Effects of Ethephon Application on Color Development of 'Gala Must' Apples

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Abstract

Fruit peel color is an important quality parameter and marketing attribute that influences consumer acceptance. Red color development in apples is due to the formation of anthocyanin pigments in the apple skin. Anthocyanin production, and therefore apple color is influenced by a range of environmental and management factors in the orchard. Ethephon is a compound that slowly releases ethylene which in turn can stimulate anthocyanin accumulation in apples. The aim was to evaluate the influence of ethephon to the color development of 'Gala Must' apple variety. The study subject of the experiment was Gala Must apple variety grafted on M 9. The trees were trained as slender spindles. The distance of plantation is 3.5 x 1.2 m. To study color development of the apple fruits were experimented the following variants of treatment: 1. Control – no treatment; 2. Ethephon – 300 ppm; 3. Ethephon – 400 ppm. Ethephon were sprayed one time 2 – 3 weeks before commercial harvest. The research was conducted during the period of 2013 year. During the research, it was studied the amount and average of fruits, tree production, quality, firmness of fruits, hydrolysis and color index. In the present research work, it was demonstrated that ethephon may be included in the system of color development of "Gala Must" apple variety fruits, the dose of 400 ppm, applied one spray 2 – 3 weeks before commercial harvest, where the level of profitability was 184.0%.

Keywords: *apple, color, ethephon, quality, yield*

INTRODUCTION

Apple is an important species for our economy, bringing a considerable breakdown in the budget of Republic of Moldova. Horticulture development program in 2020 is expected to produce 980 000 tons of fruit, of which 440 thousand tons raw material for manufacturing, 220 thousand tons for domestic market and 320 thousand tons for export (Babuc *et al.*, 2013).

From the amount of fruits for export 80-85 per cent belongs to apple crop. At the moment, the customers prefer apples of yellow, green and red color. The most wanted red apples are Red Delicious, Super Red Chef, Braeburn, Fuji, Gala varieties and their clones. However, for a more intense coloration, it is necessary to implement

new management techniques to improve quality. Getting a more intense and uniform staining, currently remains one of the unresolved problems until the end of fruit producers (Babuc *et al.*, 2013).

The color is a typical characteristic of the variety, which is due to pigments present in the cells of the epidermis and hypodermis. During growth and ripening in apples chlorophyll pigments prevail. As the maturing stage approaches, their color changes by the presence of the complementary color and overlapping. Carotenoid pigments give the complementary color, feature apples ripened: yellow or red. Anthocyanin generally forms complementary color in apples, which prints red fruits (Burzo *et al.*, 1999; Curry, 1997; Larrigaudiere *et al.*, 1996).

In apples, anthocyanin, are founded in the cells of the epidermis and 2-3 layers of hypodermis cells. Intensifying synthesis of anthocyanin pigments takes place 2-3 weeks before apples harvesting. The biosynthesis of these pigments occurs during ripening and it is genetically controlled and influenced by the ambient temperature, the optimum range being +16 – 22°C. During this period appears the coating and surface color in some varieties, which are determined by pigments flavonoids. As the differences between day and night temperatures are higher, the biosynthesis of anthocyanin pigments is more intense (Curry, 1997).

In recent years, in different countries, to enhance color the fruit is used the growth regulator whose active ingredient is ethylene (Looney, 2004; Mc Glasson, 1985).

The investigations conducted with ethephon during the fruits ripening period demonstrated that the treatment intensified fruit coloring. Considering that the fruit apple color depends on the anthocyanin share, which are determined by the environment and exogenous regulators that influence the accumulation of anthocyanin (Lieberman, 1979; Yang, 1985).

When the treatment with ethylene in dose of 150-300 ppm is followed by climate conditions that favor development anthocyanin pigments, the fruit color is more pigmented. When treating with growth regulators but the weather conditions are not favorable, physiological maturation will advance without anthocyanin pigments development (Wang and Dilley, 2001).

The scientific news of the obtained results is that for the first time in Republic Moldova is trying to recommend for use ethephon to the color development of "Gala Must" apple variety.

MATERIALS AND METHODS

The research was conducted during 2013 year in apple orchard founded in the autumn of 2009 at the company „Codru-ST” Ltd with tree crown like „knip boom”.

The subject of the experience was Gala Must apple variety grafted on M9 rootstock. The trees was conducted as sleander spindle. The plantation establishment is 3.5 x 1.2 m.

To study the influence of ethephon to the color development of "Gala Must" apple variety fruits were treated with the following variants:

1. Control – no treatment;
2. Ethephon – 300 ppm;
3. Ethephon – 400 ppm.

The treatment was made with portable sprayer in the early morning hours without wind, when the temperature was at least +18°C and continued to rise.

