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INFLUENȚA FERTILIZĂRII FOLIARE ȘI RADICULARE ASUPRA PROCESELOR DE CREȘTERE ȘI RODIRE LA MĂR
INFLUENCE OF LEAF AND RADICULAR FERTILIZATION ON APPLE GROWTH AND FRUITING PROCESSES

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Abstract

Fertilization is a basic condition of agriculture, as a branch of sustainable development. It is often recommended to supplement mineral nutrition with organic product administration because, through their bio-stimulating effect, it potentiates mineral nutrition. Under these conditions, between 2020 and 2022, a bifactorial study was carried out on three apple cultivars (5-7 years after planting), grown at the Research Institute for Fruit Growing Pitesti-Maracineni, in a high-density orchard. The influence of five foliar and one soil fertilizers, on the background of standard mineral fertilization, over the mineral elements and chlorophyll content of the foliar apparatus for 'Red Braeburn', 'Jonagold Boerekamp', and 'Jonagold Novajo' cvs. was studied. Indicators of growth, fruiting processes, and fruit quality were also assessed. The foliar diagnosis results indicated that the level of mineral elements (N, P, Ca, Mg, Zn, Cu, and Fe) was within the limits of normality established for apple leaves, except for manganese, which accumulated in slightly excess (108.8, compared to 100.0 ppm). On average, during the experiment, the fertilization variants significantly increased the foliar level of mineral elements such as K, Cu, and Fe, compared to the control. Regarding the growth-fruiting processes, the mean of the tree trunk cross-sectional area annual growth was 6.6 cm^2. Given that the percentage of fruit set fluctuated around 66.9%, a fruit yield of 66.8 t/ha was obtained. On average, the percentage of fruit set increased significantly by 16.9-19.5% when CropMax (0.2%), M1 (0.5%), and M2 (0.5%) products were applied, and fruit yield by 19.3-21.2% for Poly-Feed (1%) and Fertisol (2 kg/tree). The fruit weight ranged from 72.3 to 443.2 g, with an average of 166.5 g. The average values recorded for firmness, juice pH and total soluble content were 76.4 units HPE-II- FFF Bareiss, 3.6, and 12.7°Brix respectively. All fertilization treatments significantly increased the average weight of the fruit, by 6.2-9.2%, compared to the untreated variant. The results of the study certify the favorable effect of supplementing the fertilization plans with the studied products, containing biostimulators that enhance and harmonize the physiological processes of the apple in a high-density system.

Cuvinte cheie: soiuri de măr, indexul conținutului de clorofilă, diagnoza foliară, calitatea fructelor
Key words: apple cultivars, chlorophyll content index (CCI), trunk cross-sectional area (TCSA), foliar diagnosis, fruit quality

1. Introduction

Fertilization represents a basic technological sequence of agriculture, as a branch of sustainable development. Fruit tree crops have particular economic value and therefore stimulate these systems' productivity is of high importance. Although frequently, in the attempt to increase the productivity of orchards, the limit to excessive fertilization can be easily exceeded, it is also scientifically proven that adequate nutrient management optimizes both fruit production and orchard economic efficiency (Tanou et al., 2017) but, sometimes, may have a negative effect on the environment (Baldi et al., 2021). It is often recommended to supplement mineral nutrition with organic products because, through their bio-stimulatory effect, they potentiate the effects of mineral nutrition (Gryzb et al., 2014, Drobek and Cybulska, 2019). Fertilizing soil with organic products has the advantage of providing plant nutrients while improving some soil characteristics, including the microbiome (Mosa et al., 2015, Wang et al., 2017, Rana et al., 2022). Foliar application of fertilizers is also preferred when a rapid plant response is sought. It has been documented that, in practice, the effect of biostimulants to optimize fruit production is due to their ability to increase nutrient uptake (Drobek and Cybulska, 2019), and plant development, while also having a positive economic effect by reducing fertilizer inputs. Moreover, nutrition programs take into account the fact that trees are perennial organisms, which face many types of stress throughout their lives, and focus on the use of bioactive molecules, responsible for stimulating tolerance/protection mechanisms (Tanou et al., 2017).

To enphasize the influence of five foliar fertilizers and one fertilizer with soil application, against the background of standard mineral fertilization, on the growth and fruiting processes of the apple species, in 2020-2022 period, a study was carried out on three apple cultivars (5-7 years from planting), grown at RIFG Pitesti in a high density system.

2. Material and methods

The studies were carried out in the southern zone of Romania, at the Research Institute for Fruit Growing Pitesti (RIFG), during 2020-2022. The area is characterized by a temperate-continental climate, with a mean annual temperature of 10°C, sunshine duration accumulating 2,261.2 hours, and an annual rainfall of 710.3 mm. During the study period, the average air temperature fluctuated around 10.7°C. The lowest temperatures were recorded in January (-14.1°C absolute minimum in 2021), with an average minimum of -4.3°C. July was the warmest month of the year and its maximum temperatures averaged 30.9°C, while the absolute maximum reached 38.3°C in 2021. In July the precipitation level was reduced (25.3-52 mm) and a water deficit of 78.6-102.5 mm was registered. Also, most of the precipitation was distributed in May (104.1-166.2 mm) and June (65.4-104.0 mm), except in 2022, when the maximum level of precipitation fell in August (142.1 mm).

