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QUALIFICATION OF THE USE OF PLANT YIELD-ENHANCING PRODUCTS WITH PHOTOSYNTHETIC AND GROWTH PARAMETERS

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ABSTRACT
In our experiment, we investigated the effect of some of the most commonly used plant conditioners and yield enhancers in production of nursery-gardens and reference plantations, which are based on photosynthetic and growth parameters of saplings and productive stocks. The one-year old apple sapling was UEB 3177/1 variety, commertially called Sirius. In addition to the growth parameters (such as shoot length and stem diameter), the total chlorophyll and carotenoid contents, which determine photosynthetic activity, were also examined in both nursery-gardens and reference plantations. The individual and combined application of yield-enhancing and conditioning agents were involved in a total of six treatments.
The application of iron and flavonoid containing preparation alone or in combination resulted a significant difference in total chlorophyll content compared to the control stock. In the case of the studied growth parameters, the combination of the flavonoid and humic acid containing preparations and the sole use of flavonoid agent proved to be the most effective in the longitudinal growth of the sapling. In the terms of trunk size, the combination of the same formulation proved to be the best treatment compared to the control stock. Our results may have been influenced by weather conditions, they can be considered as preliminary results, and our studies should be repeated in the next growing season to draw valid conclusions.

Keywords: yield enhancer, trunk circumference, longitudinal-growth, chlorophyll, carotenoid

INTRODUCTION

The current plant conditioner/yield enhancer market is oversupplied. Due to the difficulties of the authorization process, some active substances are still sought to be authorised and commertialized in this category. Starting from next year, more products and active substances are expected to be introduced as more rules are lifted, making the current situation even worse. Due to the continuous subtraction of pesticide active ingredients, the focus of producers is increasingly shifting to the efficient use of yield-enhancing and conditioning agents. There is an over-supply of such products from manufacturers and distributors, some of which are of outstanding quality and efficacy and which, when combined with each other, can greatly contribute to the development of resistance to pests and pathogens. Plant protection is increasingly focusing on generally good or excellent condition of the stock. However, manufacturers have no interest in offering competing products in combination with each other, so they do not conduct experiments in this direction. In practice, however, it has been observed that the combination of certain active substances has a serendipitous synergy that results in spectacularly beneficial effects against certain infections or pests, as well as after abiotic stress situations.
The continuous and inappropriate use of chemical, inorganic fertilizers leads to the degradation of soil fertility and structure, and to the accumulation of heavy metals in plant tissues, which greatly affects the nutritional and palatability value of the fruit (SHIMBO ET AL., 2001). The so-called biofertilization is based on the use of natural raw materials,

including decomposing organic matter residues, animal manure and micro-organisms (bacteria, fungi, algae) (CHIRINOS ET AL., 2006). Biofertilization is now a very important method for meeting the nutrient needs of plants, while also reducing undesirable effects on the environment. In general, biofertilizers promote the uptake of nutrients in the rhizosphere, participate in improving soil conditions and enhance plant growth by producing growth stimulants (ABOU EL-YAZIED AND SELLIM, 2007).

Humus materials are highly complex heterogeneous mixtures (MACCARTHY ET AL., 1990). The establishment of favourable parameters is influenced by humic acid through a number of plant physiological processes, as it plays a crucial role in cellular respiration, photosynthesis, protein synthesis, water and nutrient uptake and enzymatic processes (CHEN ET AL., 2004).

Essential nutrients are usually present in the soil in sufficient amounts but not in a form that plants can absorb. As a result, many horticultural crops are deficient in zinc, boron, manganese, copper, molybdenum and iron, which negatively affects crop yield and quality (SUMAN ET AL., 2017). As a nutrient, iron (Fe) plays a key role in plant biology, acting as a cofactor for more than 140 enzymes and thus participating in the synthesis of chlorophyll molecules too.

The plant flavonoid-based conditioner also have a significant conditioning effect in the treated orchard stock, as well as increasing the plant's resistance to abiotic stress (GOMBOS, 2021).

In our experiment, we aimed to evaluate the effect of three yield enhancing/conditioning agents, applied individually and in certain combinations, on different photosynthetic and growth parameters of apple trees.

