AgroLife Scientific Journal - Volume 4, Number 2, 2015
ISSN 2285-5718; ISSN CD-ROM 2285-5726; ISSN ONLINE 2286-0126; ISSN-L 2285-5718

THE PLANTING PERIOD AND THE SIZE OF CLOVES INFLUENCES ON GARLIC PRODUCTION

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Abstract

Climate change raises a number of issues of farmers. Even if growing spring garlic in Romania usually occurs in March, recent changes of temperature and moisture abundance on soil that occurred during February-March period compelled farmers to seek new periods and methods of garlic cultivation. For example, in the spring of 2012 garlic could not be grown before early April.
The assessed results obtained by the cultivation of garlic on April 2nd, 7th and 12th showed us that the best results and yields were obtained on the crop originated from April 2nd, with a 7.75 t/ha garlic production as compared to 6.25 t/ha (garlic cultivated on April 7th) and 4.75 t/ha (garlic cultivated on April 12th). In addition the production quality was superior for the crops originating from April 2nd.
The results obtained show clearly that it is necessary a permanent assessment of planting date according to climate change in order to have a satisfactory productivity in the new environment and better manage existing genetic resources.

Key words*: Climate change, spring garlic, production.*

INTRODUCTION

Garlic (*Allium sativum* L.) is one vegetable species known since ancient times. References to this plant are found in the Bible, in the Koran, in studies and archaeological evidence reflecting its importance both as food as well as medicinal plants (Parejo et al., 2002; Tapsell et al., 2006; Petcov-Uzun et al., 2011).
Garlic belongs to one of the most important groups of plants, in terms of economic importance, namely family *Alliaceae* (Brewster, 1994).
Currently is cultivated mainly between 30^0 and 45^0 parallels in both northern and southern hemispheres. Garlic (*Allium sativum* L.) is a species easy to cultivate, it does not require special facilities and productions can be over 24 tons per hectare. At the level of the year 2011, according to data provided by the FAO, the total garlic planted areas (worldwide) amounted to 14119023 ha, with an overall output above 237211446 tons. The undisputed leader is China with more than 78% worldwide prduction, followed by India and Korea. The European Union is the fourth world producer with a cultivated area of about of 37.819 ha with an outcome around of 283.154 tons. Spain (15,660 ha - 8.93 t/ha), France (2,700 ha - 7.18 t/ha) and Italy (3,150 ha - 9.69 t/ha) are also among the countries with the largest areas of cultivation of garlic in the EU in the year 2011.
In Romania garlic is cultivated on large areas in Oltenia, Muntenia, Banat and Central Moldova. Thus cultivated area in 2011 was 12.2 thousand hectares with a total production of 66,606 tons.
Garlic is grown for bulbs, cloves, false stem and green leaves, which are eaten fresh or used as flavors for dishes, sausages, canned meats and vegetables. Garlic is also used in the pharmaceutical industry. Bulbs of garlic as well as young green parts of the plant have a similar use of onions, but in lesser quantities. Because it contains essential oil, garlic is considered less of a food itself, and more of a spice of nutritional importance (Luchian, 2007).
The bulb contains 25-30% dry with high content of sugar (20-26%) protein (6-7%), Vitamin C (10-20 mg), vitamin B1, B2, E and minerals (calcium, phosphorus, potassium -

around 540 mg to 100 g of fresh substance). Also contains phytoncides with bactericidal activity with tonic and antiseptic properties and a wide range of antioxidants (Petcov-Uzun et al., 2011).

The main bioactive substance from the bulbs of garlic is allicin, which has a role in reducing blood lipid content. (Leighton et al., 1992) noted that flavonols in this species, represented mainly by quercetin, inhibits tumor growth. Garlic is rich in antioxidants, which helps to destroy free radicals - particles that can damage cell membranes, interact with genetic material and contribute to the aging process and the development of a number of diseases including heart disease and cancer. Actually, the chemical composition of garlic (*Allium sativum L.*) is determined by its genotype and culture conditions. Plants respond to abiotic stressors by producing amino acid proline. Here we can specify Cenad garlic (grown on Timis County, Romania), which proved to be a good accumulator of proline in normal hydration and in drought conditions. Instead quantitative determination of chlorophyll pigments from fresh leaves of garlic Cenad population has been a below average content of 7.95 mg /L for chlorophyll a and 4.76 mg /L for chlorophyll type b (Petkov-Uzun et al., 2009).

