

Management capabilities of generative development of apple trees

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Abstract

Aim: In field and laboratory experiments, we investigated the viability of application of boric acid and Melaphen, growth regulator of the next generation, to optimize the generative activity of apple plants (Golden Delicious variety) at different stages of the annual growth and development cycle. **Methods:** To achieve this goal, we used field and laboratory research methods. The research was conducted in 2013-2016. **Results:** We revealed the effect of boric acid (at concentration of 0.1%) on the setting-up, differentiation and further development of generative buds of apple trees. **Discussion:** The application of boric acid in the fall contributes to strengthen and accelerate the formation of floral sprouts. The use of this compound before the beginning of the vegetation period improves the fertilization process. The growth stimulator Melaphen has the same effect on the generative activity of Golden Delicious as boric acid in the autumn and spring season. We identified an indirect effect of Melaphen on the apple plants resistance against spring frosts. Summer plant treatment with Melaphen contributes to a certain increase of economic crop, a significant increase in the activity of shoot growth in the second half of the growing season, as well as the weakening of the setting-up generative buds and the time shift in their development. **Conclusion:** We have demonstrated the possibility of adjustment of the fruit yield formation, when using the preparations under study, through directional increase of the concentration (biological activity) of growth factors of the auxin nature in certain plant organs and tissues, and change in this regard the nutrients displacement vector toward relevant attracting centers.

Key words: Apple tree, economic crop, generative development, growth regulators

INTRODUCTION

Ensuring sustainable functioning of the garden ecosystem is a priority problem of present-day ecology, physiology, and agronomy.^[1] Its solution is associated with the need for stable production of quality biological products, in this case, fruit. Meanwhile, regular fruiting of plants is constrained by frequent manifestation in various regions of many abiotic stressors. And even in the southern regions of the Russian Federation, despite its unique natural and climatic potential, in some years, there has been a cold with sharp temperature fluctuations in winter, spring frosts or droughts, and elevated air temperature during the summer season. According to some estimates,^[2] loss of fruit yield under the action of appropriate stress factors can reach 80-100%. The other facts of the fruiting periodicity are known as well (especially for apple trees), they are related to biological characteristics of used pomology varieties or age of plants.^[3]

Earlier^[4] highlighted the role of the production process as a set of complicated biochemical reactions in the plant body, occurring with the direct involvement of solar radiation in the synthesis of the diversity of organic substances. Moreover, the functioning activity of individual links of a production process depends on the balance between endogenous stimulators and inhibitors. However, the integrated indicator of the production process efficiency, the most important from a utilitarian viewpoint, is the amount of economic crop of plants.^[5] Obviously, to attenuate the fructification periodicity, it is appropriate to develop specific methods of targeting affecting the regulatory system of the plant body that defines the nutrients distribution pattern among the various organs and tissues of plants in specific phenophases (stages of organogenesis), providing,

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thus, the adjustment of the formation of the fruit yield in appropriate weather and agronomic conditions. Given that the basis of regulatory systems is the range of endogenous stimulators and growth inhibitors,^[4] the most realistic way to control them is the intensification (suppression) of hormone synthesis or additional introduction into the plant of synthetic, physiologically active analogues of the respective hormones.

Various physiologically active substances used in agriculture are presented in the article.^[6-8] In the specialist literature,^[9] there is some information about the prospects of the application of various physiologically active substances for improving the productivity of fruit plants and their resistance against different stressors. However, this literature lacks the description of action mechanisms of used drugs on the formation of economic efficiency or sustainability of the plant organism against the impact of adverse environmental factors. The lack of such information does not allow developing a management strategy of generative activity of fruit plants during the periods between fruiting years.

There are other, no less intriguing data from the viewpoint of possible regulation of the generative activity of fruit plants. They concern the so-called “inorganic growth substance,” which includes boric acid.^[10]

We managed to reveal its beneficial effect on the germination of pollen grains and accelerating the growth of pollen tubes. In addition, some scholars^[11] have shown the effectiveness of autumn foliar application of boron to increase fruit set of sweet cherry. Meanwhile, the influence of autumn treatment with boron of apple plants on their productivity has not been studied.

The purpose of the present research is to justify the possibility and application timing of boron-containing compound (boric acid) and growth regulator of next generation named Melaphen to change the hormonal field of apple plants providing optimization of their generative activities at different stages of the annual cycle of growth and development, including that in adverse weather conditions.

