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РОЛЬ ІОНІВ КАЛЬЦІЮ У ПОПЕРЕДЖЕННІ ВЕРХОВОЇ ЦВІЛІ ТОМАТІВ В УМОВАХ ЗАХИЩЕНОГО ГРУНТУ

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THE ROLE OF CALCIUM IONS IN THE PREVENTION OF RIDING MOLD OF TOMATOES IN PROTECTED SOIL

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АНОТАЦІЯ

Серйозною проблемою, з якою можна зіткнутися при вирощуванні томатів у теплицях, є верхова цвіль, при цьому загальна врожайність може скоротитись майже на третину. Відомо, що поява верхової цвілі томатів спостерігається при недостачі кальцію в субстраті. Тому важливою задачею є проведення постійного контролю вмісту кальцію у витяжці із субстрату, що відіграє важливу роль у попередженні розвитку цієї хвороби.

У роботі досліджено вплив концентрації макроелементу кальцію в субстраті з мінеральної вати на ріст і розвиток культури томату сорту «Біоранж» в умовах захищеного грунту.

ABSTRACT

Riding mold is a serious problem that can be encountered when growing tomatoes in greenhouses, and the overall yield can be reduced by almost a third. It is known that the appearance of riding mold of tomatoes is observed in the absence of calcium in the substrate. Therefore, an important task is to conduct constant monitoring of calcium content in the extract from the substrate, which plays an important role in preventing the development of this disease.

The influence of the concentration of the macroelement calcium in the substrate of mineral wool on the growth and development of the culture of tomato variety "Biorange" in a protected soil is investigated.

Ключові слова: томати, теплиця, крапельний полив, кальцій, кальцієва селітра, верхова цвіль, комплексонометрія.

Keywords: tomatoes, greenhouse, drip irrigation, calcium, calcium nitrate, riding mold, complexometry.

Tomato culture (Solanum lycopersicum L.) is of great importance in the world. Tomato today - one of the most popular crops, thanks to its valuable nutritional and dietary qualities, a large variety of varieties, high feedback on the cultivation techniques used. Its fruits are consumed both fresh and in the form of various foods. Tomato fruits are eaten fresh, boiled, fried, canned, dried and used to make tomato paste, tomato puree, tomato juice, ketchup and other sauces, lecho, etc. And the share of processed tomatoes accounts for more than 65% of world production. This popularity of tomato fruit is primarily due to the pleasant harmonious taste due to the optimal ratio of sugars and organic acids [1,2]. It is known that the taste of the fruit is determined primarily by the amount of dry matter and the ratio of acids and sugars in the cell juice. In red tomatoes the dry matter content is on average from 3.5 to 5.5%, in yellow and orange - 5.5 to 7%. Pink tomatoes in comparison with red accumulate more dry matter, pigments, provitamin A, pectins, ascorbic acid, the content of lycopene in them reaches 8.5 mg% [3]. Doctors have found that lycopene and provitamin A (beta-carotene) inhibit the growth of cancer cells and prevent the development of cardiovascular disease [2].

The rating of varieties and hybrids of tomato on the market is currently low, despite the fact that in recent years there have been many new products. These are mainly varieties and hybrids of foreign selection, many of them are not sufficiently adapted to the natural and climatic conditions of Ukraine. Thus grades of domestic selection do not always have high quality of fruits and good productivity, besides, as a rule, are unsuitable for transportation on long distances. Therefore, the production of high-yielding tomato hybrids that meet the demands of the modern market is very important [4].

Tomato - heat-demanding culture, the optimum temperature for growth and development of plants is +22 ... + 25 °C, at temperatures below 15 °C does not bloom, dies when frozen below 0 °C, at temperatures below + 10 °C plant growth stops , the pollen in the flower does not ripen and the unfertilized ovary disappears. Tomato does not tolerate high humidity, but requires a lot of water for fruit growth. Tomato plants are demanding to light. In its absence, plant development is delayed, the leaves fade, the buds fall off, the stems are strongly elongated. Lighting in the seedling period improves the quality of seedlings and increases plant productivity.