The quantity of solution per tree was 0.5-0.6 liters considering the amount of trees per unit area and the quantity of water needed which is 1500 l/ha. For a more positive grip of the solution with the foliar surface was added Silwet L77 in the in a percentage of 0,1%.

The soil was kept as grass silage on the intervals between rows and field sprayer on strips between the trees rows with the width of 1.2 m.

Location of plots was made into blocks, each variant having four replicates Each replicate has 7 trees. At the border between the rehearsals and experimental plots were left one untreated tree to avoid the duplication of variants or repetitions while performing treatments.

The average weight of a fruit, production per tree and per unit area and their redistribution in diameter were established during harvest.

The evaluation was performed using apple firmness penetrometer FT 327, which secures ingress resistance of pulp a piston area of 1 cm². Was conducted 10 assessments of firmness, being recorded media.

Hydrolysis index was established using iodine test. The fruits were compared with the diagram 10 drawn gradation conversion of starch elaborated to Ctifl collaborators (France).

The degree of acetylene emanation was established with ethylene analyzer ICA 56. This analyzer is a toolbox equipped with a pump which causes direct ethylene concentration in a space. The minimum tolerance is 0.2 ppm.

The color intensity of fruit area was determined by the method described by Alina Basak a 5-point scale. First gradation fruits colored from 1 - 25%, second – 26 - 50%, third – 51 - 75%, forth – 76 - 90% and fifth – 90% or more from the fruit surface.

The chemical composition of the fruit was assessed by the content of soluble solids and titratable acidity.

The significance of differences men values of investigeited parametrs was determined by using the LSD test for the likelihood of 0.05.

Tab.1. The influence of the Ethephon dose on production and quality parameters of 'Gala Must' apple variety

Nr. d/o	Variants	Number of fruits, pcs/ tree	Average weight, g	Production		Comparing with control variant, %
				kg/tree	t/ha	
1.	Control	85	149.7	12.72	30.27	100.0
2.	Ethephon – 300 ppm	86	150.3	12.92	30.74	101.6
3.	Ethephon – 400 ppm	88	149.1	13.12	31.21	103.1
LSD P< 0.05		4.1	2.52	0.34	1.14	-

RESULTS AND DISCUSSIONS

Fruit production is a main index characterizing the efficacy of ecological factors and agro-technical measures used in orchards variety Gala Must. The production of fruit obtained from a tree, and the average weight of their influence on the maturation step and the degree of coloring of the apples. It was studied the fruit production and the average weight of apples because in the studies effectuated by Looney, 2004 and Mc Glasson, 1985, was demonstrate hat treating the trees 2-3 weeks before harvest with ethephon products to intensify the fruit coloration, register foreclosure of fruits development and it decreases the production per tree and unit area.

The conducted investigations demonstrated that the number of fruits in the tree crown didn't differ (tab. 1) because it was undertaken adjustments of the bearing load. If in the control variant, without treatment, the number of fruit was 85 pcs/tree, then in the variant was used Ethephon – 300 ppm this number was 86 pcs/tree. When treating the trees with Ethephon – 400 ppm, the mentioned index didn't increase much being 88 pcs/tree.

This homogeneity in the number of fruit trees crown was recorded due to manual thinning of apples after the fall ovaries in June. The optimum amount of fruits in the trees crown was recommended to be 80 ± 5 pcs/tree.

The necessity to establish the optimal load of fruit in the crown of the tree is influenced by the degree of coloring of fruits. In the amount of fruits in the trees crown is high, their average weight is low and the coloring process is more difficult and even some fruits are left poor colored.

When, the number of fruits is smaller than the optimal number, their average weight grows faster

and the maturity and fruit coloration process happens earlier than the deadlines.

The average weight of a fruit on the studied variants didn't suffer any changes compared to control variant. When the dose of Ethephon was 300 ppm, the average weight of a fruits was 150.3 g, or with 0.6 g higher than in the control variant. Once the dose of Ethephon increased to 300 ppm, the average weight of fruits decreases by 0.6g compared with control variant and with 1.2 g compared with the variant where the treatment with Ethephon was made in dose of 300 ppm. This small difference happened due to different number on fruits in trees crown, but not due to the use of the growth regulator base of Ethephon whose influence is not statistically assured yet.

