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THE EFFECT OF FERTILIZERS ON THE QUALITY OF APPLE FRUITS

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Abstract

In the period 2019-2021, the effect of different doses of complex fertilizers of the 16:16:16 type applied alone and together with some foliar fertilizers of the Fertil Star and Aurora types on the production, quality and accumulation of some nutrients in the leaves of the 'Florina' apple variety was monitored, cultivated on a cambic faeziom soil type from Mehedinți. The productions were obviously marked by the complex application of the 3 macroelements, being between 20.35 t/ha and 25.61 t/ha. A clear influence of fertilization on the total dry matter content was found, between 11-17%, the increase being directly proportional to the intake of nutrients from the applied fertilizers. High concentrations of K cause their acidity to increase, which has the consequence of changing the ratio of sugar/organic acids and finally changing the taste in the sense of increasing the flavor. Nutrient elements in the leaves changed favorably as a result of the application of doses and types of fertilizer.

Key words*: apple, fertilizers, quality.*

INTRODUCTION

Apple (*Malus domestica* Borkh.) occupied third place as the most consumed fruits, worldwide (FAOSTAT, 2021). Five apple varieties were among the most popular for growing - 'Golden Delicious', 'Red Delicious', 'Granny Smith', 'Florina' and 'Melrose' (Petkova et al., 2022).

The 'Florina' apple variety has a French origin and it was imported in 1977 and now is quite common (Dobrevska et al., 2022).

Fresh apple consumption in the EU is approximately 15 kg per capita and is expected to increase by 1 kg by 2030, while consumption of processed apples is around 8 kg per capita (EC, 2020). Fruits and vegetables are the most important natural sources of vitamin C. Since apples are very popular globally, they could be an excellent source of vitamin C in the human diet (Lemmens et al., 2020).

Contemporary trends in horticulture are aimed at limiting the use of mineral fertilizers to the necessary minimum, which is to guarantee adequate profitability of production while maintaining high-quality fruit and at the same time preventing environmental pollution. In this situation, it is necessary to develop a rational method of N fertilization of apple orchards, allowing minimization of the use of fertilizers (reduction of costs) and reduction of the risk of contamination of the soil with an excess of nitrates, while achieving optimal tree growth, yield and fruits quality (Kowalczyk et al., 2022). Intensive apple production has primarily focused on increasing productivity through intensification of fertilizers and water, resulting in high production, financial and environmental costs (Stefanelli et al., 2010).

Potassium is among essential mineral nutrients with long-known importance for plant development and yields. Its optimal supply is very important under the conditions of climate change and in view of the need to obtain good yields of high-quality fruits (Kuzin & Solovchenko, 2021). Reaching this goal requires up-to-date fertilization management systems presuming balanced use of both organic and chemical fertilizers (Gitea et al., 2019). An adequate supply of K is essential for uptake of other nutrients and plays an important role in the formation of yield improvement (Xu et al., 2020).

Titratable acidity of fruit is an important parameter in determining fruit maturity and key determinant of fruit taste. It also serves as food substance and need by body in little amounts. (Azher et al., 2020). Researchers showed that titratable acidity of different apple varieties

grown in world ranged from 0.10% to 0.36% respectively Chakespari et al., 2010, Vieira et al., 2009, and Durrani et al., 2010, to 0.60%, Dzanagov et al., 2021.

Increasing the acidity value of the fruits has the effect of changing the ratio of sugar/organic acids and finally changing the taste in the sense of increasing the flavor of the fruits (Dilmaghani et al., 2005).

In order to elucidate some aspects regarding the effectiveness of foliar and root fertilizers in an appple orchard, we conducted research in the period 2019-2021 in Mehedinți County with complex root fertilizers as well as with two foliar fertilizers.

MATERIALS AND METHODS

The experiment was located on a cambic faeziom soil type in Mehedinti County, in an apple orchard, with the 'Florina' variety comprising the following variants:

V1 - unfertilized control;
V2 - Fertil Star foliar fertilizer;
V3 - Aurora foliar fertilizer;
V4 - $N_{48}P_{48}K_{48}$ root fertilizer;
V5 - $N_{80}P_{80}K_{80}$ root fertilizer;
V6 - $N_{48}P_{48}K_{48}$+Fertil Star 5 l/ha;
V7 - $N_{48}P_{48}K_{48}$ +Aurora 4 l/ha;
V8 - $N_{80}P_{80}K_{80}$ +Fertil Star 5 l/ha;
V9 - $N_{80}P_{80}K_{80}$ + Aurora 4 l/ha.

