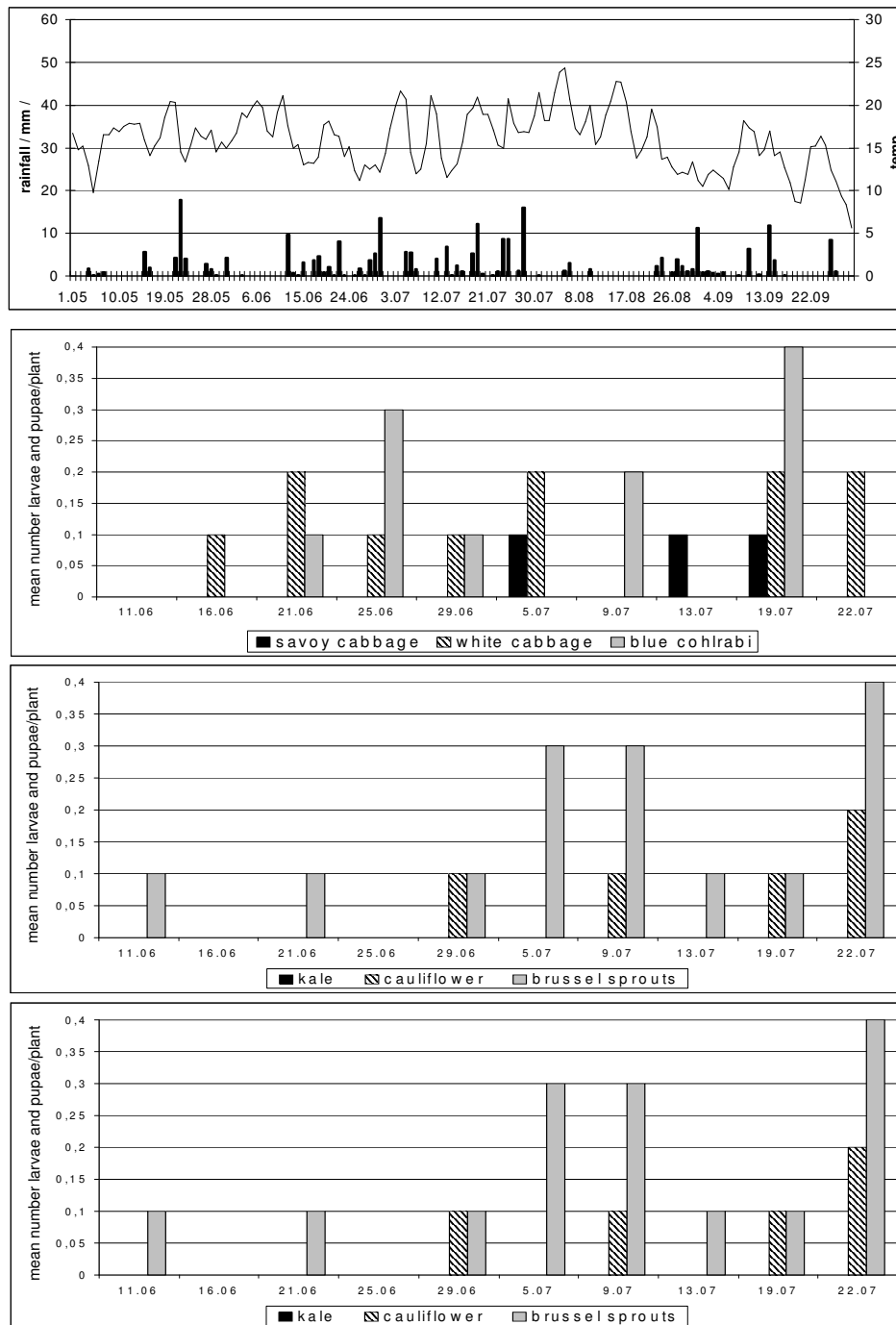


Fig. 1. The population dynamics of diamondback moth (*Plutella xylostella* L.) on different cabbage vegetables in 1993