METHODS

To achieve this goal, we used field and laboratory research methods. The research was conducted in 2013-2016.

Field Experiments

Field experiments were carried out in experimental plantings of the Botanical Garden of the Kuban State Agrarian University (Krasnodar, Russia, 45°20'41" north latitude, 38°58'33" east longitude). This area is characterized by leached chernozem soil and moderately continental climate. Experimental orchards of apple trees on the rootstock M 9

were planted in 2006 under the scheme of 4 m × 2 m. The gardening system corresponded to the recommended for this fruit zones.^[12] We studied Golden Delicious apple trees whose fruits are intended for consumption in the winter season.

Experimental design #1. The effect of boron-containing compound (boric acid) on the fruiting characteristics of apple trees depending on the application timing.

The following options were considered:

1. Plants treatment with water (control).
2. Plants treatment with boric acid solution (at the concentration of 0.1%) during the period of transition from vegetation to rest (October 2013, 2014).
3. Plants treatment with boric acid (at the concentration of 0.1%) before the beginning of the growing season (March 2014, 2015).

Experimental design #2. The effect of Melaphen drug on growth and development peculiarities of apple plants depending on the application timing.

The following options were considered:

1. Plants treatment with water (control).
2. Plants treatment with Melaphen (at the concentration of 1×10^{-9} M) during the period of transition from vegetation to rest (October 2014).
3. Plants treatment with Melaphen (at the concentration of 1×10^{-9} M) before the beginning of the growing season (early March 2015).
4. Plants treatment with Melaphen (at the concentration of 1×10^{-9} M) during the fruit growth phase before the onset of sustained hot weather in the region (July 2015).

Melaphen preparation, synthesized in A.E. Arbuzov Institute of Organic and Physical Chemistry of the Kazan Scientific Center of the Russian Academy of Sciences is a melamine salt bis (oxymethyl) of phosphinic acid. Its advantage is the water solubility, the availability of the growth-regulating activity, and the effect in ultra-low concentrations: 1×10^{-9} M.^[13]

The experiments were carried out in six-fold replication.

Field experiments were conducted in accordance with the program and methodology of variety investigation for fruit, berry and nut cultures.^[14]

Laboratory Experiments

To explore the degree of stability of the studied apple tree varieties against frost in the control variant as well as at the application of Melaphen, we employed the artificial freezing technique. In the phase of “divergence of petals - beginning of flowering,” the branches with buds, cut in the morning, were frozen for 4 h in a climatic chamber “Binder” KV 53 at a temperature of $-3.0^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$ to study the change in viability of pollen.

The viability of pollen was determined using solution of iodine in potassium iodide,^[15] the degree of formation and differentiation of floral buds, as well as the stages of organogenesis, were studied with the use of MBS-1 microscope;^[16] the concentration of indoleacetic acid (IAA) was determined by capillary electrophoresis according to the methodology described in the specialist literature.^[17]

The contents of nucleic acids were determined in the matter, preserved by boiling ethanol. Removal of acid soluble material and lipids, as well as the separation of nucleic acids, was carried out according to Schmidt and Thannhauser technique. The concentration of nucleic acids in solution was determined by spectrophotometric method according to Spirin.^[18]

Experiments were conducted in double replication. Error, when conducting analyses, did not exceed 3.0%. The experimental results were processed by mathematical statistics methods.^[19]

RESULTS

Processing of apple plants with boric acid or Melaphen changes the activity of the growth and development processes of plant organism.

Effect of Boric Acid on the Fruiting Characteristics of Apple Plants Depending on the Application Timing

Under the effect of boric acid (autumn treatment) in generative buds of fruit formations of apple trees, we noted a significant increase in the concentration of IAA (almost by 2.0 times), RNA content (by 15%), as well as the RNA/DNA ratio, which is indicator of functional activity of the plant organism [Table 1].

These physiological and biochemical changes are associated with the intensification of the formation and differentiation processes of generative buds, and in the future – with the increase in the number of flowers in the apple plants and, respectively – enhancement of economic efficiency [Table 2].