Mehedinti County (44.63°N 22.88°E) is located in the southwestern part of Romania, on the left bank of the Danube.

Fertilizers were tested alone or in paired combinations, in comparison to an unfertilized control.

Applied foliar fertilizers have the following chemical composition:

Fertil Star: N-67%, P_2O_5-6%, K_2O-4.2%, Cu-0.025%, Fe-0.100%, Mn-0.010%, Zn-0.008%, B-0.020%, Mo-0.001%, chelates with EDTA Na

Aurora: N-10%, P_2O_5-0.5%, K_2O-3.5%, B-1.5mg/l, Ca-1g/l, Co-1.16 mg/l, Cu-3.8 g/l; Mn-0.08, Fe-1.4 g/l; S-3.8 g/l, Mg-1.8 g/l; Zn-1.5 g/l, biostimulant plant extract.

Complex extraradicular fertilizers 16-16-16, were applied in two stages: 1/3 of the dose in autumn and 2/3 of the dose in spring in the budding phase, the complex being incorporated into the soil at both stages.

Foliar fertilizers were applied in three stages:
- after tying the fruit;
- two weeks after the first foliar fertilization;
- two weeks after the second foliar fertilization.

For characterization of climatic elements were used information from the nearest weather station, namely Drobeta Turnu-Severin Weather Station. According to this data, the climate is Cfax type, continental climate, with a weak Mediterranean influence, with an average annual temperature of 10.8°C and an average annual rainfall of 539.9 mm.

The soil on which the experiment was placed was cambic faeziom type with the following characteristics:
- profile formed by horizons: Am, Bv, B/C, C;
- clay texture;
- medium bulk density (1.38-1.49 g/cm^3);
- medium total porosity (44.6-48.3%);
- hygroscopicity coefficient 4.76%;
- medium supply degree with nitrogen (3.26% humus, Nt = 0.14-0.15%);
- good supply degree with phosphorus (52 ppm P);
- very good supply degree with potassium (210 ppm K);
- weakly acid-neutral reaction (6.38-7.53);
- second quality class.

The 'Florina' variety is characterized by medium to large fruit size, with a smooth, greenish-yellow surface, the skin is hard, greenish-yellow, covered with red-orange with darker streaks on almost 80% of the surface (Petkova et al., 2020). The pulp is yellowish-white, with greenish shades, juicy, consistent, with a slightly acidic sweet taste.

Analytical methods were applied, as fallows. Total soluble dry matter content was determined using a digital refractometer at 20°C and expressed as %.

The titratable acid content (acidity) was determined by titration with 0.1 N sodium hydroxide (NaOH) using phenolphthalein as indicator.

Redox titration determined vitamin C using Iodine solution of juice sample and finally determine the titrate required for standard (Mohammed & Hazim, 2016).

Statistical analysis were processed using the statistical package SPSS 17.

RESULTS AND DISCUSSIONS

The average production obtained in the three years of experimentation was between 20.35 and 25.61 t/ha. Radicular fertilization leads to higher yields depending on the applied dose: 22.4-23.55 t/ha. Unilateral fertilization with Fertil Star results in a small increase in production compared to the unfertilized control, 1.10 t /ha, which is only significant.

Very significant production increases are obtained by using higher doses of root fertilizer, respectively $N_{80}P_{80}K_{80}$ - 23.55 t/ha, as well as for complex fertilizers $N_{48}P_{48}K_{48}$, $N_{80}P_{80}K_{80}$ + foliar fertilizer Fertil Star - 24.83 t/ha and Aurora 25.61 t/ha (Table 1), which is in concordance with the results obtained by Zheng et al., 2016 and Dzanagov et al., 2021.

An important criterion in assessing the reaction of an apple tree to the application of mineral fertilizers is the fruit quality indicators (Doroshenko, 2006).