MATERIAL AND METHOD

Our 2-year experiment (2021-2022) in nursery-gardens and reference plantations was set up in the fields of Holland Alma Kft and Inno Fruitplant Kft, wich are located on the borders of Csobád village (GPS: 48°17'00.8" N, 21°01'51.2" E). The annual rainfall of the experimental area in the Hernád Valley is 510 mm. It is a cool, humid growing area, because the annual temperature sum is lower than the national average. The average annual temperature is 9.96 C°. The soil type of the experimental area is classic alluvial soil, with Arany soil index of 43-47 and a humus content of 2.3-2.7%. This soil has a deep topsoil (70-80 cm) with a thick layer of clay (4-5 cm) at the bottom. The subsoil is a greyish clay with a larger sand fraction, which is alluvial, fine at 3.5-4 metres, and then passes into a coarser gravel.

Treatments and measurements were carried out on one-year-old apple sapling of the same rootstock/variety combination. The one-year old apple sapling was UEB 3177/1 variety, usually called Sirius.

During the experiment, the following yield enhancers and conditioners were applied: Flavo Plant, a plant flavonoid conditioner, applied at 2 L ha^{-1}; Bistep, a humic acid-based formulation, applied at 3 L ha^{-1}; Solvitis Fe, a foliar fertilizer, also applied at 3 L ha^{-1}.

The treatments were repeated three times on 15-22 June, 29 June and 19 August.

Besides the control stock, the treatments were: 1. Flavo Plant, 2. Bistep, 3. Solvitis Fe, 4. Flavo Plant + Bistep, 5. Flavo Plant + Solvitis Fe. In the experiment, the control stock and each treatment were set in four replicates. After the plots were marked out, the rootstock part of each one-year-old apple sapling was marked with marker paint. The studied one-year-old apple sapling stocks were arranged in 6 rows next to each other. There were also 10 apple saplings per plot, with four plots per treatment.

In scheduling the measurements, the morpho-physiological measurements were taken simultaneously with the application of the yield enhancers and conditioners. The measurements started on the day of the first application of treatments and was considered as the basic (zero) condition.
Shoot length was measured by recording the height above the ground of the apple sapling in the selected plots (10 plants per plot). The change in longitudinal growth dynamics refers to the period between 2 successive measurement dates. Measurements of the height of the apple sapling were taken at 7-day intervals using a measuring slat.
The determination of the growth parameters also included an examination of the trunk circumference. The measurement was taken 1 cm above the grafting point. The growth dynamics in this case also refer to the period between the measurement dates. The trunk circumference was measured at 4-week intervals using a digital measuring instrument.
The leaf samples were collected from the middle part of the one-year-old apple sapling, so the measurements were made on the middle-aged leaves, as in the reference plantations. The date of leaf sampling for the physiological measurements was 31 August. During sampling, in the nursery-gardens, 1 leaf sample was randomly collected from 3 individual plants in each replicate, while in the reference plantations the leaf samples were collected from the marked side branches. Photosynthetic pigments were determined in the collected samples using a spectrophotometer. The total chlorophyll and carotenoid contents were calculated according to the method of Moran and Porath (1980) and Wellburne (1994).
Statistical analysis was performed by Sigma Plot for Windows using One Way ANOVA Test.

RESULTS

Our results showed significant differences in the shoot length dynamics between treatments and control stocks at the first, tenth, eleventh and twelfth measurement time points (*Figure 1*).