Cloves begin to vegetate at 4^0C. Typically minimum temperature of vegetation is 4^0C, the optimum of 18-20^0C and 25-30^0C maximum. The rooted bulbs withstand in the winter up to -25^0C. From bulbs stored at 20-24^0C, planted late spring, bulbs are no longer obtained. It is a long day plant, very pretentious to light and if it is grown in shaded places bulbs are not formed. It is sensitive to excess but also the inadequacy of water in the soil. Until the bulb formation it must ensure 70-75% of the field capacity, which is to be reduced afterwards to 60-65%. Specific consumption for garlic is 5-6 kg N, 1-1.5 kg P_2O_5, 4-5.5 kg K_2O, 2-3 kg CaO and 0.5 kg MgO per ton of bulbs (Draghici, 2004).

As we know in most cases garlic is multiplied, vegetative, by cloves, because many of its varieties have lost, in time, the ability to produce fertile flowers: the root system is poorly developed; fasciculate roots are developing to a depth of 15-29 cm. In soil the grow bulb (or head of garlic) of the species cultivated in Romania is composed of 10 to 20 cloves. Usually those facing towards the inside of the blub are smaller. Cloves are nothing more than auxiliary buds, usually going by three, formed from fleshy sheets, hypertrophied at armpit of leaf sheaths. Outside, each clove is protected by thin, translucent, white or pink coats. Each clove houses bud. The basal part of cloves differentiates a random number of roots which starts to develop when, after detachment, are placed in germination conditions. Cloves are fixed with the basal part on the stalk itself in the form of flattened disk. They are all together protected by 3-4 white-silver, white-yellow or pink parchment sheets. Leaves in number of 8-15, are linear, lanceolate and in the median part through superposition form false stalk. After leaf formation the central bud of bulb may abort flowers or may form a floral-filled cylindrical stalk with a height of 0.80 to 1 m with sterile flowers. Floriferous stems formation is favored when the bulbs are exposed to low temperatures or when low temperatures are associated with long days at the beginning of the formation of bulbs (Draghici, 2009).

Changing climatic conditions and temperature fluctuations are the main causes of production losses in most species cultivated thus they are a limiting factor for the production of garlic. This requires constantly looking for solutions to increase plant productivity in their new environment and a better management of the existing genetic resources. In fact, in-depth knowledge about the varieties of garlic, its production and changes over time are quite limited, even if garlic is cultivated and consumed for thousands of years (Simon & Jenderek, 2003).

Garlic has moderate temperature requirements. Thus the optimum temperature is 18-29 ^{0}C and long days, with a minimum of 2-3 ^{0}C and maximum of 25-30 ^{0}C (Ciofu et al., 2004). However in the current climate change situation requires the use of garlic varieties and the best crop conditions to maximize the production. For example in Italy garlic phenotypes with very good resistances to temperature variations, very productive and higher quality characteristics were selected (Di Stefano, 2012).

Garlic has high demands regarding lighting conditions. Grown in shady places it favors not

the formation of bulbs. Due to its superficial root system it requires more water. Thus the soil moisture should be 70-75% of field capacity until bulb formation and 60-65% in its maturity period for the varieties currently cultivated. However the excess moisture leads the bulbs to rot.

In this period of climate change purpose of this study was to underline some aspects of garlic cropping technology, to establish and to recommend the best time to plant spring garlic in a traditional garlic culture of Romania. In this situation we followed the objectives: The influence of the planting season on growth and development of garlic plants; The influence of the planting season on the size of garlic bulbs; The influence of the planting season and of the cloves size on the number of cloves the garlic bulbs are made of; The influence of the planting season and of the cloves size on the production of garlic and Commercial quality of garlic bulbs. Also we try, taking into consideration the climate conditions, to recommend the best planting material to achieve maximum efficiency.

MATERIALS AND METHODS

The experiences have been placed in their own micro-farm from the city of Magurele, Pruni village, Ilfov County, on an area of 2500 m^2. To improve the soil structure, on its surface this was embedded with perlite with granulation of 4 mm. The perlite was provided by S.C. PROCEMA S.R.L., Romania. This treatment was necessary because the soil structure in this region is too little aerated. Preparation of the land was done in the autumn prior to the experiment: phosphorus fertilization (300-350 kg/ha superphosphate) and potassium (100-150 kg/ha potassium sulphate), deep plowing at 28-30 cm and soil shredding.