Table 1. Productions (t/ha) obtained for the Florina variety as a result of the use of different doses of root and foliar fertilizers on average for 3 years of experimentation (2019-2021)

Variant	Production	% to the unfertilized control	Difference from unfertilized control t/ha	Statistical significance
Unfertilized control	20.35	-	1.10	-
Fertil Star	21.45	105.2	1.75	x
Aurora	22.1	108.6	2.05	x
$N_{48}P_{48}K_{48}$	22.4	110.0	3.20	x
$N_{80}P_{80}K_{80}$	23.55	115.7	3.60	xxx
$N_{48}P_{48}K_{48}$ +Fertil Star	24.01	117.9	3.66	xxx
$N_{48}P_{48}K_{48}$ +Aurora	24.50	120.4	4.15	xxx
$N_{80}P_{80}K_{80}$ +Fertil Star	24.83	122.0	4.48	Xxx
$N_{80}P_{80}K_{80}$ + Aurora	25.61	125.8	5.26	Xxx

DL5% = 1.04 DL1% = 2.46 DL0.1% = 3.11

Note:
- No statistical difference compared to control;
- x - significantly positive compared to control;
- xxx - very distinctly significantly positive compared to control.

The production quality was assessed by the dry matter content (%), soluble dry matter (%), titratable acidity. These indicators are of particular importance in obtaining high quality fruit by balancing these indicators.

It can be clearly seen that by using different doses of root and foliar mineral fertilizers the total dry matter content increases.

Thus, for the unfertilized control, dry matter content has a value of 13.83%, while applying the two single foliar fertilizers, dry matter content increases to values of 14.59% and 14.92%, i.e. by 5.5 and 7.8%.

Table 2. Total dry matter content over the 3 years of experimentation depending on the dose of fertilizer

Variant	Dry matter %	% to the unfertilized control	Difference from unfertilized control t/ha	Statistical significance
Unfertilized control	13.83	-	-	-
Fertil Star	14.59	105.5	0.76	-
Aurora	14.92	107.8	1.09	xx
$N_{48}P_{48}K_{48}$	14.72	106.4	0.89	-
$N_{80}P_{80}K_{80}$	15.59	112.7	1.76	xx
$N_{48}P_{48}K_{48}$ +Fertil Star	15.09	109.1	1.26	x
$N_{48}P_{48}K_{48}$ +Aurora	15.25	110.3	1.42	xx
$N_{80}P_{80}K_{80}$ +Fertil Star	15.73	113.7	1.90	xxx
$N_{80}P_{80}K_{80}$ + Aurora	15.88	114.8	2.05	xxx

DL5%=0.9 DL1%=1.31 DL0.1%=1.77

Note:
- No statistical difference compared to control;
- x - significantly positive compared to control
- xx - distinctly significantly positive compared to control;
- xxx - very distinctly significantly positive compared to control.

The application of root mineral fertilizers has the effect of increasing the dry matter content to the values of 14.72% and 15.59%, i.e. by 6.4-12.7%. Similar values regarding dry matter content were also reported by Mitre et al., 2009.

The combined application of root and foliar fertilizers leads to significant or distinctly significant increases when using a dose of less than 48 kg of active substance (a.s.) and a significant increase when using the dose of 80 kg a.s./ha, the increase of dry matter content reaching values of 1.9-2.05%.

The soluble dry matter content (%) was also favorably influenced by the doses and types of fertilizers used (Table 3).

The soluble dry matter content has been slightly modified by the doses and types of

fertilizers. This content, as can be seen from the data in Table 3, increases with the application of different doses and types of fertilizers, but the increases are less significant or even insignificant.

Thus, following the application of Fertil Star and Aurora foliar fertilizers alone, as well as with small doses of root mineral fertilizers 48 kg a.s./ha, the increases are insignificant (0.11-0.56%).

Only in the situation of fertilization with high doses of root mineral fertilizers 80 kg a.s./ha the percentage obtained increases, 0.64% and 0.88%, being significant or distinctly significant.

Table 3. Influence of fertilizers on soluble dry matter content, %

Variant	Soluble dry matter %	% to the unfertilized control	Difference from unfertilized control t/ha	Statistical significance
Unfertilized control	10.96	-	-	-
Fertil Star	11.07	101.0	0.11	-
Aurora	11.25	102.6	0.29	-
$N_{48}P_{48}K_{48}$	11.37	103.7	0.41	-
$N_{80}P_{80}K_{80}$	11.58	105.6	0.62	X
$N_{48}P_{48}K_{48}$ +Fertil Star	11.43	104.3	0.47	-
$N_{48}P_{48}K_{48}$ +Aurora	11.52	105.1	0.56	-
$N_{80}P_{80}K_{80}$ +Fertil Star	11.60	105.8	0.64	X
$N_{80}P_{80}K_{80}$ + Aurora	11.84	108.1	0.88	Xx

DL 5% = 0.61 DL1% = 0.80 DL0.1% = 1.01

Note:
- No statistical difference compared to control;
- X - significantly positive compared to control;
- xx - distinctly significantly positive compared to control.