In the experimental plots area the soil has a sandy-loamy texture up to 80 cm and is clay-sandy in depth, it has low humus reserve (70.09 t/ha), is slightly acidic pH (5.62), has low exchange capacity (11.6 me/100 g), and a base saturation of 73.2%. The nitrogen index, the content of mobile phosphorus (P-Alc) and potassium (K-AL) are very low (0.82, 25.4 ppm P and 65.6 ppm K). The soil was maintained mowed sod grass, on 78% of the surface between rows, and as a bare soil strips within row. The water requirement was ensured by drip irrigation based on the Penman-Monteith potential evapotranspiration. The fertilization treatments were administered on a mineral fertilization background, established with the Smart Fertilizer program according to the expected fruit yield and soil properties.

To highlight the effect of supplementing mineral nutrition with foliar or ground application fertilizers, in the apple species, in the spring of 2020, a bifactorial experiment was established, in which the first experimental factor was the fertilization variant (A), with graduations: a_1 = control (exclusively mineral fertilization), a_2 = Poly-Feed 1% (foliar application), a_3 = Fertisol 2 kg/tree (soil application), a_4 = CropMax 0.2% (foliar application), a_5 = fertilizer M1, a_6 = fertilizer M2 and a_7 = fertilizer F. Data regarding the composition of the fertilizers used in the study are presented in Table 1.

Poly-Feed (Table 1) is a soluble NPK fertilizer for foliar nutrition, acting as a vegetative stimulator of flowering and fruiting, improving fruit production and quality. Fertisol 4:3:3 (Table 1) is a 100% natural fertilizer (guano), suitable for any type of soil, which improves soil structure and fertility. CropMax (Table 1) contains in super concentrated form the whole range of growth regulators necessary for plants and is a powerful stimulator of plant metabolism, to compensate for deficiencies caused by external stress factors. Fertilizers M1, M2, and F (Table 1) intended for foliar fertilization stimulate plant metabolism and increase their immunity, reducing biotic and abiotic stress.

The second experimental factor was the cultivar (B), with graduations: b_1 = 'Red Braeburn', b_2 = 'Jonagold Boerekamp' and b_3 = 'Jonagold Novajo', 5 years old trees at the start of the study. All three cultivars were grafted on the M9 rootstock, and the planting distances were 1 m within row and 3 m between rows. The fertilization variants were organized in subdivided plots, with three replications randomly disposed (21 experimental plots per cultivar).

The chlorophyll content was appreciated by chlorophyll content index (CCI) determination, which consisted in measuring the CCI, using the CCM 200 device from Optiscience, on samples of 30 leaves in 3 repetitions for each fertilization variant per cultivar, 7 days after the last application of foliar fertilizers. Leaf analysis (foliar diagnosis) was used to obtain direct information about the nutritional state of the trees. To carry out the foliar diagnosis, after the application of the fertilization treatments and the appearance of the terminal bud, whole, healthy leaves were harvested from the second third of the shoots located in the median zone of trees canopy. The leaves were dried in a convection oven, at a temperature of 55-60°C, until constant weight. They were later ground finely and the powder was stored in paper bags. Until the laboratory analysis a second dry treatment (55-60°C) was applied. The methods presented in Table 2 were used for foliar diagnosis.

The vegetative growth process was recorded by measurements of trunk diameters. The calculation of the cross-sectional area of the trunk (TCSA) was carried out in the spring before the trees started to grow and in the autumn at the end of the growing season. The annual increase in TCSA was also determined as the difference between the values calculated for the cross-sectional area of the trunk in autumn and spring of the same year. Fruits were picked at harvesting maturity, established using the starch test (stage 2). Fruit production was determined by weighing the fruits harvested on each tree. To evaluate the quality of the fruits, determinations were made of the mass of the fruit (with the help of the electronic Kern balance), the firmness of the pulp (with undisturbed structure Bareiss Fruit Firmness Tester – HPE II Fff), the total content of soluble substance (with the refractometer electronic Atago Palette) and fruit juice pH (Horiba LAQUA pH/ORP/COND Meter D74, equipped with Horiba pH sensor 0030/0040).

IBM SPSS 20 program was used for the statistical processing of the data. Two-way and One-way ANOVA, followed by Duncan`s Multiple Range Test (α=0.05) was performed to highlight the effect of the fertilizer. Pearson correlation coefficients among all analyzed parameters were computed. Except for foliar diagnosis (2020-2021), determinations were performed in each of the three experimental years. In this paper, only the effect of fertilizer on vegetative growth, yielding, and some fruit quality indicators, depending on cultivars was studied and statistically significant data were discussed.

3. Results and discussions

A descriptive analysis of the data (Table 3) indicated that the foliar **chlorophyll content index** (CCI) varied between limited 14.92 and 60.93, with an average of 33.54. As can be seen from Figure 1, although except product M2, all studied fertilizers increased CCI, significant influences were recorded only under Poly-Feed, CropMax, F fertilizer, and Fertisol treatments. On average, the highest efficiency had the soil fertilization, with Fertisol 2 kg/tree, which ensured an increase of the CCI indicator by approximately 11%, oscillating, depending on the cultivar, between 5.4% ('Jonagold Boerekamp') and 21.6% ('Red Braeburn') compared to the control (untreated variant). Fertilization with fertilizer F had a similar effect to Fertisol treatment, providing an average CCI increase of 8.8%.