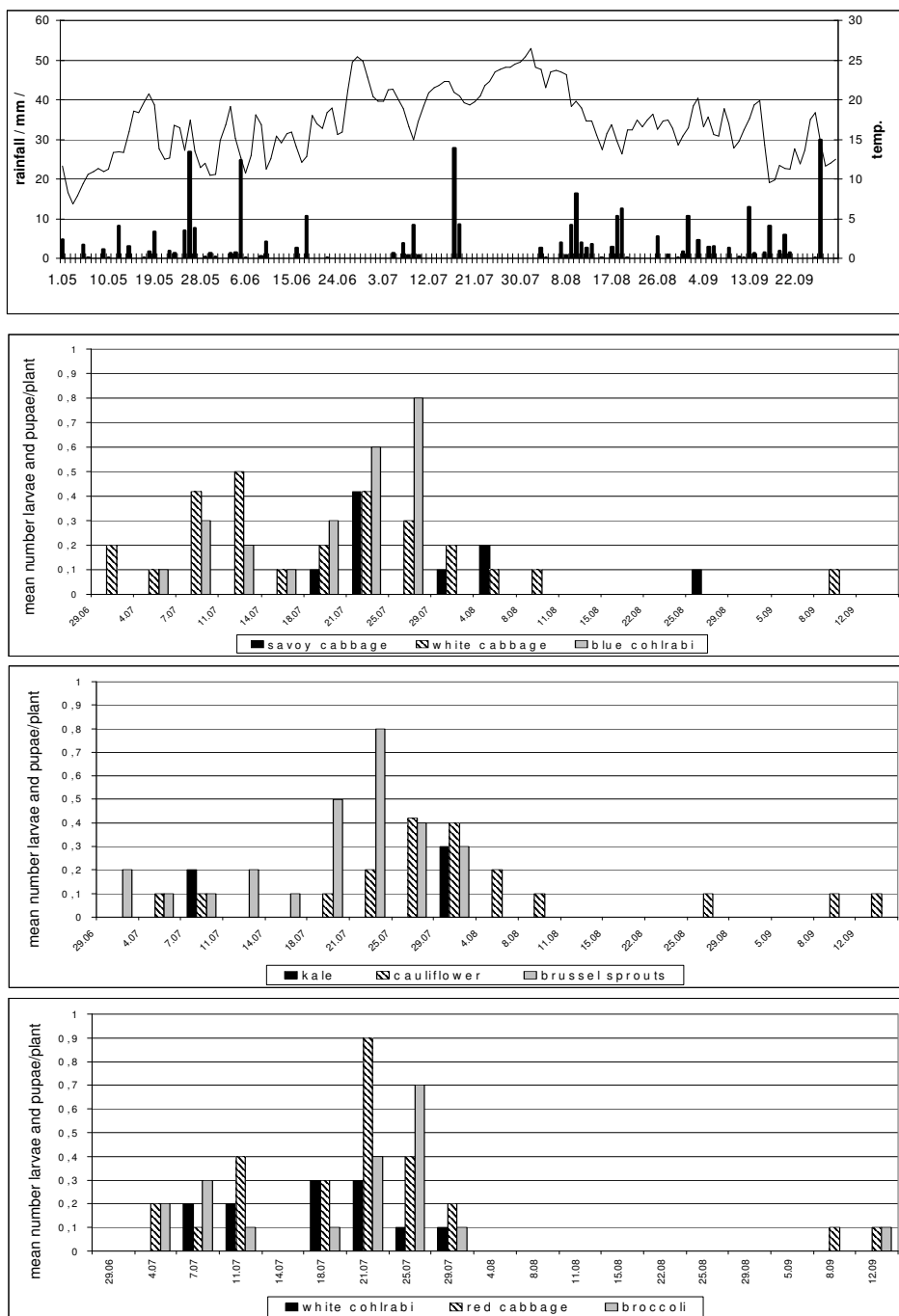


Fig. 2. The population dynamics of diamondback moth (*Plutella xylostella* L.) on different cabbage vegetables in 1994

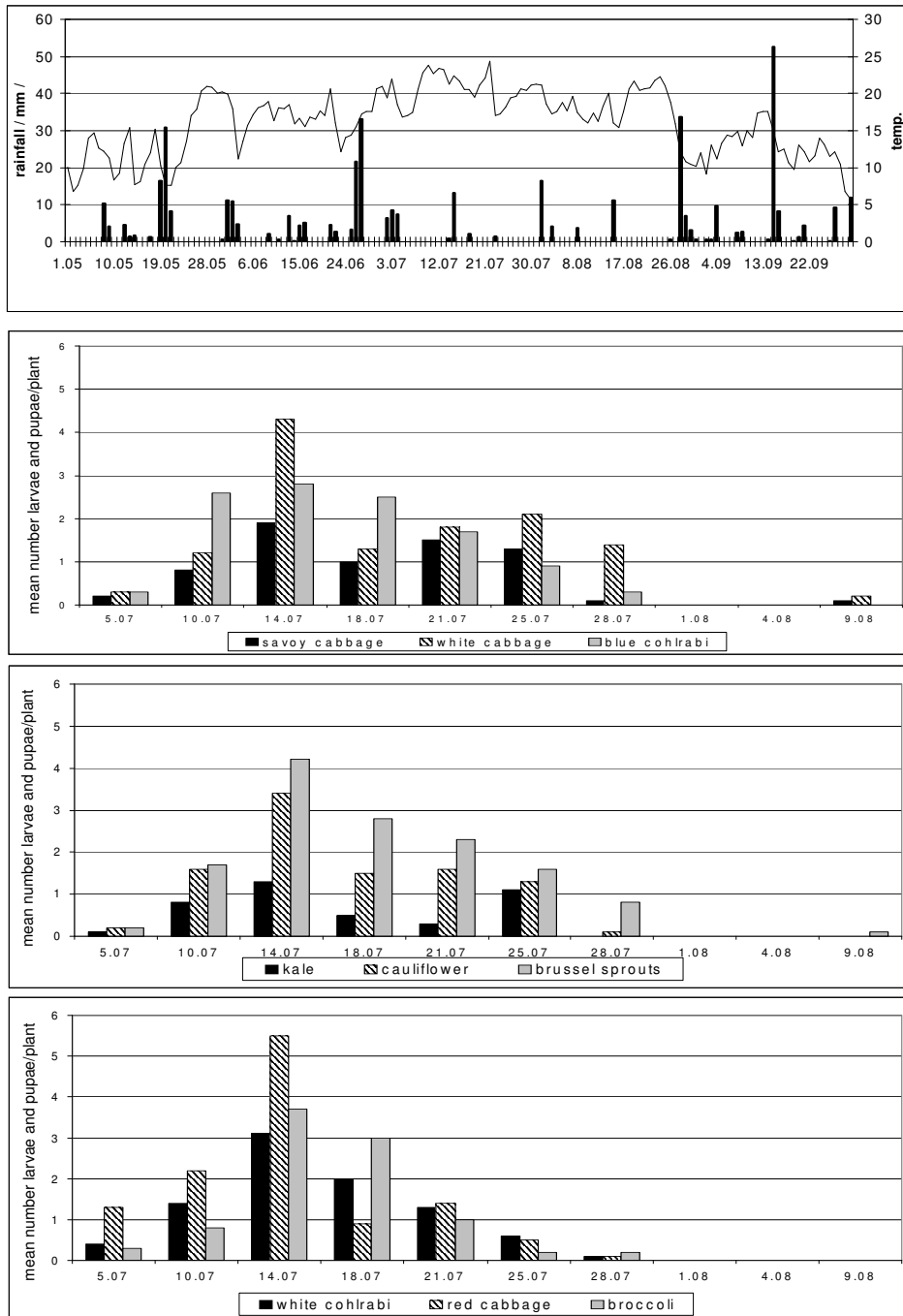


Fig. 3. The population dynamics of diamondback moth (*Plutella xylostella* L.) on different cabbage vegetables in 1995