The titratable acidity of apple fruits is expressed %, the determining factor of its value being the potassium concentrations that directly proportionally influence this quality indicator.

It can be observed from the data in Table 4 that for the unfertilized variant was registred the lowest titratable acidity value, 0.352%. Root fertilization with $N_{48}P_{48}K_{48}$ causes an increase of this indicator by 0.036% or by 10.2%. Root fertilization with $N_{80}P_{80}K_{80}$ and together with Fertil Star causes the increase of this indicator by 19.6% and, respectively 19.8%, compared to the unfertilized control.

The most obvious statistically guaranteed percentage increases are obtained in the case of using root fertilizer together with foliar fertilizers 18.2-27.8%.

Table 4. Titratable acidity according to different doses and types of fertilizers

Variant	TA %	% to the unfertilized control	Difference from unfertilized control t/ha	Statistical signify cance
Unfertilized control	0.352	100	-	-
Fertil Star	0.391	111.1	0.039	x
Aurora	0.402	114.2	0.050	xx
$N_{48}P_{48}K_{48}$	0.388	110.2	0.036	-
$N_{80}P_{80}K_{80}$	0.421	119.6	0.069	xxx
$N_{48}P_{48}K_{48}$+ Fertil Star	0.416	118.2	0.064	xxx
$N_{48}P_{48}K_{48}$+ Aurora	0.431	122.4	0.079	xxx
$N_{80}P_{80}K_{80}$+Fertil Star	0.422	119.8	0.070	xxx
$N_{80}P_{80}K_{80}$+ Aurora	0.450	127.8	0.098	xxx

DL5% = 0.037 DL1% = 0.041 DL0.1% = 0.056

Note:
- No statistical difference compared to control;
- x - significantly positive compared to control;
- xx - distinctly significantly positive compared to control;
- xxx - very distinctly significantly positive compared to control.

The content of vitamin C for the variety 'Florina' varied under the influence of fertilization between 8.1 mg/100 g and 8.9 mg/100 g in comparison with the control variant, for which the content of vitamin C recorded the value of 7.8 mg/100 g.

Table 5. The content of vitamin C in the 'Florina' variety

Variant	Vitamin C (mg/100 g)
Unfertilized control	7.8
Fertil Star	8.1
Aurora	8.3
$N_{48}P_{48}K_{48}$	8.5
$N_{80}P_{80}K_{80}$	8.9
$N_{48}P_{48}K_{48}$ +Fertil Star	8.2
$N_{48}P_{48}K_{48}$ +Aurora	8.5
$N_{80}P_{80}K_{80}$ +Fertil Star	8.4
$N_{80}P_{80}K_{80}$ + Aurora	8.8

The data correlate with those obtained by Dzanagov et al., 2021, for the same variety. Reporting to the unfertilized control where the recorded vitamin C content was 7.8 mg/100 g,

the recorded increases were between 0.3-1.1 mg / 100 g.

It is observed that the highest amount of vitamin C is registered in the fertilized variants. The highest amount of vitamin C was recorded in the $N_{80}P_{80}K_{80}$ variant of 8.9 mg/100 g. In all the other fertilized variants, smaller but higher amounts of vitamin C are obtained compared to the unfertilized control.

According to Schuphan, 1956, Mapson, 1970, and Fisher, 1999, cited by Câmpeanu et al., 2009, apple contains 2-30 mg ascorbic acid per 100 g, depending on the cultivars.

CONCLUSIONS

The experience with different doses of root and foliar fertilizers carried out during 2019-2021 on the apple crop, 'Florina' variety, highlighted the following aspects:

- Both the foliar fertilizers used, Fertil Star and Aurora, as well as the complex root fertilizers in doses of 48 and 80 kg a.s./ha increased production by 5.2-8.6% for foliar fertilizers and by 10.0-15.7% to root fertilizers, registering significant increases.
- The application of foliar fertilizers in combination with root fertilizers had the effect of obtaining significant production increases of 17.9-25.8%, greater increases being obtained when Aurora foliar fertilizer was used, which has a more complex chemical composition as well as biostimulatory extract from plants. In this case, production reaches 25.61 t/ha compared to 20.35 t/ha obtained for the unfertilized control.
- Analyzing some production quality indicators such as total dry matter, soluble dry matter, titratable acidity and vitamin C, it was found that these indicators were also improved especially as a result of the combined use of foliar fertilizers with root fertilizers, when very significant increases of these indicators are obtained.

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