For 'Red Braeburn' cultivar, the highest CCI values were recorded for the Fertisol and fertilizer F treatments (CCI 21.6-22.6, higher than in the control variant), and for 'Jonagold Novajo', when CropMax was applied (with a CCI increase of 10.8% compared to the control). Finally, for 'Jonagold Boerekamp' cultivar in Fertisol treated plots an increase in CCI by 5.4% was determined.

The **foliar diagnosis** results (Table 4) indicated that the level of mineral elements (N, P, Ca, Mg, Zn, Cu, and Fe) varied within the normality limits allowed for the apple species, except Mn, which accumulated in a slight excess (108.8, compared to 100.0 ppm). On average of the cultivars, during the experiment, the fertilization variants significantly influenced the K (Fig. 2), Cu (Fig. 3), and Fe (Fig. 4) levels, compared to the control.

Under the Fertisol (ground application) and Product M2 (foliar application) treatments, the highest foliar concentrations of **potassium** were determined (by 27.57 and 28.51%, respectively, compared to the control variant) (Fig. 2). However, the only statistically ensured effect of the two fertilizers to increase the level of this element in the leaves was recorded for 'Jonagold Boerekamp' cultivar. On the contrary, when applying fertilizer F to the cultivar 'Red Braeburn', an effect of reducing foliar K by about 8% was highlighted.

For all three studied apple cultivars, **copper** accumulated in significantly higher amounts in the variants fertilized with M2 and M1 products (on average, by 79.2-87.4% compared to the control) (Fig. 3). For the **iron** foliar level, a very different response of the cultivars was observed (Fig. 4), in the sense that the F product had increased efficiency for the 'Red Braeburn' cultivar by assuring 63.64% higher foliar Fe content, compared to the control. As for 'Jonagold Novajo' cultivar, the highest level of Fe was recorded when CropMax was applied, but the results were not statistically ensured.

Regarding the **vegetative growth process**, the trunk cross-sectional area of the trees recorded an average annual increase of 6.31 cm^2 and oscillated between the limits of 0.03 and 11.18 cm^2 (Table 3). Also, on the background of a **fruit set** oscillation around 66.85% (0.00-100.00%), an average **fruit yield** of 66.81 t/ha (1.33-188.65 t/ha) was recorded.

On the average of the three cultivars, as shown in Figure 5, fertilization did not significantly influence the **annual growth of trunk cross-sectional area** (TCSA). However, for 'Red Braeburn' cultivar, the annual growth of TCSA was lower in the fertilized plots, with the lowest annual increase recorded under M1 and F fertilizer (28.4 and 34.4% less compared to control). For 'Jonagold Novajo' cultivar, similar to 'Red Boerekamp', the effect of fertilization on the annual increase of TCSA was not statistically assured, compared to the non-fertilized variant.

The **percentage of fruit set** increased significantly, by 17.0-19.5%, when applying CropMax 0.2% and fertilizer M1 0.5% and M2 0.5% (Fig. 6). However, the individual analysis of the three cultivars indicated that, with some exceptions in the 'Red Braeburn', the fertilizers had positive although non-statistically assured effects on the fruit set process.

Fruit yield recorded a significant average increase of 19.3 and 21.2% when fertilized with Poly-Feed 1% and Fertisol 2 kg/tree (Fig. 7). Among the studied cultivars, significant increases in fruit production were obtained for 'Red Braeburn' by 17.5 and 14.2% under Poly-Feed and Fertisol treatments. For 'Jonagold Novajo' a similar effect was recorded when fertilized with Poly-Feed, CropMax, and Fertisol, with fruit yield increases ranging from 34 to 35.8%.

The statistical analysis of the data related to the fruit quality indicators (Table 3) indicated that the **fruit weight** oscillated between 72.26 and 443.19 g, with an average of 177.56 g. The average values determined for **firmness**, juice **pH**, and **total soluble solids** content were 76.38 HPE-II-FFF Bareiss units (48.80-90.20), 3.56 (3.0-4.6) and 12.5, respectively °Brix (8.8-16.4). Except for juice pH, for fruit weight, firmness, and total soluble solids significant oscillations depending on cultivar × fertilizer interaction were registered (Figs. 8-10).

At a constant level of the cultivar factor, an effect of increasing **fruit weight** was observed in all fertilized variants, a trend that is also found for the two 'Jonagold' cultivars (Figure 8). The highest fruit weight increase was recorded for 'Jonagold Boerekamp' cultivar under Poly-Feed and M1 treatments (by 13.2 and 14.6%, respectively). All fertilization options ensured an increase of fruit weight by 8.4-13.1% for 'Jonagold Novajo' cv. In contrast to these, for 'Red Braeburn' cv., higher-weight fruits (with a maximum increase of 7%, compared to the control were harvested only when CropMax, Poly-Feed, and especially Fertisol were applied.

Regarding the **fruit firmness**, although no significant differences were recorded on the average of the cultivars compared to the non-fertilized variant, a maximum firmness increase by 2.8 % compared to the control was recorded for 'Red Braeburn' cv. under M1, Fertisol, and CropMax application (Fig. 9). Significant increases of up to 3.6% in fruit firmness were also observed for 'Jonagold Novajo' cv., especially in the variants fertilized with M1, F, M2, and CropMax. Unlike these two cultivars, for 'Jonagold Boerekamp' cv., all treatments resulted in a significantly reduced fruit firmness.