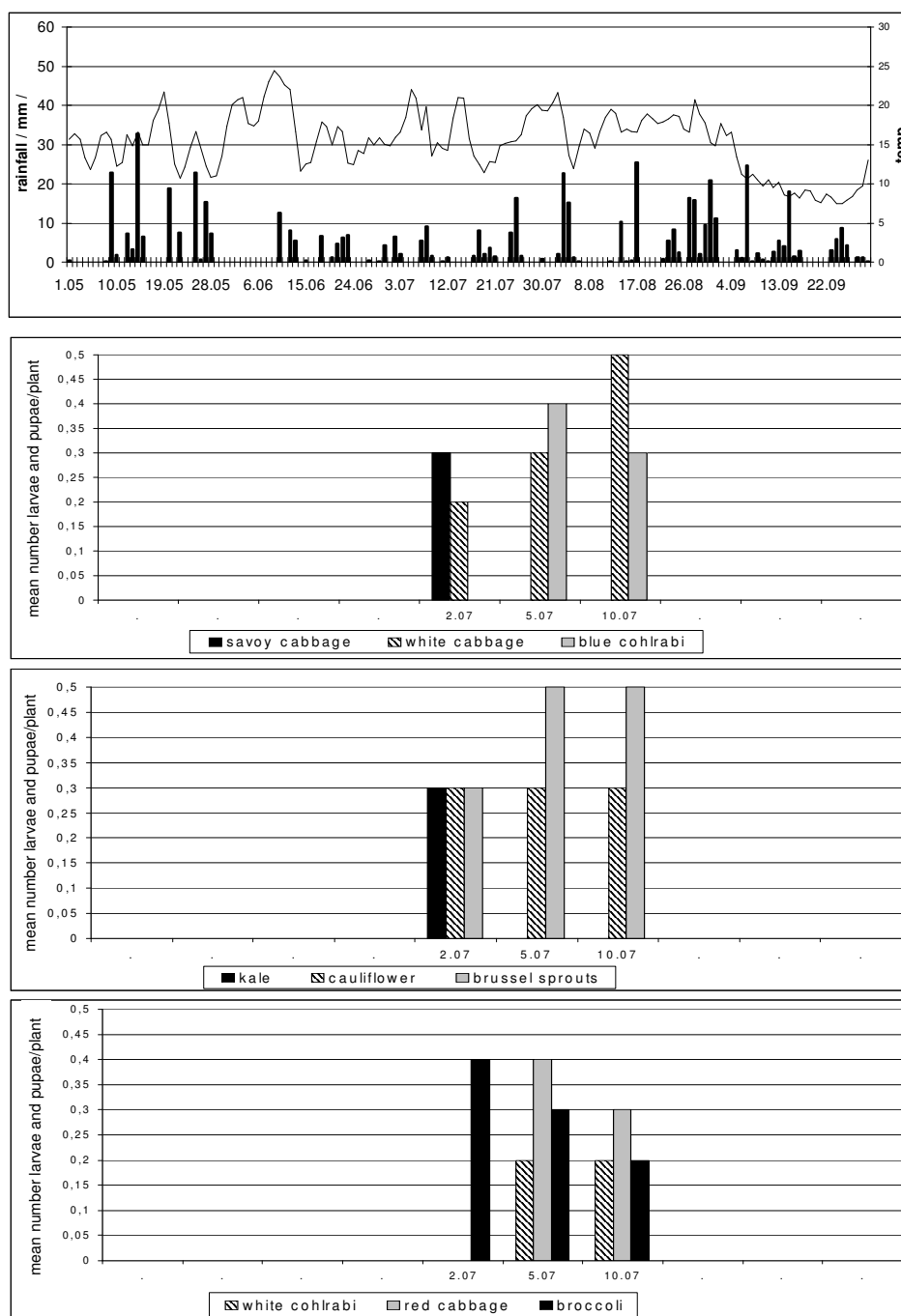


Fig. 4. The population dynamics of diamondback moth (*Plutella xylostella* L.) on different cabbage vegetables in 1996



