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COMPARATIVE STUDY OF DIFFERENT CULTIVARS OF LETTUCES IN UNHEATED POLYETHYLENE GREENHOUSE DURING WINTER-SPRING PERIOD

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Abstract

The aim of our study was to test some varieties of lettuce in unheated greenhouse (high tunnel) for the winter growing with November transplanting. The experiment was carried out in the period 2015-2016 in the experimental field on University of Forestry - Sofia (42° 7′ N, 23° 43′ E). Were selected 19 cultivars (16 Batavia and 3 Lollo types) with different requirements for the terms and conditions of cultivation. The seedlings were planted on the block method with four replications in the second ten days of November in polyethylene greenhouse. Until the time of harvesting, four surveys have been made on the percentage of rooted and dead plants. During the harvesting of production (second ten days of March - early April) were made biometric measurements (diameter and average weight per plant). Several cultivars for winter indoor cultivation were highlighted: 6 from Batavia, all of Lollo, and two from Batavia for outdoor. Regardless of recommendations given for each cultivar it needs they to be screened for each region, microclimate and growing period.

Key words*: Batavia type, Lactuca sativa, Lollo type, High tunnel, November transplanting.*

INTRODUCTION

One of the first fresh vegetables on the market, appearing early in the spring, is lettuce. The lettuce is cool season-hardy crop and develops at a temperature of 5-25°C. The optimal temperature for its growth and development is 16-18°C (Lorenz and Maynard, 1988; Kartalov et al., 2007).

Temperatures above 25°C cause the bolting. (Genkova, 2009) and at a temperature below 5°C growth of plants stops (Cholakov, 2009). Young and hardened plant (stage 7-8-th leaf) can withstand lowering the temperature to -5/ -6°C (Cholakov, 2009; Divina, 2016).

One way to year-round production of salads is their greenhouse production. An alternative to glass-greenhouses are polyethylene tunnel greenhouses without heating (Tüzel and Leonardi, 2009). They are economically viable to maintain and produce quality produce (Wells and Loy, 1993).

Salad is one of the first crops grown in a polythene greenhouse, along with warm-season tomatoes and cucumbers, to get off-season production (Lamont, 2005). In the US, the UK, Belgium and Germany lettuce rank as one of the main crops for cultivation in plastic tunnel greenhouses (Lamont, 2009).

The factors that affect the quality of lettuce are the growing season, the weather conditions and the variety (Koudela and Petříková, 2008). High tunnels protect salads from the unfavorable weather conditions encountered in their outdoor cultivation, thus affecting the time of harvesting, increasing the yield and quality of the produce, and thus these facilities are an alternative for creating early planting of lettuces (Santos et al,. 2009; Wallace et al., 2012).

It has been established that the salad growing season influences more on the yield and quality of the produce than the composition of the nutrient solution whose effect is not so well expressed (Fallovo et al., 2009). Date of planting also has a significant impact on yield (Sharma et al., 2009). In the winter production of leafy vegetables and the earlier date of planting, the length of the growing season is not reduced until the harvest, however seedling before the fall of the low winter temperatures and the occurrence of winter frosts leads to greater plants in the spring (Borrelli et al., 2013).

Lebeda et al. (2007) describe seven *Lactuca sativa* morphotypes, which cover seven main groups of varieties (including oil-bearing plants) that differ phenotypically (by Kristkova et al., 2008). In the Mediterranean region (Spain, Italy), as well as in the Middle East and North Africa, the main type is Rommaine (Cos) lettuce, in its different shapes and colors. In Northern Europe, both Cos lettuce and Batavia are popular. Stalk (asparagus) lettuce remains important in Egypt, the Middle East and China. All except iceberg found in red and green color of leaves (Ryder, 2002).

Two of the widespread types for Northern and Central Europe, which also enter in Bulgaria, are the Batavia and Lolo.