Similar to firmness, on the average of the cultivars, **total soluble solids (TSS)** did not show significant oscillations (Fig. 10). At each cultivar level, different trends of TSS were observed: significant reduction, by 3.5-3.6%, in the variants fertilized with Poly-Feed and M2 for 'Red Braeburn' cv. and by 5%, in the variant fertilized with M2 for 'Jonagold Boerekamp' cv., but an increase by 4.8-7.5%, also significant when Fertisol, M1, M2, and F were applied in 'Jonagold Novajo' cv. plots.

The analysis of the **correlations** between the mineral elements determined in the leaves of the trees included in the present experiment, highlighted a reduction in the level of P, K, and Zn and an increase in the level of calcium and magnesium under the condition of increased nitrogen level (Table 5). Phosphorus correlated positively with zinc and manganese. Except for the significant negative correlations of calcium, magnesium, and iron with potassium, positive significant correlations were established for calcium with Mg, Zn, Mn, and Fe. Similar positive correlations were observed for Mg with Zn, Cu, Mn, and Fe, for Zn with Mn and Fe, but also between Mn and Fe.

A positive correlation of CCI with leaves N, Ca, Mg and pH was recorded. In addition, a high level of CCI was correlated with reduced levels of P and K. Among the mineral elements, P, Zn, and Mn appear positively correlated with the vegetative growth of trees, and K, with the percentage of fruits set. P, Zn, and Mn showed reduced levels in trees that had high fruit set percentages and fruit yields, while Ca and Mg were negatively correlated with fruit set percentages.

Interestingly, CCI and N had high values in trees with low vegetative growth, and low fruit weight, but high fruit yield (without a significant increase in the fruit set percentage).

Minerals such as P, Ca, Mg, Zn, Mn, and Fe were positively correlated with high pH, and high foliar levels of P, Ca, Zn, and Mn was correlated with TSS accumulation in fruits. Fruit firmness was reduced under the conditions of accumulation in leaves in high concentrations of P, K, Zn, and Mn.

The most correlations of mineral elements were established with juice pH, followed by fruit set percentage and firmness, yield, and annual growth of TCSA. The least correlations were established between minerals and fruit weight. Cu showed no significant correlation with growth processes, yield, or fruit quality, and Fe only correlated with pH. The strongest correlations were established between CCI and N (positive), Zn and pH (positive), followed by Mn and pH (positive), Mn and binding percentage (negative), N and fruit weight (negative), yield and fruit mass (negative), N and fruit yield (positive).

Overall, a negative correlation between fruit yield and fruit weight was observed.

In general, fruit yield was reduced for trees with high vegetative growth. The graphs in the Figure 11 describe the specific correlation established between yield and vegetative growth for each fertilization treatment. Thus, very significant linear and negative correlations are highlighted in the case of the control and Fertisol variants, and polynomial for the other fertilization variants studied. An increase in vegetative growth is recorded in the variants fertilized with Polyfeed, CropMax, and M1. For Polyfeed there is also a shift of fruit production to the area of very small growths, an increase in fruit production, but there are also some cases with low fruit production for the entire range of vegetative growth. In the version fertilized with Cropmax, there is an increase in the cases with productions between 50-120 t/ha in the area of small growths of TCSA (below 5 cm^2), less accentuated compared to Polyfeed. When fertilizing with M1, an even more shift is observed increased fruit production towards the area of very small vegetative growth. After the control variant, M1 is the next with fruit productions between 50 and 100 t/ha. Similar to Polyfeed, low fruit production is also observed, especially in the area of below-average growth.

In the variants where Fertisol, M2, and fertilizer F were applied, the TCSA increases are lower, similar to the control. It is highlighted, similar to the variants discussed above, a concentration of cases with high productions in the area of reduced vegetative growth. Fertilization with Fertisol also shows some cases with high yields (over 100 t/ha) similar to Polyfeed, but unlike it, a reduction in cases with low yields. For M2 and F fertilizers, small fruit productions occur over the entire range of vegetative growth.

Related to leave mineral content, Velemis et al. (1999) showed by multiple regression analysis the fact that for the apple species (Starkrimson cultivar) the yield was correlated to foliar content of N, P, K, Ca, Mg, Mn, Zn, and Fe. The authors also stated the leaf nutrient sufficiency levels for macronutrients (%): N 2.43-318, P0.12-0.22, K 1.04-2.07, Ca 0.80-2.13, Mg 0.33-1.15 and for micronutrients (ppm): Mn 28.5-258.0, Zn 13.0-80.5 and Fe 76.5-186.5. Compared to these limits, in the present study, a lower level of N and Mg and a higher one for P were found. Velemis et al., 1999 state that the orchard site, plant material, and fertilizers influence the foliar mineral composition. In addition, the cultivar and the rootstock differ in terms of nutrient uptake from the soil, an aspect that also influences foliar concentrations of minerals. In general, there are differences regarding the correlations between the foliar mineral content and the growth-fruiting processes, or at least differences at the level of statistical significance.