The biological material consisted of a variety of local spring garlic (*Allium sativum* L.).

The culture methodology

Culture of garlic (*Allium sativum* L.) was set up in some sunny days, in the first half of April 2012. Cloves were introduced at about 3 cm deep in the ground, at a distance of 25 cm between rows and at 15 cm on the row. Planting was carried out at three different dates, on 2012 and 2013, April 2nd, April 7th and April 12th.

The cloves been used were of different sizes, exterior (large), medium and central (small). The experimental variants are set out in Table 1.

Maintenance works applied to culture were: manually hoeing by 2-3 times, additional fertilization to start of bulbs formation with Compex III (NPK 15.15.15.), dripping irrigation, especially in the phase of formation of the bulb, and combating disease and of garlic bite (*Suillia lurid*) with Sinoratox 35 EC 0.15%.

Table 1. Experimental variants

Var.	Planting date	Positioning cloves used at planting	Dimension
V1	2.04.2012 2.04.2013	exterior	large-sized
V2		middle	medium-sized
V3		central/core	small-sized
V4	7.04.2012 7.04.2013	exterior	large-sized
V5		middle	medium-sized
V6		central/core	small-sized
V7	12.04.2012 12.04.2013	exterior	large-sized
V8		middle	medium-sized
V9		central/core	small-sized

The amount of propagating material used for the planting was based on the size of the clove and plant density (Table 2).

Table 2. Quantity of planting material used according to the size cloves

Cloves size	Quantity	The distance between rows	The distance between plants	Density
	g/m2	cm	cm	cloves/m2
Large - exterior cloves	75	25	4	1250.00
Medium sized - middle	50	25	3	1333.33
Small - central cloves	35	25	2.5	1600.00

The harvest methodology

The harvest of garlic bulbs (*Allium sativum* L.) was carried out when the first signs of maturation were noticed - total yellowing and the beginning of leaves drying namely first harvests were conducted in 6th of June and the last on 23rd of June.

It was not allowed final drying of the leaves before harvesting because the bulbs that exceed the harvest period are stripped out of husks and

come off in cloves which leads to great losses both at harvest as well as during storage.
Harvesting was carried out on dry weather. The bulbs were removed from the earth by shaken (avoiding mechanical injuries) and were seated to dry on the surface for two days in the sun and after drying the leaves were cut leaving about 1.5 - 2 cm above the bulb shoulders and the root was shortened to 1 cm. The harvested garlic was stored at a temperature of 1-3 °C and an air humidity of 75%.

The garlic quality evaluation
After being harvested, the plants were measured for length, diameter and the height of garlic bulbs. The cloves were also counted for each garlic bulb in order to quantify the differences.
The results of the measurements were analyzed by analysis of variance (analysis significance of difference-Duncan test).

RESULTS AND DISCUSSIONS

Plant emergence was different depending on the cloves size and planting date. Thus the large cloves planted on April 2nd arose after 15 days from planting. Also, medium and small cloves sprouted after 16 days. At the later planting cloves were emerged after a lower number of days but with differences in the sizes of cloves (Figure 1).

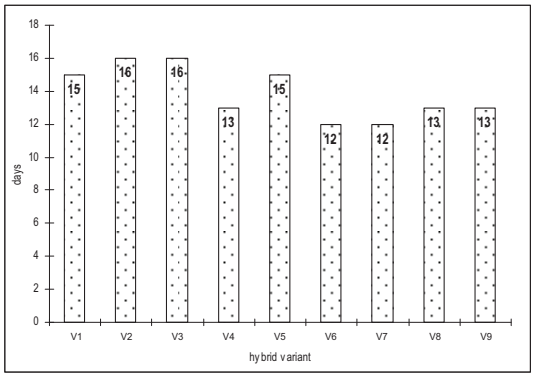

Figure 1. Number of days from sowing to sprouting

The number of leaves per plant was different depending on planting date.
At planting operations on April 2nd, plants from large and medium cloves presented a higher number of leaves than the rest of the variants. The lowest number of leaves was recorded at variants planted on April 7th (Figure 2).