The production of fruit on a tree and a surface unit is in direct correlation with the number of fruits and their average weight. The highest fruit production registered in the variant treated with Ethephon – 400 ppm being 13.12 g/tree or 31.21 t/ha. In the variant where the treatment with the growth Ethephon was made in dose of 300 ppm, the fruit production was 12.92 kg/tree or 30.74 t/ha, and in control variant the studied index was respectively 12.72 kg/tree or 30.27 t/ha.

The statistical data about fruit production (tab.1), does not indicate significant statistical changes between the studied variants and the control variant. The results obtained demonstrate that using the Ethephon to color the fruits of Gala Must variety 2-3 weeks before harvest does not influence on the productivity and the average weight of a fruit.

Investigations conducted demonstrate that the share of fruits with different diameter depends directly with the production of trees registered in the crown.

Tab. 2. The influence of Ethephon dose on distribution of fruits according to their diameter on 'Gala Must' variety

Nr. d/o	Variants	The share of fruits (%) according to their diameter (mm)				Average diameter, mm
		56-60	61-65	66-70	71-75	
1.	Control	1.2	5.6	49.8	43.4	69.8
2.	Ethephon – 300 ppm	1.4	6.6	50.0	42.0	69.5
3.	Ethephon – 400 ppm	1.4	6.7	49.7	42.2	69.3

In this case, the study focused not only on knowing the average fruit diameter, but also in separating them from 5 to 5 mm in relation to experience variants.

The results obtained in table 2 show that the quality of fruits registered in the studied variants does not differ essentially.

A low quality production was registered when treating with Ethephon in dose of 400 ppm on ha. The share of fruits with the diameter 56-60 mm was 1.4%, the ones with the diameter 61-65 mm - 6.7%, the ones with the diameter 66-70 mm - 49.7% and the ones with the diameter 71-75 mm - 42.2%. As a result the fruits of first category and of extra quality were 91.9%.

Next, in ascendant order was placed the variants treated with Ethephon in dose of 300 ppm followed by the control variant. In the variant treated with Ethephon in dose of 300 ppm the share of fruits with the diameter of 56-60 mm was 1.4%, the ones with the diameter 61-65 mm - 6.6%, the ones with the diameter 66-70 mm - 50.0 and the ones with the diameter 71-75 mm - 42.0%.

In the control variant, the share of fruits with the diameter 56-60 mm, 61-65 mm and 66-70 mm was respectively 1.2%, 5.6% and 49.8% and the ones with the diameter 71-75 mm was 43.4%. Therefore, the share of fruits of first and extra quality category was 93.2%

The fruits with the diameter 56-60 mm in the studied variants were 1.2-1.4 %, the ones with the diameter 61-65 mm- 5.6-5.7 %, the ones with the diameter 66-70 mm- 49.7-50.0 and the fruits with a diameter larger than 71 mm- 42.0-43.4%.

The average diameter of fruit is an indicator that depends directly on the number of fruits in the crown of the tree and the average weight of a fruit. The smallest diameter during the research was registered in the variant were was made treatment

with Ethephon in dose of 400 ppm being 69.3 mm followed by the variant treated with Ethephon in dose of 300 where the mentioned index was 69.5 mm. The highest average diameter was registered in the witness variant where no treatment was made being 69.8 mm.

The study conducted demonstrates that large differences between variants in the study on the fruit diameter location from 5 to 5 mm and the average diameter of an apple didn't record. Therefore, the fruits with a constant diameter will react identically when treated with Ethephon designed to optimize fruit maturation and coloration and only under the influence of the used dose can be determined how physiological processes are running in apples.

Determining the degree of ripening of apples is made using indicators such as: background color determined by comparing with colorimetric boards; pulp firmness determined penetrometer; the number of days from blossoming to harvesting; the presence of starch in the cross section of apples (iodine test); soluble solids content and titration acidity levels and intensity acetylene recess.

Practically, from the above indicators only the intensity acetylene recess can be controlled directly with the metabolic activity of fruits the rest of them being environmental factors influencing metabolism. The index accuracy depends on different factors such as climate conditions, fertilization, irrigation, age and the physiological state of the tree and so on.

The data from conducted investigations (tab. 3) demonstrates that the fruit pulp firmness after the treatment with the growth on the base of Ethephon made on 10.08.12 was the same on all the studied variants being 9.4-9.5 kg/cm².