At the same time, using boric acid in the spring time causes to a significant reduction (compared to control) in dead flowers

Table 1: The effect of boric acid on physiological and biochemical parameters of the generative buds of apple plants (November 2014)

Variant	IAA, mg/kg	RNA, mg/g	RNA/DNA
Control	3.03±0.13	7.15±0.18	3.5
Boric acid	5.71±0.16	8.21±0.22	4.6

IAA: Indoleacetic acid

and ovaries (first and second waves of fall) that also leads to increased fruit yield. According to our data, the highest harvest in the experiment was generated when using boric acid in the spring season (by 17% higher than in control and by 8% higher than in the “autumn treatment” variant).

It was noted that the application of boric acid in the autumn season leads to some acceleration in the development of apple plants.

The Effect of the Melaphen Drug on Growth and Development Peculiarities of the Apple Plants Depending on the Application Timing

The experiments have shown that Melaphen accelerates the development of floral buds of apple plants. The beginning of vegetation in the treated plants (autumn season) was recorded for 3-5 days earlier than that in the control.

It is also noteworthy that under the effect of Melaphen (fall and spring application periods), the viability of the pollen grains of apple trees increases by 2.3-2.7 times [Figure 1]. Moreover, even in the conditions of short-term temperature fall this figure significantly exceeds the control values.

The application of Melaphen during the autumn and spring seasons provides for the formation of a larger (compared to control) number of ovaries in the tree and, moreover, smoothes out noticeably the second and third wave of fall that determines high economic efficiency of plants in these experimental variants [Figure 2 and Table 3].

At that, the vegetative growth parameters (mean and total length of shoots) were slightly higher than the control values.

At the same time, the application of the drug in the summer season before emergence of high summer temperatures contributes to the reduction of inefficient preharvest fall of the fruit and thus increases economic yield. At the same time, the application of Melaphen in the specified period activates the growth of shoots (by the end of the vegetation period the

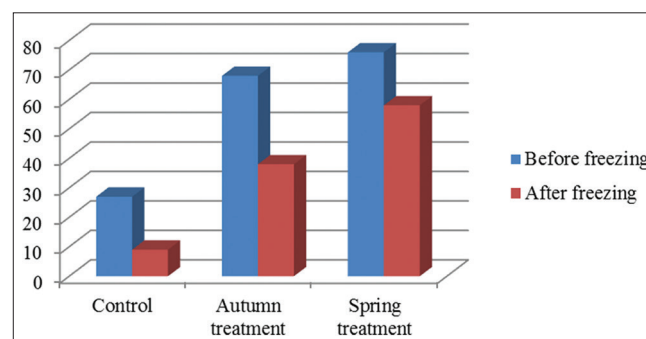


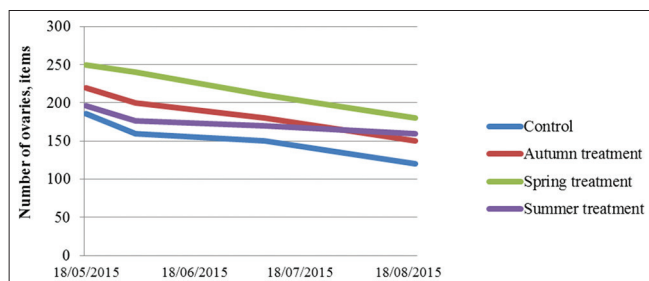
Figure 1: The effect of Melaphen on the viability of the pollen of the Golden Delicious apple trees at short-term exposure to freezing temperatures depending on the drug application timing

Table 2: The effect of boric acid on the generative activity of apple plants depending on the processing timing (2014-2015)

Variant	Setting-up generative buds (%)	Number of flowers, items/tree	The abscission of flowers and ovaries (first and second wave) (%)	Economic efficiency, kg/tree (on average for 2014-2015)
Control	40	1940	86	19.3
Boric acid				
Autumn	48	2100	83	20.8
Spring	42	1896	71	22.5
HCP ₀₅	1.1	23.4	3.2	1.6

Table 3: The effect of Melaphen on the vegetative growth and generative development of Golden Delicious apple trees depending on the drug application timing (2015-2016)

Variant	Length of shoots in the tree, cm (September 2015)		Economic crop, kg/tree	The stage of floral buds development, January 2016
	Average	Total		
Control	38	2948	20.3	V
Melaphen				
Autumn	39	3015	21.5	V
Spring	42	3235	24.4	V
Summer	45	3611	22.5	IV
HCP ₀₅	1.6	15.8	1.1	-

**Figure 2:** The effect of Melaphen on the fall of the ovaries of Golden Delicious apple trees

average length of the shoot is 22% greater than in control) and significantly hinders setting-up and development of floral buds. Thus, in the third decade of January, the control plants of Golden Delicious apple varieties were at the V stage of floral buds development (setting-up of 38%), while at the application of Melaphen, floral buds development corresponded to the Stage IV (setting-up of 21%).