Type Batavia is characterized by open to strong heading; generally medium thick, rather strongly blistered leaves, predominately yellowish or medium green; leaf margin with weak to strong undulation (UPOV, 2017). In cold conditions not always have a clear position (DUS Test, 2016). It produces moderately dense heads with a crunchy texture and intermediate between iceberg and loose leaf types. Varieties are in red or green color (Divina, 2016). Lebeda et al. (2007) refers Batavia type to Crisphead lettuce (var. *capitata* L. nidus jäggeri Helm), together with Eissalat и Iceberg type (by Křístková et al., 2008)

Lollo type - it is non-heading; thin leaves with strongly undulated leaf margin. The plant as a whole shows mainly the undulating leaf margins. In general, strongly blistered leaves, blisters are rather small (UPOV, 2017). Forms tender leaves that are delicate and mildly flavored. Varieties come in green and red and green or purple color (Divina, 2016). Lolo type refers to Cutting lettuce (var. *acephala* Alef., syn. var. *secalina* Alef., syn. var. *crispa* L.) and this morphotype is extremely heterogeneous (Křístková et al., 2008).

In order for varieties to reveal their full potential and productivity, they need to be screened to check their adaptation in a given area. This should be done locally, across a broad range of contrasting environments to define and identify the most stable and well adapted varieties for a certain period of vegetation and environment (Dufault et al., 2006). Proper selection of varieties makes it possible to avoid bolting when growing at higher temperatures (Rader and Karlsson, 2006).

The aim of our study was to test and compare some of the offered lettuce cultivars in unheated polyethylene greenhouses (high tunnel) for the winter-spring growing season as November transplanting.

MATERIALS AND METHODS

The field experiment was conducted during 2015-2016 at the experimental field (42° 7′ N, 23° 43′ E and 552 m above sea level) of the University of Forestry, Sofia, Bulgaria. The soil type is fluvisol, slightly stony and slightly acidic ($pH_{(H2O)}$ 6.2). For the purpose of the experiment was used unheated polyethylene greenhouse (high tunnel) covered with a standard transparent strengthen and UV stabilized polyethylene.

Lettuce cultivars: They were selected and tested 19 cultivars of salads, 13 of them are Dutch, three Swiss, two Italian and one French. Selected cultivars refer to two types: Batavia and Lollo (16 are Batavia type, 3 are Lollo type). Of these, six are intended for growing outdoors. Origin, type of lettuce cultivars and recommended season and growing conditions are described in Table 1.

Seedlings were planted in the second ten days of November. The period of transplantation in the polyethylene tunnel was determined in order to use the final moment for planting in this type of cultivation facility for the Sofia region, in line with the ongoing climate change. The date of planting was 12.11.2015, which was fixed according to the weather conditions and the medium-term forecast for the month.

They were used previously produced seedlings and lettuces were grown on a flat surface, in a row, with a plant spacing of 25 cm. The experiment was performed in a blocking method with four replications, with 18 plants for each replication per cultivar. In the polyethylene greenhouse was used drip irrigation and all care during growing period were the same for all variants.

Table 1. Origin, type of lettuce cultivars and recommended season and growing conditions

Variants No.	Cultivars	Origin	Type	Season	Conditions
1.	*Maritima*	Netherland	Batavia	Spring-Summer-Autumn	outdoor
				All year round	indoor
2.	*Funride*	Switzerland	Batavia	Spring-Summer-Autumn For summer cultivation	outdoor
3.	*Kriska*	Italy	Lollo Bionda	Spring-Summer-Autumn	outdoor
				Autumn-Winter	indoor
4.	*Florine*	France	Batavia	Spring-Summer;Autumn-Winter	outdoor indoor
5.	*Funtasia*	Switzerland	Batavia	All year round without high and low temp	outdoor
6.	*Noisette*	Netherland	Batavia	All year round	outdoor indoor
7.	*Malice*	Netherland	Batavia	Spring/Autumn	outdoor
				Autumn-Winter-Spring	indoor
8.	*Fuzila*	Netherland	Batavia	Spring-Summer-Autumn	outdoor
9.	*Satine*	Netherland	Lollo Rossa	Autumn-Winter-Spring	indoor
10.	*Fanela*	Netherland	Batavia	Spring-Summer-Autumn	outdoor
11.	*Sementel*	Netherland	Batavia	Autumn-Winter-Spring	outdoor indoor
12.	*Frisady*	Netherland	Batavia	Spring-Summer-Autumn	outdoor
				All year round	indoor
13.	*Donertie*	Netherland	Batavia	Autumn-Winter-Spring	indoor
14.	*Jazzie*	Netherland	Batavia	Autumn-Winter-Spring	indoor
15.	*Aquarel*	Netherland	Batavia	Spring-Summer-Autumn	outdoor
16.	*Isi 45194*	Italy	Lollo Bionda	Autumn-Winter-Spring	outdoor indoor
17.	*Funfix*	Switzerland	Batavia	Autumn-Winter-Spring	outdoor
18.	*Ostralie*	Netherland	Batavia	Autumn-Winter-Spring	indoor
19.	*Hettie*	Netherland	Batavia	Autumn-Winter-Spring	indoor