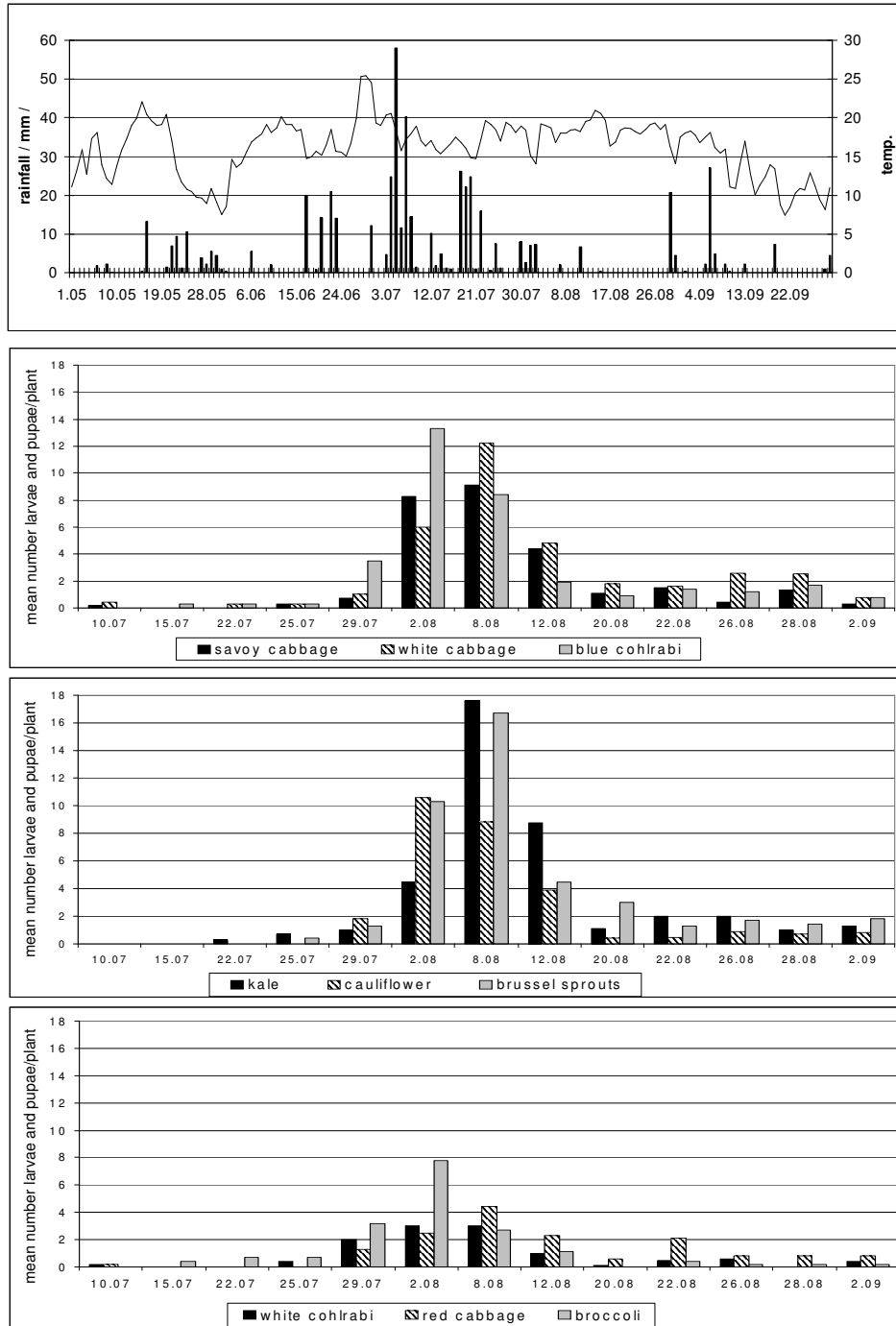


Fig. 5. The population dynamics of diamondback moth (*Plutella xylostella* L.) on different cabbage vegetables in 1997

## CONCLUSION

1. The highest infestation of diamondback moth in the period 1993-1996 was observed in mid-July, while in 1997 it occurred in the beginning of August.
2. In all the years of the study, the greatest number of caterpillars was noted on Brussels sprouts. In all the years of the research, except 1997, the least infested among the tested vegetables was kale.
3. Heavy rainfalls may be an important factor decreasing the number of diamondback moth caterpillars on the vegetables.

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PORÓWNANIE WYSTĘPOWANIA TANTNISIA KRZYŻOWIACZKA  
(*PLUTELLA XYLOSTELLA* L.) NA RÓŻNYCH WARZYWACH KAPUSTNYCH

Streszczenie

W latach 1993-1997 obserwowano występowanie tantnisia krzyżowiaczka na 9 różnych odmianach botanicznych warzyw z rodziny kapustowatych. W doświadczeniu wykorzystano późne odmiany: kapusty włoskiej - Vertus, kapusty głowiastej białej - Amager, kapusty czerwonej - Langendijker, kapusty brukselskiej - Maczuga, kalafiora - Pionier, kalarepy niebieskiej - Masłową, kalarepy białej - Delikates, jarmużu - Zielony Kędzierzawy oraz brokuła włoskiego - Piast. Najliczniejsze żerowanie gąsienic obserwowano w drugiej połowie lipca i na początku sierpnia. Nie stwierdzono różnic w terminie i długości występowania tantnisia na poszczególnych odmianach, ale stwierdzono różnice w liczebności ich zasiedlenia. Najwięcej żerujących gąsienic we wszystkich latach obserwowano na kapuście brukselskiej, a najmniej na jarmużu.

## ANTIOXIDANT ACTIVITY AND PHENOLIC CONTENT IN SOME STRAINS OF MUSHROOMS (*AGARICUS BISPORUS*)

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### Summary

Antioxidant activity of phenolic extracts from mushrooms of four strains as Roxx, Maxx, A15 and 2200 were determined. Free phenolic content of fresh mushrooms ranged from 176 to 487 mg·kg<sup>-1</sup>. Five days storage at temperature +2°C induced an increase (1.6 fold on average) of free phenolic content in all strains of mushrooms except 2<sup>nd</sup> flush of Roxx strain. Antioxidant activity (EC<sub>50</sub>)<sup>-1</sup> value of fresh mushrooms, determined by scavenging of stable 2,2-diphenyl-1-picrylhydrazyl (DPPH·) radical varied from 2.46 to 8.95, depending on strain and flush number. Highest value of (EC<sub>50</sub>)<sup>-1</sup> was found for mushrooms from the second flush of Maxx strain. (EC<sub>50</sub>)<sup>-1</sup> of mushrooms from the first flush of Roxx strain was over 3.2 fold higher than that from the second one. Similar trends were observed for the antiradical efficiency (AE). Storage of mushrooms diminished highest values of (EC<sub>50</sub>)<sup>-1</sup> and AE (Roxx 1<sup>st</sup> flush and Maxx 2<sup>nd</sup> flush) by 70-75% but it did not change significantly these values for A15 and 2200 (1<sup>st</sup> flush) strains. Regression analysis showed a negative high correlation ( $r = -0.904$ ) between free phenolic content and AE. Storage of mushrooms all tested strains decreased significantly (an average 36%) antioxidant activity of free phenolic extracts measured by the method based on coupled oxidation of β-carotene and linoleic acid.