The authors also note negative correlations between fruit weight and yield, similar to RIFG study, and a reduction in the total content of soluble solids for large fruit yield, which in the case of the three cultivars ('Red Braeburn', and the two 'Jonagold') is, however, insignificant. Similar cultivar-dependent negative correlations between foliar N and K, K and Mg were also reported by Velemis et al. (1999).

In contrast to the RIFG study, Zydlik and Pacholak (2000) found cultivar-dependent positive correlations of yield with Mg and negative correlations with K, but the negative correlations between firmness and K were similar in the two studies, as was the correlation positive between P and total soluble solids. In contrast, in the present study, the correlation of firmness with K was positive.

Studies regarding the effect of fertilizers on vegetative growth report different results, depending on the species, cultivar, and the type and dose of fertilizer. Thus, not all fertilizers stimulated vegetative growth (Thalheimer et al., 2002; Masny et al., 2004). However, there have also been a series of positive results related to the application of amino acid-based products (Aminoplant, BiaminoPlant) (Drobek et al., 2019), but also other biostimulators (Rana et al., 2022). Data on the effect of bio-stimulators on fruit yield are also different. For example, increases in fruit production were reported for olive species, although were not significant (Leogrande et al., 2022). Bennewit et al. (2017) reported the reduction of total soluble solids when applying fertilizers containing high doses of nitrogen and, contrary to the present study, higher vegetative growth but an insignificant influence on fruit yield.

4. Conclusions

This paper reports the results of a 3-year study on the effect of supplementing basic mineral nutrition in the apple orchard with foliar and soil fertilizers on the leave accumulation of mineral elements, growth and fruiting process, and fruit quality of the cultivars 'Red Braeburn', 'Jonagold Boerekamp', and 'Jonagold Novajo'. The results indicated that the treatments influenced significantly, but differently depending on the cultivar CCI, leaf iron content, vegetative growth process, fruit weight, firmness, and total soluble solids. Oscillations dependent on the fertilization variant, regardless of the cultivar, were recorded for K and Cu, but also fruit yield. CCI was increased mainly by soil administration of Fertisol, but also under the foliar F and CropMax treatments.

Potassium was increased especially by Fertisol and the foliar fertilizer M2, while Copper by the two foliar fertilizers M1 and M2. Fe increased when applying the foliar F at 'Red Braeburn' cultivar. The annual growth of TCSA was reduced in the variants treated with fertilizer F (at 'Red Braeburn' and 'Jonagold Novajo ' cvs.) and under CropMax, M1, and M2 (at 'Jonagold Boerekamp' cv.) treatments. Poly Feed, Fertisol, and CropMax similarly boosted fruit production in 'Red Braeburn' and 'Jonagold Novajo' cvs.. All fertilizers increased fruit weight in the two 'Jonagold' cultivars. Poly-Feed and Fertisol had similar effect for 'Red Braeburn' cv.. Fertisol, CropMax, and M1 increased fruit firmness in 'Red Braeburn' cv., CropMax, M1, M2, and F, in the 'Jonagold Novajo' cultivar. Contrary, for 'Jonagold Boerekamp', the effect of fertilization was to reduce fruit firmness. TSS increased significantly but only for 'Jonagold Novajo' cultivar when Fertisol, M1, M2, and F were applied.

As an overview, we can highlight the stimulatory effect on fruit production and fruit mass observed in the case of soil (Fertisol) and foliar fertilization (PolyFeed, CropMax), but also the increase in fruit firmness and TSS content was observed in some cultivars when fertilized with M1, M2 and F products.

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Tables and Figures

Table 1. Information regarding the composition of Poly-Feed, Fertisol, CropMax, M1, M2, and F fertilizers used in the study

Fertilizer	Principal components	Micronutrients and other components		Dose
Poly-Feed	N: P: K	Fe=1300 ppm		1%-foliar application
	=21:21:21	Mn=600 ppm		
		Zn=180 ppm		
		Cu=130 ppm		
		Mo=90 ppm		
		B=200 ppm		
Fertisol	guano N total=4%	Fe=1000 mg/ kg	pH 7	2 kg/tree-soil application
	N organic=3.6%	Mn=500 mg/ kg	Dry matter=88%	
	NH_4NO_3 =0.4%	Zn=420 mg/ kg	Humidity=12%	
	P_2O_5 =3.0%	Cu=105 mg/ kg		
	K_2O=3.0%	Mo=22 mg/ kg		
	MgO=1.3% CaO=10.0%	B=50 mg/ kg Co=2 mg/kg		
	C/N=9			
	Organic matter 62%			
Cropmax	Biostimulator N=0.2%	Fe=220 mg/l Mn=54 mg/l	Growth stimulators (*auxins, citochinines, gibberellins*)	0.2%-foliar application
	P=0.4% K=0.02%	Zn=49 mg/l Cu=35 mg/l	Organic amino acids Vegetal enzymes	
	Ca=10 mg/l	B=70 mg/l	Polizaharides	
	Mg=550 mg/l	Mo, Co, Ni=10	Vitamins (E and C)	
		mg/l	Carotenoids	
M1 **M2** **F**	Biostimulator N K Mg Organic matter	Cu B	Plant extracts (*Betonica* off., *Stachzs* off. Amides, Proteins, Coline, Polysaccharides, Betaine, Tannin	- 0.5% -foliar application - 0.5% -foliar application - 1% -foliar application