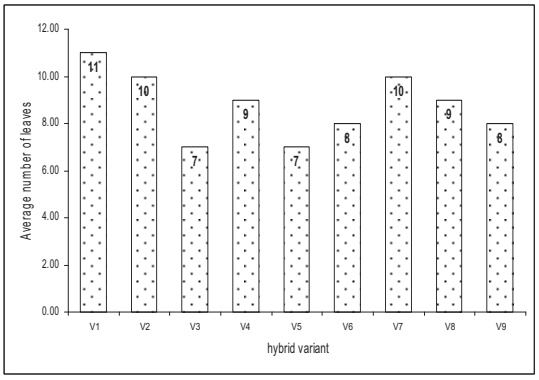

Figure 2. Average number of leaves per variant at planting

Plant heights were consistent with the size of the cloves used. The garlic heights, by the period of planting (Figure 3).

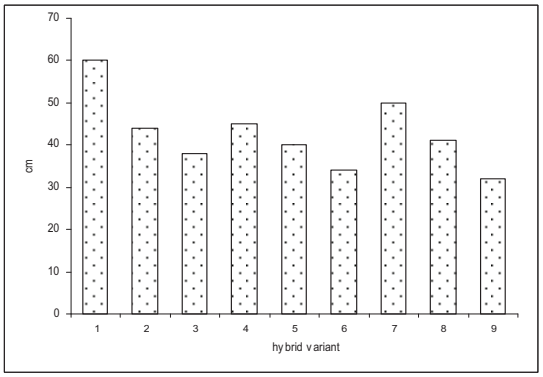

Figure 3. Garlic plants heights

The diameter of the garlic strains were greater at variants from larger cloves and much lower for those derived from lower cloves but the size also varied according to the date of planting (Figure 4).

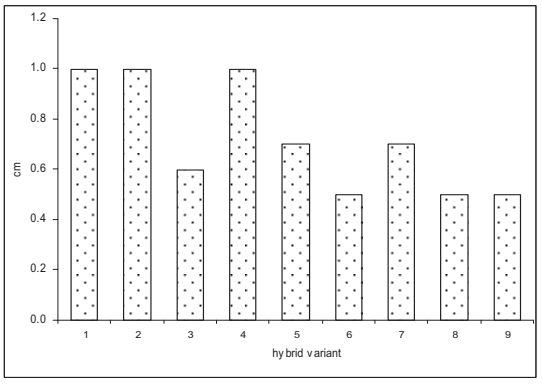

Figure 4. Evolution of garlic plants diameter

The bulbs weight obtained from cultivated plants was different according to the size of cloves used and the planting date. For instance, from the large cloves planted on April 2nd, the larger bulbs of 34.7 g were obtained. Also,

from the medium and small cloves the average weight of bulbs of garlic was much lower (17.67 g respectively 15 g) (Figure 5).

Figure 5. Weight of garlic bulbs depending on planting date and size of cloves

It is noted from the statistically data of significant negative differences, respectively significant distinct at variants 2 and 3 (Table 3).

Table 3. Synthesis of the garlic bulbs weight depending on clove size - the date of planting: 02/April

Variant	Weight of garlic bulbs, g	Difference		Significance
		g	%	
Average	22.44	0	100	Control
V1	34.67	12.22	154.46	***
V2	17.67	-4.78	78.71	O
V3	15	-7.44	66.83	OO
DL5% = 3.020		DL5% in % = 13.4554		
DL1% = 5.000		DL1% in % = 22.2772		
DL0.1% = 9.370		DL0.1% in %= 41.7475		

The size of the bulbs harvested from the variant planted on April 7th was lower compared to those planted on April 2nd. Their size ranged between 25.33 g and 13.67 g. Statistical interpretation of data obtained shows that there were differences in the size of the bulbs, planted on April 7th.

These differences are significant distinct negative for V6 and significant positive for V4 (Table 4).

At the planting of April 12th, the out of time plantation, differences between the size of harvested bulbs can be noticed, these being comprised between 18.67 g at V7 when large cloves were planted and 11.67 g at V9 when small cloves were planted.