Tomato fruits have high nutritional, taste and dietary qualities. Caloric content of ripe fruits (energy value) - 19 kcal. They contain 4.5-8.1% dry matter, half of which are sugars, mainly glucose and fructose, as well as organic acids (3.5-8.5%), fiber (0.87-1.7%). Fruits also contain proteins (0.6-1.1%), pectin (up to 0.3%), starch (0.07-0.3%), minerals (0.6%). Tomato fruits are high in carotenoids (phytoen, neurosporin, lycopene, nealikopin, carotene (0.8-1.2 mg / 100 g of raw weight), lycosantin, lycophil), vitamins (B1, B2, B3, B5), folic acid and ascorbic acid (15-45 mg / 100 g of raw mass), organic (citric, malic, oxalic, tartaric, succinic, glycolic), high molecular weight fatty (palmitic, stearic, linoleic) and phenolic (p-coumaric, caffeic, ferulic) acids. Anthocyanins, stearin, triterpene saponins, abscisic acid were found in the fruits. Choline present in tomatoes lowers blood cholesterol, prevents fatty degeneration of the liver, increases the body's immune properties, promotes the formation of hemoglobin. In the peel of tomatoes found flavonoid naringenin, which has anti-inflammatory action. The content of trace elements in 1 kg of fruit: sodium - 40 mg, potassium - 2680 mg, calcium - 110 mg, magnesium - 120 mg, iron - 6 mg, copper - 0.97 mg, phosphorus - 270 mg, sulfur - 140 mg, chlorine - 400 mg, manganese - 1.89 mg [5,6].

Calcium (Ca) together with potassium [7] is an important macronutrient for plants. Calcium affects the metabolism of carbohydrates and proteins in plants. The need for calcium is manifested in the earliest stages of growth, it is necessary for the construction of the plant. Lack of calcium inhibits the processing and absorption of spare nutrients (starch, protein), which are used by seedlings, young leaves and growing shoots. This can lead to the drying of young growing parts of the plant and then to the death of the whole plant.

Calcium regulates water balance, binds soil acids, provides normal conditions for the development of the root system of plants, improves the solubility of many compounds in the soil. It promotes the absorption of important nutrients by plants, affects the availability of plants of a number of macro-and micronutrients. With increasing amounts of calcium in the soil increases the flow of ammonium ions, molybdenum into the plant, but decreases the mobility of manganese, zinc, boron. Lack of calcium cations in the soil leads to increased acidity of the soil solution (unless the soil is saline - does not contain excess sodium). Increased soil acidity impairs root growth and permeability. This leads to a deterioration in the use of soil nutrients and fertilizers by plants, reducing their stability, endurance and competitiveness to the whole complex of pests, especially soil. The acid reaction of the soil solution impairs carbohydrate and protein metabolism in plants, weakening protein synthesis. The number of non-protein forms of nitrogen is increasing. The process of conversion of monosaccharides into other, more complex organic compounds is inhibited. Metabolism shifts in a favorable direction for phytopathogens of fungal nature. Diseases caused by fungal parasites are usually more common on acidic soils than on neutral ones. Liming of acid soils leads to significant improvement of the soil from pathogens of fusarium and penicillin mold. However, other types of pathogens (botrytis and rhizoctonia) thrive in a neutral and slightly alkaline environment [8].

In addition to the above, calcium is involved in other important biochemical processes of the plant: promotes the transport of carbohydrates in plants; strengthens cell walls and bonds them to each other; contribute to the development of the root system; necessary for leaf development; increases plant resistance to some diseases; stimulates the activity of nodule bacteria, which fix nitrogen from the air [9].

Calcium also affects soil fertility: stimulates the activity of beneficial microorganisms that mineralize nitrogen in compost heaps; reduces soil acidity and accelerates the processes of ammonification and oxidation of sulfur; promotes the formation of humus; accelerates the decomposition of organic matter in the soil; reduces the toxicity of iron, manganese and aluminum by neutralizing their excess amounts. Calcium improves the mechanical composition of the soil and, thus, improves its air permeability and water permeability; contribute to the formation of the structure (aggregates) of the soil.

Calcium in plants is in the form of salts of pectic acid, sulfate, carbonate, phosphate and calcium oxalate. Much of it is contained in plants, 20-65% of it is soluble in water, and the rest can be removed from the leaves when treated with weak acids [10].

Calcium enters plants throughout the period of active growth. In the presence of nitrate nitrogen in the solution, its penetration into plants increases, and in the presence of ammonia nitrogen - decreases. Hydrogen ions and other cations at high concentration in soil solution interfere with receipt of calcium.

Gradually, calcium is transferred from the soil to the plants, and the soil is depleted. With age, its number in plants increases. Different plants differ in calcium intake. Chlorophyll-free flowering plants use it much less than green plants. All cereals are characterized by low calcium absorption. And succulents, cacti, legumes, perennial grasses, nightshade and cruciferous crops consume this element more than others. Among agricultural plants, a lot of calcium is removed from the soil by cabbage, alfalfa and clover. On poor acidic sandy and loamy soils, some calcium is washed away by water, so it is necessary to replenish its reserves every 5 years, carrying out liming. Plants that are particularly in need of calcium, belong to a special group - calciphilous plants, they are most sensitive to its lack in the soil.