key words: *Agaricus bisporus* mushrooms, strain, flush, phenolic content, antioxidant activities

### INTRODUCTION

Epidemiological data as well as *in vitro* studies strongly suggest that foods containing natural antioxidant phytochemicals have strong protective effects against various degenerative disease risk (Ames *et al.* 1993, Weisburger 1999). Commercially produced mushrooms are valued primarily as a culinary food. However, the bioactive components of mushrooms of nutritional, medicinal and biological importance, have received recently much more attention. The bioactive properties of 10-oxo-*trans*-8-decanoic acid, natural metabolite of most mushrooms was described by Beelman *et al.* (2003). It stimulates growth and

secondary metabolite production by mycelia and fruiting body formation from mycelia. Oxidation products of one of the major mushroom phenolic compounds L-3,4-dihydroxyphenylalanine (L-DOPA) probably trigger cellular processes that upregulate the overall antioxidant status of the cell (Shi *et al.* 2004). In recent years, particular attention has been given to a specific class of antioxidant phytochemicals, the polyphenols, which are comprised basically of phenolic acids and aminoacids and flavonoids. Polyphenolic substances are naturally present in essentially all plant material and are prominently ubiquitous in vegetables, fruits, cereals and mushrooms. Their protective effects against various disease can be explained by the capacity of antioxidants in the plant foods to scavenge free radicals which are responsible for the oxidative damage of lipids, proteins and nucleic acids (Decker 1997).

Mushrooms accumulate a variety of secondary metabolites, including phenolic compounds, polyketides, terpenes and steroids, therefore in this study the antioxidative activities of selected mushroom strains were investigated in relation to their phenolic content.

## MATERIALS AND METHODS

Mushrooms, grown on chicken manure based compost were obtained from a commercial grower. The growing conditions were applied according to general recommendation for mushrooms production, using phase II compost involves inoculation with mushroom spawn and incubation by the mushroom grower. Four mushroom strains were tested: Roxx, Maxx, A15 and 2200. Freshly harvested mushrooms free of blotch, from each individual flush 1 and 2 were sorted by size (30-40 mm in diameter) and appearance. Diseased, damaged, open-veiled mushrooms were discarded. Stems were hand trimmed to stipe length 5 mm. Mushrooms of each strain and flush were analysed immediately as a fresh and then after 5 days storage at +2°C temperature.

Extracts of free and total phenolic compounds were prepared using published method for extraction and hydrolysis (Vinson *et al.* 1998) with some modification (Czapski & Grzegorzewska 2004). Sample (10 g) was homogenised with 60 ml of 50% aqueous methanol and then extracted by stirring for 30 min. The homogenate was filtered thorough No.2 Whatman paper on Buchner funnel under vacuum. The residue was re-extracted with 50% methanol and supernatants were pooled and transferred to 100 mL volumetric flask. Extract contained free phenols. Another weighed sample (10 g) was homogenised with 1.2 M HCl in 50% aqueous methanol and then was refluxed at 90°C for 30 min. Then further procedure was proceeded as for free phenols. The extract contained total phenols. Free and total phenolic content was determined using the Folin – Ciocalteu reagent (Ragazzi & Veronese 1973) and using catechin as a standard. All values were expressed as miligrams catechin equivalents per kilogram fresh weight ( $\text{mg}\cdot\text{kg}^{-1}$ ). There are different methods to evaluate the *in vitro* antioxidant activity of tissues. The results obtained depend on the method used (Sanchez-Moreno & Larrauri, cited by

Garcia-Alonso *et al.* 2004). For this reason in the present work two different methods were selected for evaluation of the antioxidant activity:  $\beta$ -carotene bleaching method based on coupled oxidation of  $\beta$ -carotene and linoleic acid (Emmons *et al.* 1999), and 2,2-diphenyl-1-picrylhydrazyl (DPPH $\cdot$ ) free radical scavenging assay (Brand-Williams *et al.* 1995, Sanchez-Moreno *et al.* 1998, 1999). In  $\beta$ -carotene bleaching method, aliquots (3 mL) of the  $\beta$ -carotene and linoleic acid emulsion were mixed with free phenolic compounds extract (0.1 mL) and incubated in a water bath at 50°C for 60 min. Oxidation of the emulsion was monitored spectrophotometrically by measuring absorbance at 470 nm. Control sample contained 0.1 mL 50% aqueous methanol. The degradation rate of  $\beta$ -carotene was calculated by first order kinetics. Antioxidant activity (AOA) was expressed as percentage inhibition of  $\beta$ -carotene degradation relative to the control after 60 min incubation, using the equation:

$$\text{AOA} = 100 \cdot (\text{DR}_c - \text{DR}_s) \cdot (\text{DR}_c)^{-1}$$

where: AOA is antioxidant activity;  $\text{DR}_c$  is degradation rate of the control,  $\text{DR}_c = \ln(a_c/b_c)/60$ ;  $\text{DR}_s$  is degradation rate of sample,  $\text{DR}_s = \ln(a_s/b_s)/60$ ;  $\ln$  is natural log;  $a$  is absorbance at time 0;  $b$  is absorbance at time 60 min.