Table 2. Methods utilized for foliar diagnosis

Nitrogen (N)	Kjeldahl method; SR EN ISO 20483:2014; PTL 11
Phosphorus (P)	Colorimetric determination with ammonium metavanadate, PTL 20, ed. 1, rev. 0
Potassium and calcium (K, Ca)	Flamphotometrical determination; PTL 24, ed. 1, rev. 0
Magnesium (Mg)	Atomic absorption spectroscopy (flame atomization) determination; PTL 24, ed. 1, rev. 0
Coper, iron, manganese zinc (Cu, Fe, Mn, Zn)	Dosage by atomic absorption spectrometry; PTL 30, ed. 1, rev. 0

Table 3. Statistic descriptors of annual increase of trunk cross-sectional area, fruit set, yield, fruit weight, firmness, pH, and total soluble solids

	CCI	Annual increase of TCSA (cm^2)	Fruit set percent (%)	Yield (t/ha)	Weight (g)	Firmness (HPE-II-Fff Bareiss units)	pH	TSS (˚Brix)
Mean	33.54	6.61	66.85	66.81	177.56	76.38	3.56	12.69
Median	32.90	4.45	79.65	65.33	166.51	77.00	3.59	12.65
Std. Deviation	26.40	6.39	22.32	34.03	47.65	7.43	0.27	1.25
Skewness	7.79	2.43	-1.08	0.27	1.05	-0.42	0.14	0.16
Std. Error of Skewness	0.20	0.07	0.13	0.08	0.04	0.06	0.06	0.06
Kurtosis	0.03	7.10	0.25	-0.10	1.21	-0.53	-0.22	-0.11
Std. Error of Kurtosis	-0.69	0.14	0.25	0.16	0.08	0.13	0.13	0.13
Range	0.07	44.15	100.00	187.32	370.93	41.40	1.60	7.60
Minimum	46.01	0.03	0.00	1.33	72.26	48.80	3.00	8.80
Maximum	14.92	44.18	100.00	188.65	443.19	90.20	4.60	16.40

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Table. 4 The level of mineral elements, the index of chlorophyll content and the values of indicators of growth and fruiting processes in the apple species

	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Fe (mg/kg)
Average	2.35	0.23	1.61	1.46	0.30	21.71	7.65	108.84	116.47
Minim	1.54	0.13	0.99	0.71	0.17	0.40	4.50	30.50	73.00
Maxim	2.98	0.4	2.86	3.01	0.42	74.5	23.7	227	317
Normal limits	2.2-2.4	0.2-0.3	1.25-1.75	1.2-1.6	0.25-0.40	20.0-50.0	5.0-20.0	40.0-100.0	100.0-300.0

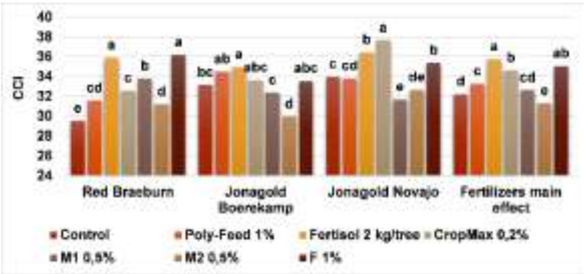

Fig. 1. Influence of fertilizers on foliar CCI depending on the apple cultivar

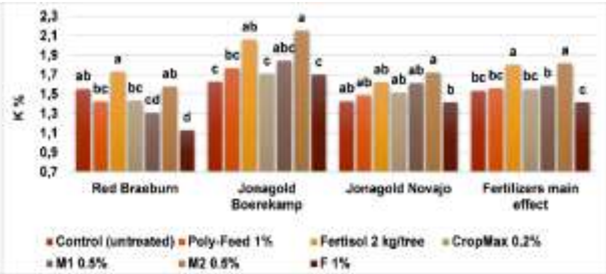

Fig. 2. Influence of fertilizers on foliar K content depending on the apple cultivar

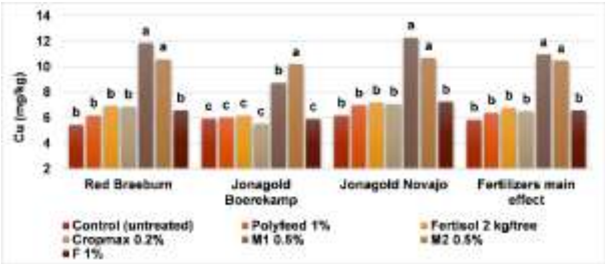

Fig. 3. Influence of fertilizers on foliar Cu content depending on the apple cultivar

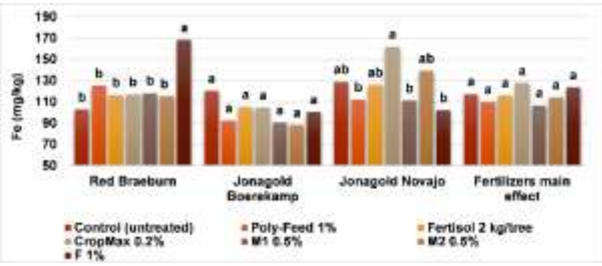

Fig. 4. Influence of fertilizers on foliar Fe content depending on the apple cultivar