During the growing period were conducted several plant surveys to account the percentage of rooted as well as the percentage of died plants until the time of harvesting.

Harvesting began in the second ten days of March and continued until the first ten days of April. During the harvesting were measured the plant diameter and the average weight per plant. The collected data were analyzed by ANOVA and were expressed as mean ± standard deviations. Post hoc analyses were conducted using Fisher's protected LSD test.

RESULTS AND DISCUSSIONS

When growing lettuces during the winter season, the period of planting seedlings and weather conditions it is important.

Generally months covering the experimental period (November '15 - April '16) were warmer compared to the average monthly temperatures in the 30-year period, reflecting global warming (Table 2).

From the time of planting until the end of November average daily temperatures were favorable for rooting of seedlings, considering that in unheated greenhouses they were better than outside.

It was found that at night the temperatures in the high tunnels are only 1 or 2°C higher than outdoor temperatures, while daytime temperatures are 10°C higher due to daytime solar radiation (Gent, 2002).

In December the outside temperature dropped, and in the middle of the month irrigation was stopped, thus the plants were prepared for wintering.

Extremely low outdoor temperatures were not recorded during this month, except for 3 days of the month (below -5°C), as in the two days are measured temperatures around the critical minimum for the lettuces in the early period of their development (-5°C), and at the last day of the month is measured at a temperature of -11°C.

January was the month with a negative average temperature, it is the only month with a lower temperature compared to '30 period. During this period the plants were not watered and were not covered with additional plant protection films. From the end of December to the end of January, temperatures were below the freezing temperature of lettuces.

Table 2. Average monthly, average minimum, average maximum and extreme monthly temperatures during the experimental period

Months	Anomaly compared to 30-year period	Monthly temperature (t °C)			Extreme monthly temperatures (number of days)				
		Average montly	Average minimum	Average maximum					
	t °C	M±SD	M±SD	M±SD	below -5 °C	-5/+5 °C	+16/+18 °C	+18/+25 °C	above +25 °C
November '15	+3.7	8.7±4.1	3.6±4.4	14.7±5.1	0	21	9	8	0
December '15	+1.5	2.1±3.3	-1.1±3.2	6.3±4.1	3	27	0	0	0
January '16	-0.4	-0.9±6.5	-4.8±6.9	3.8±7.1	13	18	1	0	0
February '16	+6.6	7.5±4.3	2.8±3.8	13.0±5.3	0	25	2	7	0
March '16	+1.8	7.1±3.0	2.3±3.0	12.6±4.8	0	25	1	5	0
April '16	+3.4	13.9±3.7	7.3±3.9	21.0±4.9	0	8	4	14	8

These low temperatures were the main limit for winter growth, which is confirming the findings of Gent (2002).

February was warm, daily temperatures triggered visible plant growth and irrigation was restored. Since mid-March, lettuces in the polyethylene greenhouse had reached the stage of harvest.

During the growing period was carried out periodic monitoring of the number of died plants. The first observation was at the beginning of December, three weeks after the seedlings were planted, to check the percentage of the rooted plants and their condition for wintering. 100% of rooting of all plants was reported (Table 3).