Free radical scavenging activity of free phenolic extracts was determined by measurement absorbance of 0.025 g·L<sup>-1</sup> 2,2-diphenyl-1-picrylhydrazyl (DPPH $\cdot$ ) free radical solution with 0.1-0.5 mL extract. Changes in absorbances at 515 nm were recorded at 1 min intervals on Semco S/Ec spectrophotometer until the absorbance reached plateau. The percentage of remaining DPPH $\cdot$  was calculated from the following equation:

$$\% \text{DPPH}_{\text{rem}} = 100A_T \cdot A_0^{-1}$$

where  $A_T$  is an absorbance at time T needed to reach the steady state (beginning of plateau);  $A_0$  is an initial absorbance.

The graph of the relation between % DPPH $\cdot$ <sub>rem</sub> and phenolic concentrations was then used to calculate from the equation of linear regression the amount of phenolic antioxidants necessary to decrease the initial DPPH $\cdot$  by 50% ( $\text{EC}_{50}$  parameter, expressed as milligrams phenolic compounds per 1g DPPH $\cdot$  (mg·g<sup>-1</sup>)). For easier and more clear presentation of results of antioxidant activity, the reciprocal value of  $\text{EC}_{50}$  was used (Czapski & Grzegorzewska 2004).  $(\text{EC}_{50})^{-1}$  is expressed in milligrams DPPH $\cdot$  per 1 mg phenols.

Time [T( $\text{EC}_{50}$ )] needed to reach the steady state at the phenolic concentration corresponding  $\text{EC}_{50}$  was calculated graphically. The parameter antiradical efficiency (AE) which combines both  $\text{EC}_{50}$  and T( $\text{EC}_{50}$ ) was determined from the following equation (Sanchez-Moreno *et al.* 1998):  $\text{AE} = [\text{EC}_{50} \cdot \text{T}(\text{EC}_{50})]^{-1}$ .

Computer programme Excel 97 was used for calculation of kinetic parameters and correlation graphically. Two ways analysis of variance and Newman-Keuls comparisons were carried out to test for significant ( $P=0.95$ ) differences between means.

## RESULTS AND DISCUSSION

Free and total phenolic contents in fresh and stored mushroom strains are shown in Table 1. Free phenolic content of fresh mushrooms ranged from 176 to 487 mg·kg<sup>-1</sup>. A point worth mentioning is that free and total phenolic contents in fresh mushrooms from the second flush of Roxx strain were over 2.3 fold higher than those from the first flush. Mushrooms from the second flush of Maxx strain contained comparable low level of phenolic compounds as those from the first flush of Roxx strain. No significant differences were observed in free phenolic content among mushrooms obtained from the flush 1<sup>st</sup> and 2<sup>nd</sup> of A15 and 2200 strains. Storage induced an increase (1.6 fold an average) of free phenolic content in mushrooms of all strains except 2<sup>nd</sup> flush of Roxx strain. Highest increase of free and total phenolic compounds after storage was observed in mushrooms from the first flush of Roxx strain (2.8 fold and 2.2 fold respectively) and from the second flush of Maxx strain (2.6 fold and 1.8 fold respectively). Mushrooms from the second flush of Roxx strain after storage indicated 18% reduction of free and 28% reduction of total phenolic compounds. Irregular minor changes in total phenolic content were observed after storage of mushrooms A15 and 2200 strains.

Table 1. Phenolic compounds content of fresh and stored mushrooms

Strain (flush No)	Free phenolic content (mg·kg <sup>-1</sup> )		Total phenolic content (mg·kg <sup>-1</sup> )	
	fresh	stored	fresh	stored
Roxx (1)	176 h	492 bc	277 h	608 d
Roxx (2)	407 de	343 fg	657 bc	476 f
Maxx (2)	209 h	544 ab	399 g	727 a
A15 (1)	475 c	486 bc	687 b	580 d
A15 (2)	487 bc	580 a	606 d	639 c
2200 (1)	327 g	450 cd	502 ef	524 e
2200 (2)	321 g	386 bf	646 c	686 b

Note: Data followed by the different letters differ significantly at P=0.95 using Newman-Keuls test (separately for free and for total phenolic content)

Several major phenolic compounds as tyrosine, glutaminyl-4-hydroxybenzene (GHB), glutaminyl-3,4-dihydroxybenzene (GDHB), L-3,4-dihydroxyphenylalanine (L-DOPA) were found in *Agaricus bisporus* mushrooms. They are responsible for enzymatic browning reactions. Among them GHB was found to be distributed in every part of the fruiting bodies at higher concentrations than other phenolic compounds (Oka *et al.* 1981). It was found during this study (data not presented here) that the colour index (ratio of surface whiteness, lightness - "L" to yellowness - "b") which is an indicant of the discoloration of mushrooms, decreased after 5 days of storage of

mushrooms all tested strains an average 18%. It is in agreement with the findings of Beaulieu *et al.* (1999) that the content of phenolic compounds in mushrooms increased significantly and their surface whiteness decreased during storage for 2 days.