Lack of calcium in the soil leads to deformation of plant cells, weak formation of integumentary tissues, abundant development of intercellular spaces, which are poorly filled with lignin. Lack of calcium slows down the growth of roots, they slip and rot. Decomposed roots attract soil phytopathogens and saprophytes, as it is a favorable substrate for them [11].

Signs of calcium deficiency are manifested primarily on young leaves: their growth is inhibited, small leaves of irregular shape are formed, chlorotic spots appear, the coccyxes of young leaves become white; the edges of the leaves twist down, turn yellow and die prematurely, the middle veins of the leaves break; at strong starvation the top of a plant and flower stalks die off, stalks grow weak. When calcium starvation on the edges of chlorotic leaves may appear brown or brown necrotic spots. Many bulbs without calcium form a weak, drooping peduncle. By timely feeding the bulbs with calcium, you can help the peduncle to become strong and straight. For liquid fertilization, calcium is made in the form of calcium nitrate (1 tb. spoon per 10 liters of water).

Plants on soils poor in calcium are fed calcium nitrate once a season. Calcium is also found in superphosphate, although it is less available to plants. For calciphilous plants, calcium is added to the soil 2-3 times during the growing season.

It should be borne in mind that excess calcium is much more harmful than its deficiency: it binds iron compounds and makes them inaccessible to plants, disrupts the absorption of nitrogen, potassium and boron, causing leaf chlorosis and the appearance of light shapeless spots of dying leaf tissue. Most plants suffer from soil alkalinization: their roots die, the plants droop and may die. In addition, it is necessary to take into account the quality of water used for irrigation: hard water contains a lot of calcium, which, unlike other elements, is introduced into the soil with each watering. Therefore it is better to use soft water for watering.

Calcium is needed by tomatoes for shoot development and fruiting, and it also contributes to the ionic balance of the plant, which slows down the effects of sodium salinity, allowing tomatoes to be cultivated even in partially saline soils by reducing toxic effects. That is why a noticeable deficiency of this element can greatly damage the tomato crop.

Calcium deficiency is most pronounced on tomato plants during the period of active growth during fruit ripening. At this time it is necessary to carefully observe the tomatoes, paying special attention to the leaves and fruits. Since the leaves in this period will constantly form new tissues, in the absence of one of the main building materials - calcium, they can be deformed, acquire a reddish-brown color and slow down in development [12].

The optimal calcium content in the substrate is from 320 to 480 mg / liter. Varieties of tomatoes with large fruits need to maintain its level in the upper limits.

Table 1.

Requirements for calcium content in the substrate of mineral wool in different periods of tomato growth

№	Indicator	Growth period						
		A	B	C	D	E	F	G
1.	Ec	2,44	2,38	2,57	2,54	2,55	2,56	2,59
2.	pH	5,5	5,3	5,5	5,5	5,5	5,5	5,5
3.	Ca^{2+}, mg/l	310	380	340	310	390	310	370

where A is the standard;
B - impregnation of mats;
C - from 1 to 3 tassels;
D - from 3 to 5 tassels;
E - from 5 to 10 tassels;
F - from 10 to 12 tassels;
G - mass fruiting.

The consequence of calcium deficiency during fruiting can be riding mold of tomato fruits.

Reasons for the development of riding mold on tomatoes. Lack of moisture and hot air lead to intense evaporation of fluid from the leaves and trunk. If during this period you do not provide access to moisture through the root system, the plant begins to suck it from the fruit. As a result, part of the fruit cells die and the riding mold of tomatoes develops, the treatment of which is much more complicated and time-consuming than the prevention of infection.

Fig.1. Riding mold of tomato fruit

Among other reasons for the development of riding mold of tomatoes are:

- calcium deficiency;
- excess nitrogen;
- high soil acidity.

Primary signs of infection. To start the treatment of ripening of tomato mold in time, it is important to know the characteristic signs of this disease. Immature fruits of the second and third hands are most prone to infection. The first symptoms appear on the tips (tops) of the fruit in the form of flat or depressed liquid spots. The color of the spots is initially dark green, and with the development of the disease changes to gray-brown, up to black. Infected fruits stop growing and deform quickly. Subsequently, the skin on the spot dries and cracks, and the disease penetrates into the fetus. Fungi of the genus Alternaria can settle on the areas affected by horse mildew, due to which the flesh of tomatoes darkens and rots.