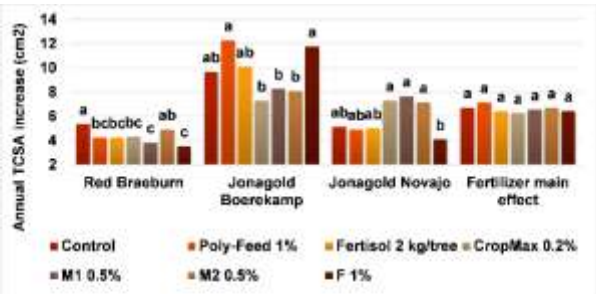

Fig. 5. Influence of fertilizers on annual increase of TCSA depending on the apple cultivar

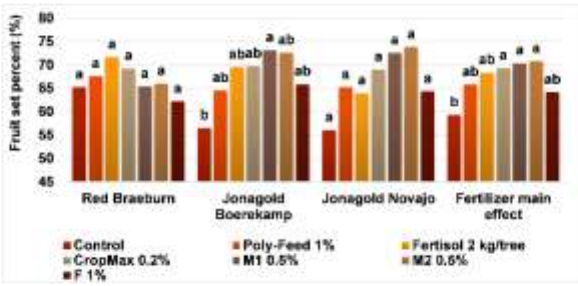

Fig. 6. Influence of fertilizers on fruit yield depending on the apple cultivar

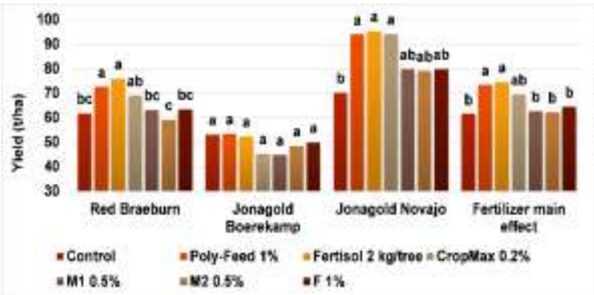

Fig. 7. Influence of fertilizers on fruit set percent depending on the apple cultivar

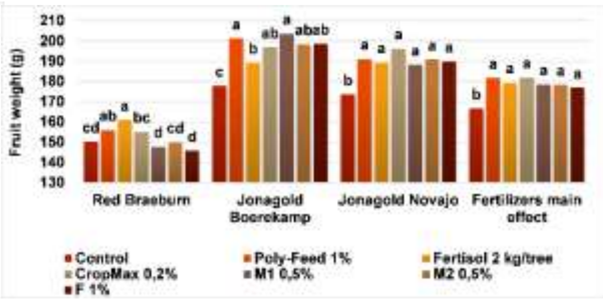

Fig. 8. Influence of fertilizers on fruit weight depending on the apple cultivar

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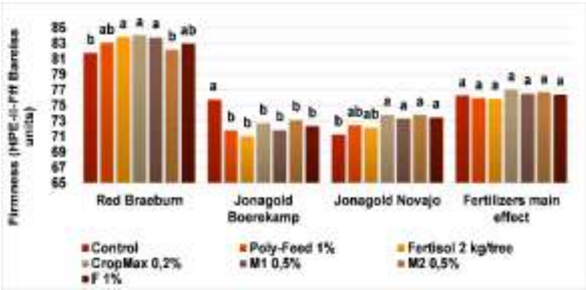

Fig. 9. Influence of fertilizers on fruit firmness depending on the apple cultivar

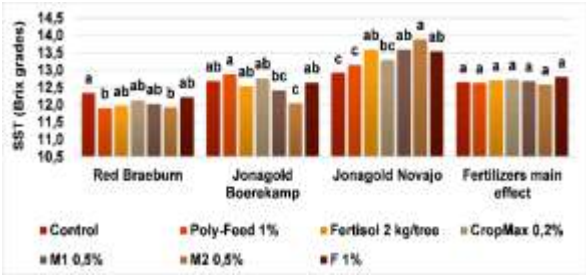

Fig. 10. Influence of fertilizers on total soluble solids depending on the apple cultivar

Table 5. Correlation matrix of leaves mineral elements, annual increase of TCSA, fruit set percent, fruit yield, fruit weight, firmness, pH, and total soluble solids