Among several methods to determine free radical scavenging, the model of scavenging the stable 2,2-diphenyl-1-picrylhydrazyl (DPPH·) radical is widely used method to evaluate antioxidant activity in relatively short time. Phenolic antioxidants (PheOH) are free radical terminators. The main reaction would be:  $\text{DPPH}\cdot + \text{PheOH} \rightarrow \text{DPPHH} + \text{PheO}\cdot$ . Table 2 shows antioxidant activity  $(\text{EC}_{50})^{-1}$  and antiradical efficiency (AE) of free phenolic extracts of fresh and stored mushrooms.  $(\text{EC}_{50})^{-1}$  of fresh mushrooms varied from 2.46 to 8.95. The highest value was found for the mushrooms from the second flush of Maxx strain.  $(\text{EC}_{50})^{-1}$  of fresh mushrooms from the first flush of Roxx strain was over 3.2 fold higher than that from the second one. Similar trends were observed also for antiradical efficiency (AE). According to following classification (Sanchez-Moreno *et al.* 1998) ( $\text{AE} \leq 10^{-3}$  low;  $10^{-3} < \text{AE} \leq 5 \cdot 10^{-3}$  medium;  $5 \cdot 10^{-3} < \text{AE} \leq 10^{-2}$  high and  $\text{AE} > 10^{-2}$  very high), antiradical efficiency of mushrooms is low, because its exponent value is  $10^{-4}$  (Table 2). It is characteristic that mushrooms (Roxx 1<sup>st</sup> flush and Maxx 2<sup>nd</sup> flush) which had the lowest level of free phenolic content (Table 1) had the highest values of  $(\text{EC}_{50})^{-1}$  and antiradical efficiency (Table 2). These findings suggests that only certain constituents are particularly responsible for strong antiradical effect. Storage diminished highest values of  $(\text{EC}_{50})^{-1}$  and AE (Roxx 1<sup>st</sup> flush and Maxx 2<sup>nd</sup> flush) by 70-75% and for mushrooms from the second flush of 2200 strain by 47% but did not change significantly these values for A15 and 2200 (1<sup>st</sup> flush) strains.

Table 2. Antioxidant activity parameters of free phenolic extracts of fresh and stored mushrooms

Strain (flush No)	$(\text{EC}_{50})^{-1}$		Antiradical efficiency	
	(mg DPPH· mg <sup>-1</sup> phenols)		AE·10 <sup>-4</sup>	
	fresh	stored	fresh	stored
Roxx (1)	7.95 b	2.75 de	3.50 b	1.03 cd
Roxx (2)	2.46 e	4.71 c	0.65 d	4.73 a
Maxx (2)	8.95 a	2.33 e	3.67 b	0.73 d
A15 (1)	4.17 cd	3.02 de	0.72 d	1.37 cd
A15 (2)	3.05 de	3.21 de	1.20 cd	1.43 cd
2200 (1)	4.71 c	3.45 cde	1.93 c	1.25 cd
2200 (2)	4.13 cd	2.26 e	1.33 cd	0.68 d

Note: Data followed by the different letters differ significantly at P=0.95 using Newman-Keuls test (separately for  $(\text{EC}_{50})^{-1}$  and for Antiradical efficiency AE)

Regression analysis showed that free phenolic content of fresh mushrooms was significantly correlated with AE (Fig. 1). The statistical analysis showed a negative high correlation between these two variables ( $r = -0.904$ ;  $P > 0.95$ ).



Several studies have reported on the relationship between the phenolic content and antioxidant activity, while others found no such relationship. Strong positive correlation between phenolic content and antioxidant activity in selected vegetables, fruits, grain products, Shitake and straw mushrooms were reported (Velioglu *et al.* 1998, Kaur & Kapoor 2002, Cheung *et al.* 2003, Cheung & Cheung 2005). No correlation between antioxidant activity and phenolic content was found in the studies of Kahkonen *et al.* (1999) and Ismail *et al.* (2004). Fact that the antioxidant activity did not show correlation with the content of phenolic compounds does not signify that these do not contribute to it but that this could be the result of the synergies or antagonisms, still unknown (Garcia-Alonso *et al.* 2004). There is a wide degree of variation between different phenolic compounds in their effectiveness as antioxidant (Robards *et al.* 1999). Statue-Gracia *et al.* (1997) stated that antioxidant activity of an extracts could not be explained just on the basis of their phenolic content but also required their proper characteristic. The efficiency of phenolic compounds as antiradicals and antioxidants is diverse and depends on many factors, such as the number of hydroxyl groups bonded to the aromatic ring, the site of bonding and mutual position of hydroxyls in the aromatic (Sroka & Cisowski 2003). Various factors may affect phenolic composition in mushrooms. One such factor may be the genetic potential of individual strain for phenolic biosynthesis. Apart from genetic background, maturation stage and flush number may also be critical in this respect. Some authors recommends that antioxidant activity of vegetables should be evaluated by different methods rather than depending on the results of a single method (Chu *et al.* 2000). Also Cao *et al.* (1996) stressed the measurement of antioxidant activity against different radicals as fruits and vegetables appear to have an optimal mixture of various antioxidants. Second model system used in our research consisting of  $\beta$ -carotene and linoleic acid, enable to screen large number of sources for their antioxidant capacity. Figure 2 shows antioxidant activity of free phenolic extracts of fresh and stored mushrooms. Storage of mushrooms significantly decreased an average 36% antioxidant activity (expressed as inhibition of oxidation) in comparison with the fresh ones. In contrast to results presented in Table 2, the highest values of antioxidant activity had extracts of fresh mushrooms 2200 (both flushes) and A15 (2<sup>nd</sup> flush) strains. Similarly as it shown in Table 2, lowest value of antioxidant activity had extract of free phenolics from the second flush of mushrooms of Roxx strain (Figure 2). Inhibition of oxidation by phenolic extract of mushrooms from the first flush of A15 was 5 fold lower in comparison with the second flush (Figure 2), and this result is contrariant to that presented in Table 2. As mentioned above some compounds which have DPPH $\cdot$  scavenging activity may not show  $\beta$ -carotene-linoleic acid antioxidant activity, relationship between these two models may not be obvious even for the same biological samples that may contain a variety of antioxidants.

Further studies on the chemical characteristic of the antioxidative components in mushroom extract are needed.