The firmness of the apples is mainly determined by their content in pectin, the substance

Tab.3. Influence of Ethephon on fruit ripening index on 'Gala Must' apple variety

Nr. d/o	Variants	Firmness, kg/cm ²		Index of hydrolysis	The amount of ethylene emanating, µl/ kg/h
		At treatment	15 days after treatment		
1.	Control	9.4	8.3	4.0	0.015
2.	Ethephon – 300 ppm	9.5	8.1	4.5	0.019
3.	Ethephon – 400 ppm	9.4	8.0	4.5-5.0	0.020
LSD P< 0.05		0.30	0.27	-	-

Tab. 4. The influence of the Ethephon growth regulator on biochemical and coloring indexes in apple fruit of Gala Must variety

Nr. d/o	Variants	Soluble solids, %	Titrateable acidity, %	Coloration index	The share of fruits picked in the first harvest, %
1.	Control	15,2	0,38	2,7	45,7
2.	Ethephon – 300 ppm	15,8	0,35	3,6	67,1
3.	Ethephon – 400 ppm	15,9	0,35	4,2	77,4

that makes up the tab median between cells and ensuring their cohesion, the structure of their cell walls and cellulose content and volume of intercellular spaces.

At 15 days after treating with the growth regulator on the base of Ethephon was registered a decrease in the fruit pulp firmness. In the control variant where no treatment was made the fruit pulp firmness was 8.3 kg/cm², or a decrease by 1.1 kg/cm² compared with the previous measurement.

When the treatment was made with Ethephon in dose of 300 ppm, the fruit pulp firmness was 8.1 kg/cm² which means it decreased with 0.2 kg/cm² compared with the control variant. This happened and when the treatment with Ethephon was made in dose of 300 ppm where the above index decreased with 0.3 kg/cm² compared with the control variant.

The obtained results demonstrate that the treatments made with the growth regulator Ethephon didn't influence on fruit pulp firmness. By increasing the treatment dose from 300 ppm to 400 ppm, it maintained the same fruit pulp firmness on apple variety Gala Must being 8.1-8.0 kg/cm².

During the fruit maturity phase occurs the process of change the starch hydrolysis into monosaccharide. This can be registered by applying the

iodine test. The starch from the fruits getting in contact with the iodine solution from potassium iodide leads to bluish pulp. If the cross-section is more colorful, it means that the fruit contains more starch.

The conducted study demonstrates that the hydrolysis index in the studied variants was 4.5-5.0. The lowest hydrolysis index was 4.0 in the control variant where no treatments with the growth regulators were made.

When treating with Ethephon, it records an insignificant influence on the ripening fruits. In the variant where the treatment with Ethephon were made in dose of 300 ppm, the hydrolysis index was 4.5, as the treatment dose increased to 400 ppm a slightly increasing the fruit maturity was registered and the studied index was 4.5-5.0.

This demonstrates that according to the hydrolysis index in the variants where treatment was made with Ethephon in dose of 300 ppm, the fruits could be picked 1-2 days after treatment for a better storage.

Ethylene is considered as the main fruit ripening hormone. This substance is biosynthesized in all plant organs and in greater quantity in climatic fruits (apples).

In order to study the intensity of fruit ripening and the influence of the growth regulator who has

Tab. 5. Economic efficiency of production on 'Gala Must' variety using the growth regulator on base of Ethephon

Nr. d/o	Variants	Sales revenue, k lei/ha	Investments to buy the product, k lei/ha	Production cost, k lei/ha	Profit, k lei/ha	Level of profitability, %
1.	Control	178,9	-	69,6	109,3	157,0
2.	Ethephon - 300 ppm	194,9	0,20	70,8	124,1	175,3
3.	Ethephon - 400 ppm	204,2	0,27	71,9	132,3	184,0

as base ethephon on maturity and fruit coloration, we studied the amount of ethylene emanated in a certain period of time.

The quantity of ethylene emanated after harvest is different in the studied variants. The lowest amount of ethylene emanated was registered in the control variant without treatment being 0.015 µl/kg/h.

The use of the Ethephon increased the quantity of ethylene emanated being 0.019-0.020 µl/kg/h. This demonstrated that the use of Ethephon intensified fruit maturation and increased by 0,004 - 0,005 µl/kg/h the quantity of emanated ethylene. The increase in dosage of Ethephon from 300 ppm to 400 ppm did not influence the studied index.

The studies, demonstrates, that the fruit pulp firmness, hydrolysis index and the amount of ethylene emanated from fruits are directly influenced by the use of the growth regulator Ethephon compared with the witness variant.

It is known that the new agricultural methods should not influence only on crop increasing but also on its quality, or at least to maintain it.

One of the indexes that demonstrate the optimum moment of harvesting is the soluble solids content. As the harvesting time approaches, the intensity of accumulation of soluble solids decreases.

The obtained data (tab. 4), demonstrated that the amount of soluble solids on Gala Must in the studied variants was 15.2-15.9 %.