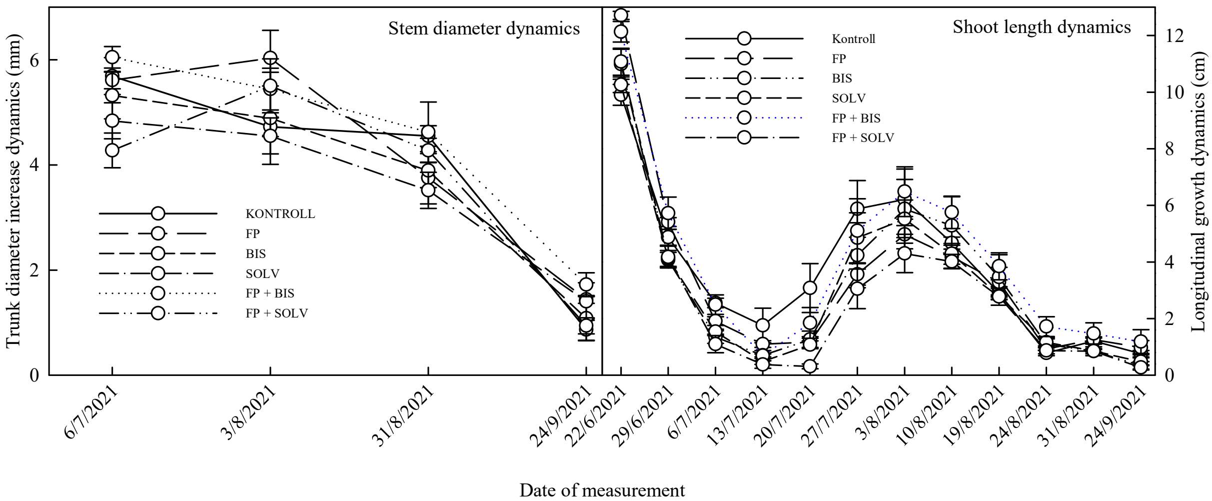

Figure 1: Dynamics of longitudinal growth (cm) and growth intensity of trunk circumference (mm) under different measurement dates and treatments (Flavo Plant [FP], Bistep [BIS], Solvitis Fe [SOLV]) and their combination (Flavo Plant and Bistep [FP+BIS], Flavo Plant and Solvitis Fe [FP+SOLV]). Date of measurement of the shoot: [1] 2021.06.22 [2] 2021.06.29 [3] 2021.07.06 [4] 2021.07.13 [5] 2021.07.20 [6] 2021.07.27 [7] 2021.08.03 [8] 2021.08.10 [9] 2021.08.19 [10] 2021.08.24 [11] 2021.08.31 [12] 2021.09.24 Date of measurement of the stem: [1] 2021.07.06 [2] 2021.08.03 [3] 2021.08.31 [4] 2021.09.24 (n=3, ± s.e.)

In the first measurement, the Flavo Plant (12.7 ±0.143) gave the longest growth, while the combination of Flavo Plant and Bistep gave a similar result (12.1 ±0.364). The lowest longitudinal growth was obtained with the Control stock (9.90 ±0.369). In the longitudinal growth, the treatment Flavo Plant and the combination of Flavo Plant and Bistep resulted in a significantly higher value compared to the control stock.
In the tenth measurement, the combination of Flavo Plant and Bistep (1.72 ±0.698) produced the longest growth. Compared to the control stock (0.79 ±0.191), the treatment combination of Flavo Plant and Bistep resulted in a significantly higher longitudinal growth.
In the eleventh measurement, the combination of Flavo Plant and Bistep resulted in the highest growth value (1.47 ± 0.381), but the sole use of Flavo Plant resulted in almost identical values (1.26 ± 0.094). The treatment combination of Flavo Plant and Solvitis Fe (0.85 ± 0.091) resulted in significantly lower longitudinal growth compared to the control stock (1.21 ± 0.105).
At the last measurement time, the combination of Flavo Plant and Bistep resulted in the highest growth rate (1.18 ±0.421). In the longitudinal growth, the treatment combination of Flavo Plant and Solvitis Fe (0.28 ±0.092) resulted in a significantly lower value compared to the control stock (0.76 ±0.113).
Stem diameter of the one-year-old apple sapling is illustrated in *Figure 1.* Based on the results of the experiment, significant differences were found between the control and the treatment stocks on the measurement dates of 06.07.2021, 31.08.2021 and 24.09.2021.
On the first measurement date, the combination of Flavo Plant and Bistep resulted in the largest increase in trunk circumference (6.05 ±0.205). In comparison, the control resulted in a lower value (5.69 ±0.351). The treatment combination of Flavo Plant and Solvitis Fe resulted in the lowest growth rate (4.28 ±0.330). In comparison with the control, the treatment combination of Flavo Plant and Solvitis Fe resulted in significantly lower value.
On the third measurement date, the combination of Flavo Plant and Bistep resulted in the largest increase in trunk circumference (4.62 ±0.572). In comparison, the control resulted in a lower value (4.55 ±0.196). The Solvitis Fe preparation caused the lowest growth value (3.52 ±0.344). In comparisons with the control, Solvitis Fe treatment resulted in a significantly lower value.
Also on the fourth measurement date, the combination of Flavo Plant and Bistep resulted in the largest increase in trunk circumference (1.72 ±0.226). In comparison, Flavo Plant resulted in a lower value (1.44 ±0.074). The control stock caused the lowest growth value (0.86 ±0.209). In comparison with the control stock, the treatment combination of Flavo Plant and Bistep and the sole use of Flavo Plant resulted in a significantly higher values.