Table 4. Synthesis of the garlic bulbs weight depending on clove size - the date of planting: 07/April

Variant	Weight of garlic bulbs, g	Difference		Signif.
		g	%	
Average	18.89	0	100	Control
V4	25.33	6.44	134.12	*
V5	17.67	-1.22	93.53	N
V6	13.67	-5.22	72.35	O
DL5% = 4.410		DL5% in % = 23.3471		
DL1% = 7.300		DL1% in % = 38.6471		
DL0.1% = 13.660		DL0.1% in %= 72.3176		

Statistically analyzing the data obtained regarding the mass of harvesting garlic bulbs according to the size of planted cloves we can appreciate that from the large cloves it obtained higher average bulbs masses. This is statistic supported by the fact that the V1 has achieved a highly statistically significant (Table 5).

Table 5. Synthesis of the garlic bulbs weight depending on clove size - the date of planting: 12/April

Variant	Weight of garlic bulbs, g	Difference		Signif.
		g	%	
Average	15.33	0	100	Control
V7	18.67	3.33	121.74	*
V8	15.67	0.33	102.17	N
V9	11.67	-3.67	76.09	OO
DL5% = 2.070		DL5% in % = 13.5000		
DL1% = 3.420		DL1% in % = 22.3043		
DL0.1% = 6.410		DL0.1% in %= 41.8043		

The planting on April 2nd yielded the largest garlic bulbs, averaging to 34.67 g. At the V7 variant, when planting was done later (on April 12th), bulbs of average weight of 18.67 g were achieved.

Statistically speaking against the average experience, a significantly negative grow was noticed, with a difference against the control batch of only 71.19% (Table 6).

Table 6. Synthesis of garlic bulbs weight depending on planting date at the variants where large cloves were used

Variant	Weight of garlic bulbs, g	Difference		Signif.
		g	%	
Average	26.22	0	100	Control
V1	34.67	8.44	132.2	**
V4	25.33	-0.89	96.61	N
V7	18.67	-7.56	71.19	O
DL5% = 4.780		DL5% in % = 18.2288		
DL1% = 7.910		DL1% in % = 30.1653		
DL01% = 14.820		DL01% in %= 56.5169		

Where they have used the medium bulbs at planting we found that the lowest weight of a bulb was obtained for the late plantings. However, statistically no real differences were found (Table 7).

Table 7. Synthesis of garlic bulbs weight depending on planting date at the variants where medium cloves were used

Variant	Weight of garlic bulbs, g	Difference		Signif.
		g	%	
Average	17.00	0	100	Control
V2	17.67	0.67	3.92	N
V5	17.67	0.67	103.92	N
V8	15.67	-1.33	92.16	N
DL5% = 5.240		DL5% in % = 30.8235		
DL1% = 8.670		DL1% in % = 51.0000		
DL01% = 16.230		DL01% in %= 95.4706		

The number of cloves formed in garlic bulbs was higher in earlier variants planted (on April 2nd) compared with the number of cloves formed on garlic planted on April 7th or 12th (Figure 6).

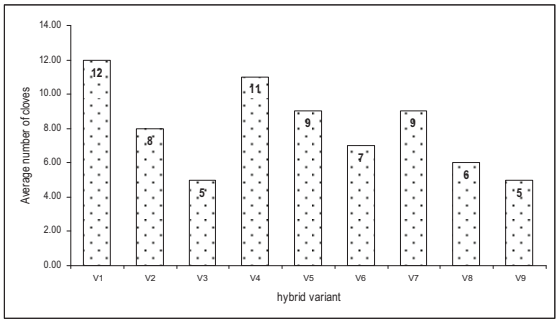

Figure 6. Number of cloves formed in garlic bulb depending on the time of planting and on the planting material size

Production levels per hectare were calculated by evaluating the size of garlic bulb and garlic quantities obtained for each variant. The data obtained is presented in Table 8.

Table 8. The crop production of garlic achieved at one ha according to the size and planting date of the bulbs

Variant	Planting date	Density	Production estimated at 1 ha
		Plants/ha	kg/ha
V1	02.April	1250000	7750
V2		1333333	5334
V3		1600000	4800
V4	07.April	1250000	6250
V5		1333333	4534
V6		1600000	4480
V7	14.April	1250000	4750
V8		1333333	4267
V9		1600000	4160

Figure 7 shows an inverse correlation between the achieved production and both cloves size at planting and planting date.