Table 3. Amount of rooted and survived after wintering plants (%)

No	Cultivars	Amount of plants (%)			
		2015	2016		
		04.12.	08.02.	11.03.	08.04.
1.	*Maritima*	100	99	53	49
2.	*Funride*	100	97	68	68
3.	*Kriska*	100	94	61	61
4.	*Florine*	100	88	69	69
5.	*Funtasia*	100	79	25	8
6.	*Noisette*	100	89	50	31
7.	*Malice*	100	92	57	53
8.	*Fuzila*	100	89	4	0
9.	*Satine*	100	86	81	81
10.	*Fanela*	100	75	43	42
11.	*Sementel*	100	100	53	51
12.	*Frisady*	100	90	47	47
13.	*Donertie*	100	97	88	86
14.	*Jazzie*	100	93	68	51
15.	*Aquarel*	100	93	40	32
16.	*Isi 45194*	100	94	92	92
17.	*Funfix*	100	79	21	15
18.	*Ostralie*	100	86	64	64
19.	*Hettie*	100	100	75	75

At the end of January, sunny weather was established and daily temperatures started to rise sharply (about 11-15°C), and at the beginning of February they reached around and above the optimum for the growing of lettuces (up to 18.8°C) and plants apparently began to grow and develop.

At the end of the first ten days of February, the second monitoring of the number of plants in the greenhouse was made to determine how many of them survived during the low temperatures in January. They were made two more monitoring in the polyethylene greenhouse - in March and April.

In February at three of tested in the polyethylene greenhouse lettuce cultivars - *Funtasia, Funfix* and *Fanela*, the number of plants has fallen below 80%, while variety *Fanela* reported a 25% death of plants. In March with less than 50% of plants were six cultivars, and in April the total number of cultivars with less than 50% plants were 8.

In descending order (from the most failed, to the least) these eight varieties rank as follows: ***Fuzila>Funtasia>Funfix>Noisette>Aquarel> Fanela>Frisady>Maritima***.

There are significant differences in the amount of plants remaining after their wintering:

F (3, 72) = 37.06 MSE = 307.06 p < .0001 at the .05 alpha level.

The causes of plant dying are complex - the season of cultivation (part of the varieties are not suitable for growing in winter), weather conditions (especially temperature), fungal diseases. Of the eight cultivars with more than 50% of the died plants, five are not recommended to be grown in the winter and are intended for open areas. In three of these losses of fungal diseases have been less than 10% and

only *Fuzila* has a high percentage (36%) loss from fungal diseases (Table 4). Attention was also paid to the *Funride,* which, although according to its description is intended for outdoor production during the favorable months of the year (spring-summer-autumn), survived successfully in a polythene greenhouse and losses were 32%.

Table 4. Recommended growing periods and conditions for the cultivation of cultivars and the amount of died plants (%)

No.	Cultivars	Recommended for		Died plants %	
		Season	Conditions	Total	Fungal disease
1.	*Maritima*	All year round	indoor	51	-
2.	*Funride*	Spring-Summer-Autumn	outdoor	32	10
3.	*Kriska*	Autumn-Winter	indoor	39	-
4.	*Florine*	Spring-Summer;Autumn-Winter	indoor	31	-
5.	*Funtasia*	Without high and low temp	outdoor	92	4
6.	*Noisette*	All year round	indoor	69	-
7.	*Malice*	Autumn-Winter-Spring	indoor	47	6
8.	*Fuzila*	Spring-Summer-Autumn	outdoor	100	36
9.	*Satine*	Autumn-Winter-Spring	indoor	19	4
10.	*Fanela*	Spring-Summer-Autumn	outdoor	58	7
11.	*Sementel*	Autumn-Winter-Spring	indoor	49	11
12.	*Frisady*	All year round	indoor	53	-
13.	*Donertie*	Autumn-Winter-Spring	indoor	14	-
14.	*Jazzie*	Autumn-Winter-Spring	indoor	49	10
15.	*Aquarel*	Spring-Summer-Autumn	outdoor	68	8
16.	*Isi 45194*	Autumn-Winter-Spring	indoor	8	3
17.	*Funfix*	Autumn-Winter-Spring	outdoor	85	14
18.	*Ostralie*	Autumn-Winter-Spring	indoor	36	22
19.	*Hettie*	Autumn-Winter-Spring	indoor	25	-

During the harvesting of the produce, biometric data were collected - diameter and average weight of the plants (Table 5).