*	N	P	K	Ca	Mg	Zn	Cu	Mn	Fe	AI TCSA	% FS	Y	W	F	pH	TSS
CCI	0.832***	-0.310***	-0.350***	0.266**	0.357***	-0.066	0.140	0.016	0.266**	-0.318***	0.120	0.497***	-0.378***	-0.043	0.257***	0.106
N %	1	-0.195*	-0.303**	0.199*	0.256**	-0.215*	0.135	-0.010	0.157	-0.521***	0.164	0.625***	-0.690***	0.534***	-0.246**	-0.176
P %		1	0.134	0.061	0.087	0.268**	0.016	0.567***	-0.043	0.335***	-0.417***	-0.376***	0.098	-0.204*	0.483***	0.188*
K %			1	-0.193*	-0.500***	-0.110	-0.060	-0.018	-0.325**	0.135	0.197*	-0.144	0.169	-0.237**	0.032	0.020
Ca %				1	0.529***	0.589***	0.072	0.635***	0.363***	0.013	-0.364***	-0.126	0.030	-0.174	0.553***	0.279**
Mg %					1	0.462***	0.265**	0.381***	0.389***	-0.085	-0.205*	-0.107	0.081	0.024	0.293**	0.096
Zn mg/kg						1	0.054	0.671***	0.299**	0.300**	-0.487***	-0.458***	0.484***	-0.490***	0.802***	0.513***
Cu mg/kg							1	0.037	-0.011	-0.057	0.038	-0.034	-0.022	0.101	-0.045	0.013
Mn mg/kg								1	0.225*	0.265**	-0.650***	-0.435***	0.118	-0.246**	0.721***	0.323***
Fe mg/kg									1	-0.001	-0.093	0.003	-0.009	-0.019	0.197*	0.118
AI TCSA cm^2										1	-0.389***	-0.462***	0.420***	-0.355***	0.172*	0.124
%FS											1	0.504***	-0.266**	0.283**	-0.564***	-0.381***
Y t/ha												1	-0.683***	0.280***	0.087	-0.045
W g													1	-0.543***	0.152*	0.254**
F														1	-0.578***	-0.508***
pH															1	0.522***

*AI-TCSA-Annual increase of TCSA; %FS-ruti set percent; Y-Yield; W-Weight; F-Firmness.

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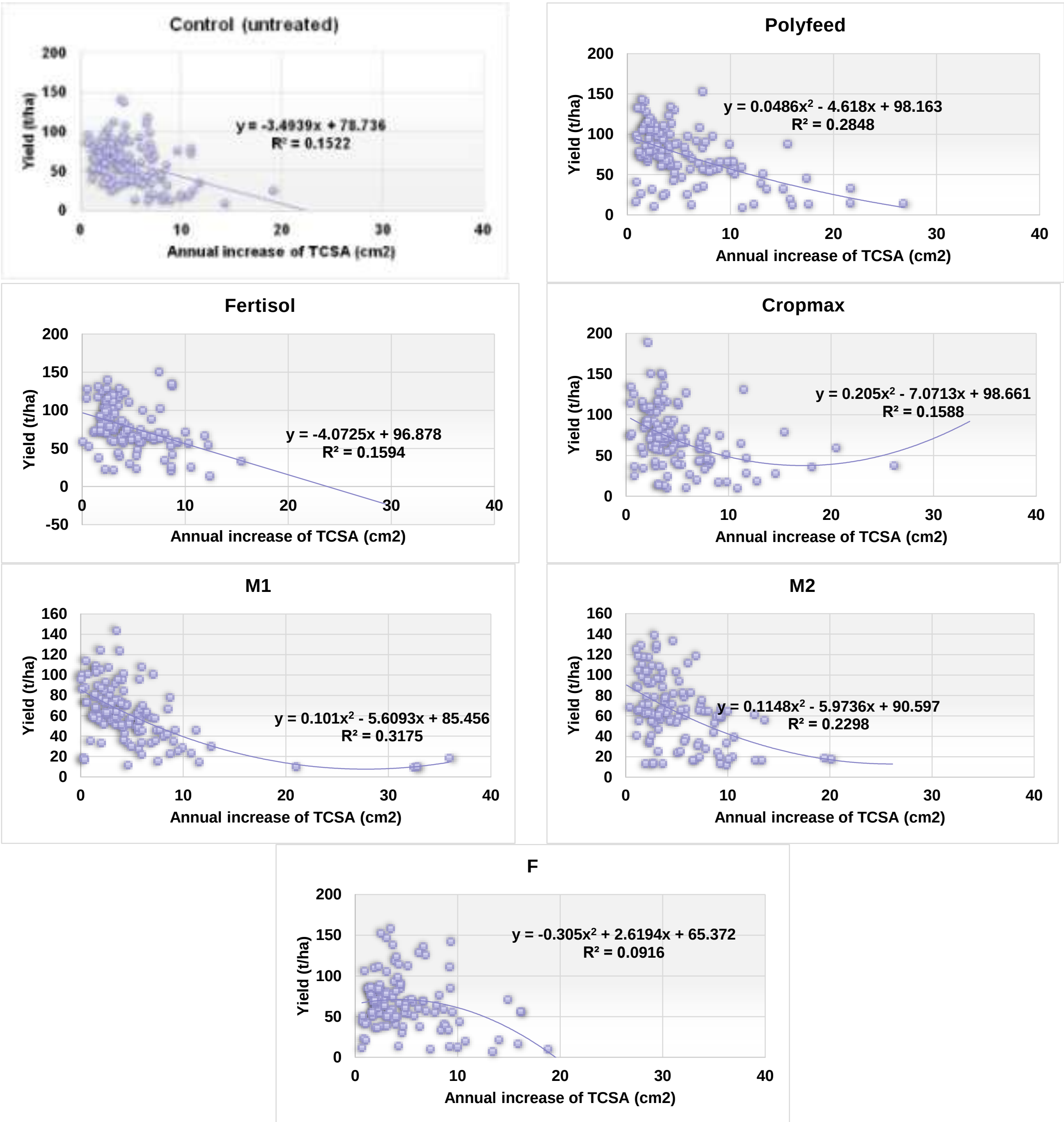

Fig. 11. Correlations between fruit yield and annual increase of trunk cross sectional area (TCSA) depending on fertilization treatment