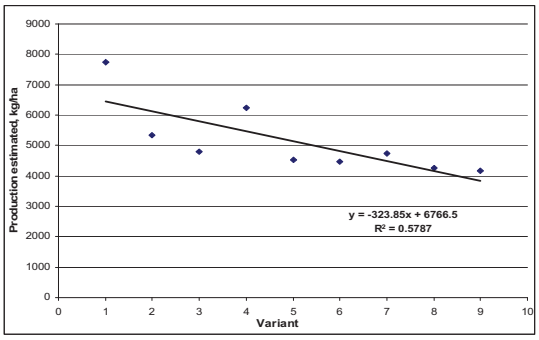

Figure 7. The correlation between planting date, planting bulbs size and achieved production

From the point of view of garlic diameter, the largest garlic bulbs were identified from all the variants planted on April 02nd, while the smallest garlic bulbs were found at the variants planted on April 12th. The data was assessed in compliance with the national quality standards. These data is presented in Table 9.

Table 9. Compliance with standard quality

Variant	Planting date	Bulbs diameter, cm	Quality class
V1	02.April	4.7	Superior
V2		3.3	First quality
V3		2.7	Second quality
V4	07. April	4.0	Superior
V5		3.7	First quality
V6		2.8	Second quality
V7	12. April	3.1	First quality
V8		2.9	Second quality
V9		2.0	Third quality – below standard quality

Changing of climatic conditions and temperature fluctuations are the main causes of production losses in most cultivated species. For example, in China, the 2011 production of garlic was lower by 30% compared to previous years (www.prettygarlic.com), with an important negative impact on garlic exports.
The global warming also affects Romania. The forecast of climate change in Romania show an annual increase of about 1.8 ^{0}C and a decrease in rainfall, for example the south of the country shows decreased values by 1.38 and 2.30% (Sandoiu, 2011). The survey results on garlic production in the last years indicate that

climate change affects the whole value chain of garlic.
In conditions of climate change, spring garlic cultivation has raised a number of challenges.
Even if the usual cultivation period of spring garlic in Southern Romania starts from the second decade of March, the lower temperatures followed by heavy rainfalls and flooding delayed the planting of garlic till early April. Such temperature conditions were consistent with planting from April 2nd, 2012-2013.
Thus in these conditions our experiments were conducted by planting of garlic in three stages: first, on April 2nd, second, on April 7th and third on April 12th.
In the first stage of planting the soil temperature was 5.3 ^{0}C, during the second stage was 6.2 ^{0}C and 7.6 ^{0}C in the third stage. Planting was carried out starting from April 2nd when the minimum temperature of 4 ^{0}C for rooting was achieved.
As seen from the results, the best results were obtained from the first planting on 2nd of April for all categories of clove sizes. This can be explained by the increasing in temperature that reached at mid-April to 18^{0}C. This temperature is not suitable for vegetative growth of garlic. These high temperatures during vegetative growth were clearly unfavorable for garlic planted on the second and third stages, namely on April 7th and 12th.
It is therefore clear the need to identify challenges and opportunities of garlic value chain and also to suggest adaptive mechanisms for climate changes.

CONCLUSIONS

The number of leaves formed on the plant varied accordingly to the planting date. At planting operations on April 2nd plants originated from large and medium cloves presented a higher number of leaves than the rest of the variants.
The lowest number of leaves was recorded at variants planted on April 7th.
Plant heights were influenced by planting period. The greatest heights were obtained from earlier variants planted.
The highest yields were obtained from all variants originated from large cloves (V1 - 43,750.0 kg/ha, V4 - 31,250 kg/ha, V7 - 23,750.0 kg/ha).
The lower yields were obtained from all variants originated from smaller cloves (24,000.0 kg/ha, 22,400.0 kg/ha, 20,800.0 kg/ha).
The garlic bulbs diameter was greater at the earliest planted variants (April 2nd) and the lowest for the variants planted on April 12th.
The climatic conditions are a limiting factor for garlic production.
In order to have a satisfactory productivity in the new environment a permanent optimization of planting date (according to climate changes) and a better existing genetic resources management are required.

ACKNOWLEDGEMENTS

This work was supported by a grant of the Romanian National Authority for Scientific Research, CNDI - UEFISCDI, financed from project number PN-II-PT-PCCA-2011-3.2-1351 - Contract No. 68/2012 and SC PROCEMA PERLIT SRL, Romania, furnished the perlite.

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