There are significant differences in the diameter of the plants F (17, 161)=5.10 MSE = 4.53 p < .0001 at the .05 alpha level, as well as the average weight per plant F (16, 40)=2.97 MSE = 1581.23 p = .002 at the .05 alpha level.

In several cultivars, the plants reached a diameter of between 25-27 cm. In descending order (from the largest diameter to the smaller), they are arranged in the following way: *Fanela>Malice>Hettie>Frisady>Noisette>Isi 45194.* Immediately after them come *Funrid*e and *Kriska*, whose diameter is close to 24 cm.

The average weight of a plant varies, depending on the type and cultivars, was from 92 g to over 230 g per plant. The largest weight per plant (220-230 g) had three cultivars that are arranged in descending order in the following way: *Frisady>Fanela>Malice.* Immediately after them was again *Funride,* with 217 g, followed by *Hettie* - 211 g. (Table 5).

Table 5. Mean value (M) and standard deviation (SD) of plant diameter and weight per plant

No	Cultivar	Plant diameter (cm)		Plant weight (g/per plant)	
		M±SD	LSD*	*M±SD*	LSD*
1	*Maritima*	23.33±1.72	c d e f g	151±34	C D
2	*Funride*	23.90±3.48	b c d e f	217±19	A B
3	*Kriska*	23.83±2.48	c d e f	204±32	A B C
4	*Florine*	22.25±1.66	f g h	194±48	A B C
5	*Funtasia*	20.33±4.51	h	0,00	
6	*Noisette*	24.71±1.80	b c d e	183±24	A B C
7	*Malice*	25.58±1.93	a b	226±64	A B
8	*Fuzila*	0		0	
9	*Satine*	22.00±1.54	g h	94±20	D
10	*Fanela*	27.33±3.20	a	228±67	A B
11	*Sementel*	22.92±2.39	e f g h	185±41	A B C

No	Cultivar	Plant diameter (cm)		Plant weight (g/per plant)	
		M±SD	*M±SD*	*M±SD*	
12	*Frisady*	24.91±1.64	b c d	231±34	A
13	*Donertie*	22.08±1.68	g h	163±17	B C
14	*Jazzie*	23.11±1.45	d e f g h	204±64	A B C
15	*Aquarel*	22.50±0.97	f g h	164±13	B C
16	*Isi 45194*	24.58±2.23	b c d e	153±38	C
17	*Funfix*	22.40±1.67	d e f g h	150±0	B C D
18	*Ostralie*	22.22±2.44	f g h	188±38	A B C
19	*Hettie*	25.10±1.52	b c	211±46	A B

*Means within a column followed by the same letter do not differ significantly based on Fisher's LSD post-hoc analyses at $p<.05$.

CONCLUSIONS

By making a comprehensive analysis of the results in individual cultivars can say several of them, which are for indoor cultivation, stand out: from type Batavia are *Hettie, Frisady, Malice, Jazzie, Florine, Sementel, Donertie. Cultivars Frisady, Malice, Jazzie* and *Sementel* are slightly more sensitive to extreme temperatures, which is expressed in a greater variation in the average weight per plant in *Malice* and *Jazzie*.

All three varieties of type Lolo showed very good results: *Kriska, Isi 45194* and *Satine*, as the last one is the type Lollo Rosso and had a very gentle and tender leaves, which affected the average weight per plant. The *Kriska* cultivar was slightly more sensitive to extreme temperatures than the other two but had a higher average weight per plant than the other two Lolo type cultivars.

Two of the cultivars, type of Batavia, which are intended for outdoor cultivation, also showed very good results when growing indoors in winter: *Funride* and *Fanela*, but the second one was a little more sensitive to extreme temperatures.

Regardless of the recommendations given in the cultivar descriptions, it is necessary to screen the offered cultivars, for each region, microclimate and growing period, which confirms the conclusions of the Dufault et al. (2006) and Maynard (2014)

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