The lowest value of the share of soluble solids was obtained in version control being 15.2%. When the growth regulator was used, it was noticed an increase of the studied index up to 15.8-15.9%. Therefore, treating with Ethephon intensified the fruit maturity and respectively it increased the quantity of soluble solids in fruits with 0.6-0.7% compared with control variant.

The share of fruit titratable acidity is in a direct dependence on the amount of soluble substances.

As the amount of soluble dry substance decreases, the fruit titration acid increases recording the highest value in the control variant - 0.38%.

The treatments with the growth regulator Ethephon decreased the share of titratable acidity being in both variants 0.35%.

The color is a feature for assessing the quality of the fruit and also an indicator to ascertain the degree of maturation to harvest. The color of apples is a feature of the variety and it is determined by the presence of pigment in the cells of the epidermis and hypodermis.

The conducted research proves that the lowest index of coloration was registered in the control variant being 2.7.

The treatments made with the growth regulator Ethephon intensified the coloration index. When treatments were made with Ethephon in dose of 300 ppm, the coloration index improved and was 3.6. The most colorful fruits registered in the variant where the treatment with the Ethephon was made in dose of 400 ppm and the studied index was 4.2

Gala Must autumn variety is a specific type because fruits reach optimal harvest time speeded and it is necessary to be picked in 2-3 stages.

The most eloquent index is the share of fruits on the first harvest. The investigations conducted demonstrate that in the control variant on the first harvest were picked 45.7% of the fruits from the trees crown.

The treatments made with Ethephon whose active ingredient is ethephon increased the share of fruits picked in the first harvest. When the treatment with Ethephon was made in dose of 300 ppm, from the tree crowns were picked 67.1% of fruits, as the dose increased to 400 ppm, the studied index increased being 77.4%

The conducted investigations demonstrate that better results of the coloration index and the share of picked fruits on the first harvest

was obtained when the trees were treated with Ethephon in dose of 300 ppm.

To achieve the planned goal is needed an agro biological argument of both technological links and whole apple cultivation technology. The final biological argument is based on biological productivity on harvest quantity and quality. At the same time the same crop can bring different revenues from sales by using the most advanced technological elements.

The conducted investigations demonstrate that the use of the Ethephon influenced positively on fruit maturity and coloration and as a result it increased the sales revenue through the sale price.

In the control variant, the sales revenue was 178.9 k lei/ha. Treatments made with the growth regulator Ethephon increased the sales revenue being respectively 194.9-204.2 k lei/ha. In the treated variants, the highest sales revenue was registered in the variant where the treatment was made in dose of 400 ppm being 204.2 k lei/ha (tab. 5).

The treatments made with the growth regulator Ethephon did not influence on the production cost because the investments made to buy the Ethephon in dose of 300 ppm and 400 ppm were respectively 0.2 and 0.27 lei/ha.

The production cost in the control variant was 69.6 lei/ha, but in the variants where treatment was made with Ethephon, it increased respectively with 1.2 and 2.3 k lei/ha. This slight increase was recorded in the result of additional costs in harvesting fruit production (tab. 1) and investment in conducting treatments.

Profit is in direct correlation with the sale revenue and production cost. The lowest profit registered in the witness variant being 109.3 k lei/ha and the highest profit was registered in the variant treated with Ethephon in dose of 400 ppm being 132.3 k lei/ha. When the treatment with Ethephon was made in dose of 300 ppm the profit was with 14.8 k lei/ha more than in the control variant and with 8.2 k lei/ha lower than in the variant treated with Ethephon in dose of 400 ppm.

The benefit of treating with the growth regulator Ethephon is proven and with the level of profitability. If, in the control variant, the level

of profitability was 157.0% then in the variant treated with Ethephon in dose of 300 ppm this index increased by 18.3% and in the variant treated in dose 400 ppm, the mentioned index increased with 27.0%.

The results of the economic efficiency of fruit production demonstrates that for Gala Must variety whose ripening period is the 3rd part of August the highest values were registered in the variant treated with the growth regulator Ethephon in dose of 400 ppm

CONCLUSION

It was observed that growth regulator on base of Ethephon influenced on firmness, index of hydrolysis, the amount of ethylene emanating, soluble solids, titratable acidity, coloration index and the share of fruits picked in the first harvest.

The growth regulator on the base of Ethephon may be utilized in the system to optimizing fruit ripening and coloring of autumnal apples variety fruits, when the treatments were made in the concentrations of 400 ppm applied one time 2 – 3 weeks before commercial harvest where the level of profitability was 184.0%.

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