Fruits affected by horse mildew ripen faster than others and crumble from the branches. It is impossible to use them fresh or for processing, and also to collect seed material from them [1].

Characteristics of the Biorange hybrid.

Indeterminate, late-maturing Dutch hybrid. Tassel simple, peduncle with articulation. Fruits of medium and large size, weighing about 250-280 g. The shape of the fruit is round or slightly heart-shaped. The fruits are ribbed, not prone to cracking. The color of ripe fruit is bright orange. The flesh is juicy, fleshy, yellow-orange, bright. The fruits are multi-chambered, with thick walls.

Features of the Biorange hybrid:

- a powerful plant with a good fruit set;
- high potential for laying a large number of brushes;
- compact plant;
- good shelf life and transportability of fruits;
- great taste.

Advantages:

- good productivity under relatively unfavorable growing conditions;
- high yield potential when grown in light culture;
- suitable for low greenhouses;
- high shelf life;
- positive consumer feedback.

There are several methods to eliminate calcium deficiency in plants [13,14]. Calcium nitrate is a water-soluble fertilizer that contains calcium and nitrogen in nitrate form. The compound is highly hygroscopic - it must be stored in a place protected from moisture. Chemical formula $Ca(NO_3)_2$. Calcium nitrate is obtained by the action of HNO_3 on limestone or by the absorption of nitrous gases (usually NO_2) by lime milk. Calcium nitrate is used as a nitrogen fertilizer, as well as to obtain particularly pure calcium oxide. To obtain granular calcium nitrate, low-temperature neutralization of nitric acid by products of limestone processing or natural limestone is used:

$$CaCO_3 + 2HNO_3 = Ca(NO_3)_2 + CO_2\uparrow + H_2O$$

Fig.2. Calcium nitrate

Calcium has a beneficial effect on the cell walls of plants, making them strong. Regular top-dressing with calcium-containing fertilizers helps to improve the appearance of products, as well as extend its shelf life. In addition, calcium nitrate is used for prophylactic purposes against the appearance of riding mold of peppers and tomatoes, core mold of apples, marginal burns of lettuce and other diseases that can be caused by calcium deficiency.

As for the method of application of calcium nitrate, it can be non-root fertilization, as well as application by drip irrigation and sprinkling. Calcium nitrate can be used on any soils and substrates, but the maximum effect is usually achieved on acidic soils. Lack of calcium in plants leads to their rapid defeat by various pathogens. That is why timely calcium supplementation is so important.

Traditionally, calcium nitrate is made in the form of crystals or granules. Granular calcium nitrate is resistant to external influences and temperature fluctuations (it can withstand temperatures from -60 °C to + 155 °C). In addition, even with long-term storage, this fertilizer does not lose its effectiveness. Another indisputable advantage of granular calcium nitrate is its explosion and fire safety. When stored in an airtight container, this fertilizer does not clump and retains its crumbliness for years. However, at temperatures above +500 °C begins to decompose with the formation of first $Ca(NO_2)_2$, then CaO and NO_2 and the release of O_2.

Materials and methods. The object of the study were tomatoes of the variety "Biorange" (yellow) during the period of mass fruiting (after 12 tassels). Feeding tomatoes was carried out according to the recipe shown in table 2.

Table 2.