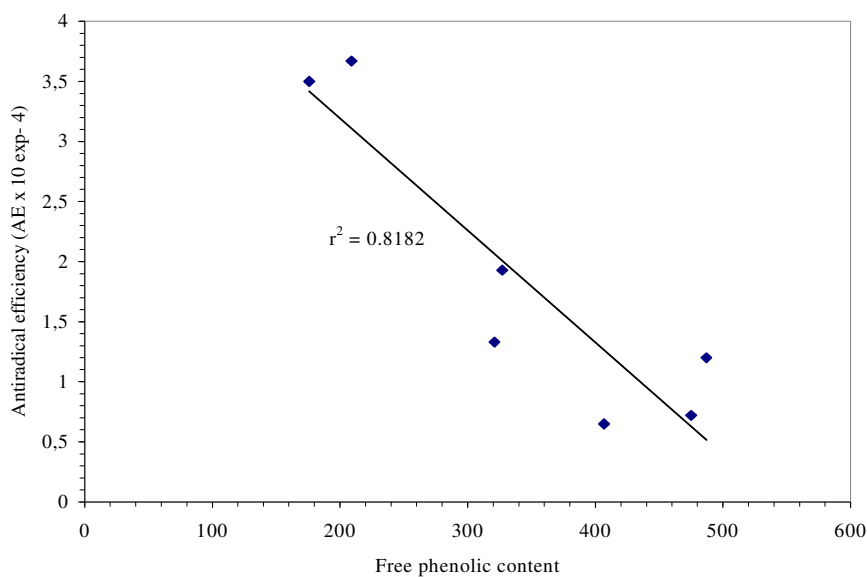
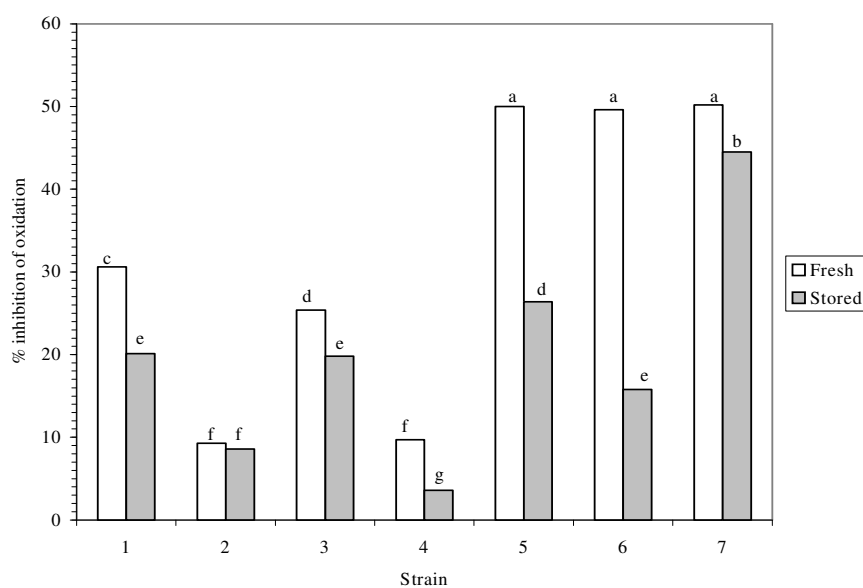


Fig. 1. Relationship between free phenols and antiradical efficiency (AE) of fresh mushrooms



Strain (flush No): 1. Roxx (1); 2. Roxx (2); 3. Maxx (2); 4. A15 (1); 5. A15 (2); 6. 2200 (1); 7. 2200 (2)

Note: Bars labelled by the different letters differ significantly at P=0.95 using Newman-Keuls test

Fig. 2. Antioxidant activity of free phenolic extracts of fresh and stored mushrooms determined by measuring of inhibition of coupled oxidation of  $\beta$ -carotene and linoleic acid

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### AKTYWNOŚĆ ANTYOKSYDACYJNA I ZAWARTOŚĆ FENOLI NIEKTÓRYCH RAS PIECZAREK (*Agaricus bisporus*)

#### Streszczenie

Oznaczono aktywność antyoksydacyjną ekstraktów fenoli czterech ras pieczarek: Roxx, Maxx, A15 i 2200. Zawartość wolnych fenoli w świeżych pieczarkach wahała się w granicach 176-487 mg·kg<sup>-1</sup>. Przechowywanie pieczarek przez 5 dni w temperaturze +2°C spowodowało wzrost stężenia wolnych fenoli średnio 1,6 razy w grzybach wszystkich badanych ras z wyjątkiem drugiego rzutu rasy Roxx. Wartość aktywności antyoksydacyjnej (EC<sub>50</sub>)<sup>-1</sup> świeżych grzybów, oznaczona metodą „zmiatania” wolnego rodnika 2,2-difenyl-1-pikrylhydrazyl (DPPH·), wahała się w granicach 2,46-8,95 w zależności od rasy i rzutu. Najwyższą aktywność antyoksydacyjną posiadał ekstrakt fenolowy pieczarek z drugiego rzutu rasy Maxx. Wartość (EC<sub>50</sub>)<sup>-1</sup> świeżych grzybów pochodzących z pierwszego rzutu rasy Roxx była ponad 3,2 razy wyższa niż drugiego rzutu. Podobne zależności stwierdzono dla wartości efektywności antyrodnikowej (AE). Przechowywanie pieczarek obniżyło najwyższe wartości (EC<sub>50</sub>)<sup>-1</sup> i AE (Roxx pierwszy rzut i Maxx drugi rzut) o 70-75%, ale nie zmieniło istotnie wartości tych parametrów dla rasy A15 i pierwszego rzutu rasy 2200. Wykazano wysoką ujemną korelację (r = -0,904) pomiędzy zawartością wolnych fenoli i AE świeżych pieczarek. Przechowywanie pieczarek obniżyło istotnie (średnio o 36%) aktywność antyoksydacyjną ich ekstraktów fenolowych, oznaczoną metodą opartą na inhibicji autooksydacji układu β-karoten – kwas linolowy.



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