DISCUSSION

In consequence of the research, we have revealed the effect of boric acid on the setting-up, differentiation and further development of generative buds of apple trees. At that, the nature of this effect depends on the application timing of boron-containing compounds. In particular, autumn plant treatment with boric acid promotes functional (growth)

activity of generative buds and, as consequence, strengthening and acceleration of the floral sprouts formation. At the same time, the application of boron-containing compounds before the beginning of the vegetation period improves the fertilization process.^[20]

As shown by the experiment, the effective influence of boric acid on the generative function of the apple tree is associated with an increase of IAA concentration in floral buds of plants. Meanwhile, it is the auxins, providing outragerous effect, activate the inflow of water and nutrients to certain organs and cells and provide their increased growth.^[5,21] In the context of the concerned problem, this could be the increase in cell layers of the meristem of the generative buds, germination of pollen, or growth of pollen tubes. The fairness of the considered hypotheses is convinced by other previously obtained results. It is established,^[22] for example, that treatment of Jonagold apple trees with ammonium nitrate phosphate fertilizer in the phase of “closure of the sepals” and 12 days after the first application leads to a significant increase in average fruit weight due to noticeable contribution to an increase of the biological activity of endogenous growth factors of auxin nature in the tissues of the developing seeds.

According to our data, growth stimulator Melaphen has an effect similar to boric acid with regard to the generative activity of apple trees in the autumn and spring seasons. However, most importantly, a similar result is achieved

using the concentrations by orders of magnitude lower than those in the case of using boron-containing compounds.^[13] At the same time, we should underline the possibility of using Melaphen to attract nutrients to build generative parts of the flower and increase their viability even at short-term exposure to freezing temperatures. Exactly, these results indicate an indirect effect of this drug on improving the resilience of plant organism to spring frosts. It is noteworthy that under the effect of another temperature stressor, such as high air temperatures in summer, Melaphen provided for reducing preharvest fall of fruit that led to a slight increase in economic yield of apple plants. At the same time, summer treatment of the apple trees with Melaphen significantly enhanced growth activity in the second half of the growing season, weakening in this regard of setting-up generative buds and time shift of their development. Apparently, application of this drug within the specified period can be used as one of the ways of combating excessive setting-up of floral buds and providing regular fruiting of apple trees in adjacent years.^[14]

CONCLUSION

In consequence of the conducted experiments, we revealed the effect of boric acid (at a concentration of 0.1%) on the generative development of apple plants. At that, the nature of this effect depends on the application timing of boron-containing compound. While the use of preparation in the period of plants transition from growing season to rest contributes to activation and acceleration of the formation of floral sprouts, the application of boric acid before the beginning of the growing season improves the fertilization process. Melaphen drug has the same effect as boric acid in the autumn and spring seasons. Its application improves the resilience of plants to spring frosts that were shown by experiments. Summer treatment of plants with Melaphen contributes to a certain increase of economic harvest, a significant increase in the activity of shoot growth in the second half of the growing season, as well as the weakening of the setting-up of generative buds and the time shift in their development.

Given the observed regularities, it is possible in due course of the annual cycle (phenological phase, plants growth, and development phases) to deliberately change the nutrients displacement vector toward relevant attracting centers: Emerging generative buds, floral organs, seeds tissues, shoot growing points, etc., increasing in them the concentration (biological activity) of the endogenous growth promoters of auxin nature. Thus, it is possible to adjust the fruit yield formation in specific weather and agronomic conditions. To control the generative activity of apple tree, it is appropriate to use synthetic analogs of auxin or nutrient elements, activating the corresponding hormonal synthesis (for example, “Melaphen” drug and boric acid). The obtained results will help to identify viability of applications in today’s

horticulture of other physiologically active substances appearing on the domestic market.

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