Uterine solution for tomato during flowering 12 tassels

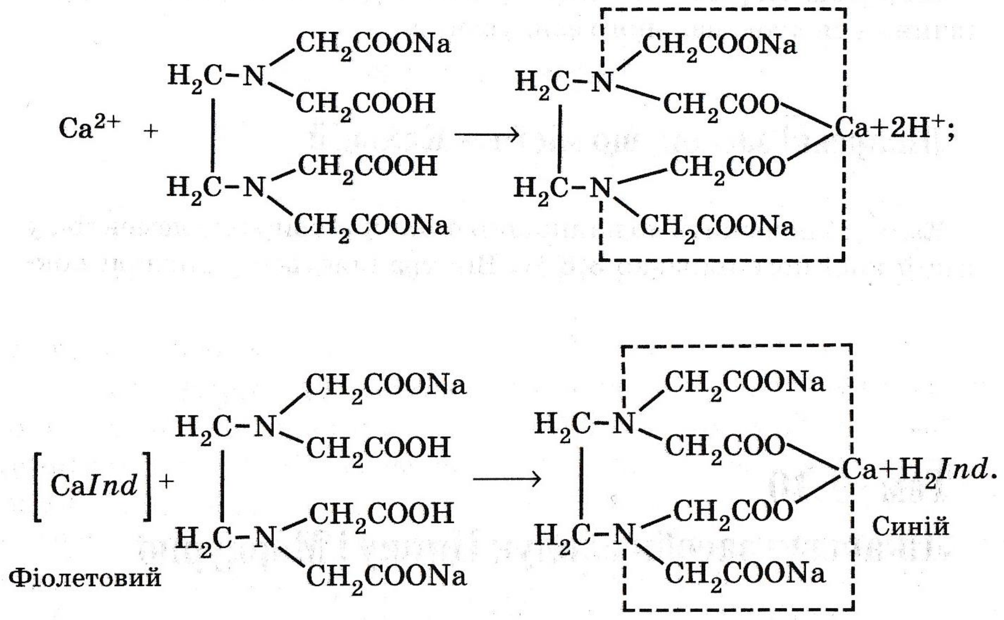
Tank A (kg/1m^3)	Tank B (kg/1m^3)
$Ca(NO_3)_2$ – 86,4 KNO_3 – 16,2 HNO_3 –0,3 – 0,5 l Chelate Fe (11%) – 0,76	HNO_3 (57%) – 26,9 l pH=5,5 KNO_3 – 4,0 KH_2PO_4 – 20,4 K_2SO_4 – 41,8 $MgSO_4$ – 36,7 Microelements: g/m^3 $MnSO_4$ (32%) – 87 $ZnSO_4$ (23%) – 92 Borax (15%) – 108 $CuSO_4$ (25%) – 14 Molybdate Na (40%) – 12

Sampling for nutrient content took place three times a week for two weeks.

Quantitative calcium content was determined in extracts from mineral wool using the method of complexometry according to the following method [15]. To do this, take 10 ml of the test solution, add 10 ml of distilled water, 1 ml of 2% sodium sulfide solution, 2 ml of 16% sodium hydroxide solution, a dry mixture of murexide indicator and titrated with 0.05 N solution of Trilon B to change color from pink to purple.

The equations of reactions that underlie the complexometric determination of calcium ions are as follows:

$$CaCl_2 + H_2\mathit{Ind} \rightleftarrows [Ca\mathit{Ind}] + 2HCl;$$



The calculation of the calcium content in the investigated extract was performed according to the formula:

$$C_{Ca} = \frac{V1 \cdot N \cdot ECa \cdot 1000}{V2} = \frac{0,05 \cdot V1 \cdot 20 \cdot 1000}{10} = V_1 \cdot 100,$$

where V_1 is the volume of 0.05N solution of Trilon B, spent on titration, ml;

N is the normal (equivalent) concentration of Trilon B, mol / l;

E_{Ca} - calcium equivalent, mg / mol;

V_2 - the volume of the test solution taken for analysis, ml.

Results and discussion

During a series of experiments, the calcium content in mineral wool extracts was determined.

Data on the change in calcium content in the substrate are shown in table 3.

Table 3.

Quantitative calcium content, mg / l for tomato in the extract of mineral wool

№	Indicator	Allowable level		Date of sampling						Average value
		low	high	17.08	19.08	21.08	24.08	26.08	28.08	
1.	pH	5,0	6,5	6,11	6,01	6,35	6,71	6,52	6,81	6,42
2.	Ec, mSm/sm	2,5	5,0	3,61	3,61	3,05	2,98	3,35	3,71	3,39
3.	Ca^{2+}, mg/l	320	480	350	400	350	250	300	500	358,3

According to the obtained data, the total concentration of salts (Ec) and the concentration of calcium ions in the studied extracts was within the norm, which corresponds to the period of growth "G" of the tomato. High pH values were eliminated by increasing the amount of nitric acid in the nutrient solution. At the time of the study, a small number of tomatoes (about 5% of plants) were affected by riding mold. Thus, by regulating the level of calcium nutrition of tomatoes, you can significantly affect their productivity and quality of products.

Conclusions

1. Complexometric method for the analysis of extracts from mineral wool is quite sensitive, simple and recommended for use in serial analyzes.

2. The determined content of calcium salts (358.3 mg / l) was optimal for growing tomatoes during the period of mass fruiting.

3. Control of calcium content can significantly reduce the damage to plants by riding mold and get a high quality crop of tomatoes.

3. By conducting regular tests it is necessary to monitor changes in the content of batteries. If the results of the analysis reveal a deficiency or excess of an element, then adjust the composition of the nutrient solution.

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