The change in total chlorophyll content as a result of these treatments is illustrated in *Figure 2.* Among the treatments, the combination of Flavo Plant and Solvitis Fe (11.9 ±0.435) resulted in the highest chlorophyll content in the nursery-gardens, while the Flavo Plant formulation (10.7 ±0.146) resulted in the highest chlorophyll content in the reference plantations.

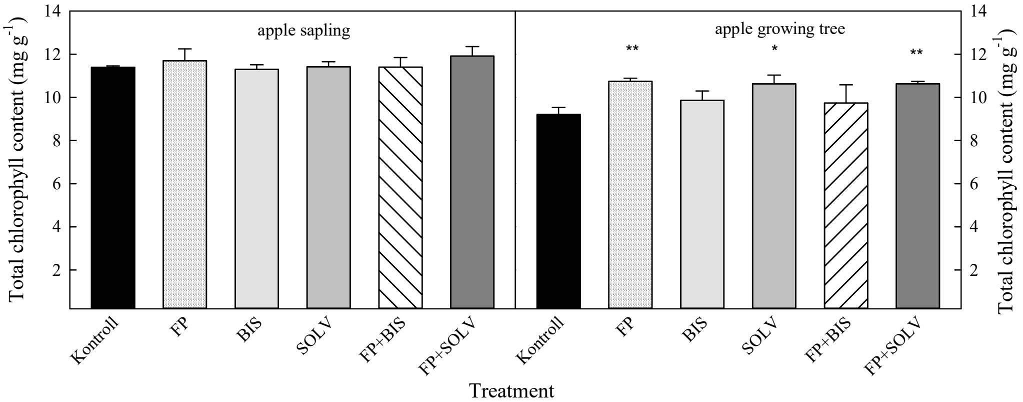

Figure 2: Changes in total chlorophyll content (mg g^{-1}) of apple sapling and apple growing tree leaf under the different treatments (Control [Control], Flavo Plant [FP], Bistep [BIS], Solvitis [SOLV]) and their combinations (Flavo Plant and Bistep [FP+BIS], Flavo Plant and Solvitis [FP+SOLV]). Specific treatments compared to control: ($P \leq 0{,}01$**, $P \leq 0{,}05$* n=3, ± s.e.) Time of measurement: 2021.09.06.

Based on our results, Flavo Plant (10.7 ±0.146), Solvitis Fe (10.6 ±0.819) and Flavo Plant and Solvitis Fe (10.6 ±0.221) resulted in significantly higher total chlorophyll content of the growing apple tree stock compared to the control (9.21 ±0.657).

Among the treatments, the combination of Flavo Plant and Solvitis Fe (9.28 ±0.966) resulted in the highest carotenoid content in the apple sapling stock, while the Bistep formulation (11.3 ±2.373) resulted in the highest carotenoid content in the apple growing tree stock.

DISCUSSION

Adequate nutrient management during the nursery period is very important, as apple sapling vigour is greatly influenced by different fertilization methods. Apple saplings are suitable for grafting if they have reached a root collar diameter of 8-18 mm, which varies from species to species. The design of overly thickened rootstocks is also impractical, as they are difficult to graft and the grafted variety does not sprout. The increase in trunk circumference after grafting is also essential, as it largely determines the growth and resistance of the grafted section, which can also have a significant impact on subsequent production processes.

The longitudinal growth of apple sapling is also greatly influenced by proper and professional nutrient management, in addition to green management. In modern fruit production, apple sapling with second-order shoots is increasingly in demand for intensive crown formation. Consequently, by ensuring optimal growth dynamics, apple sapling with crown can be grown in the year of the grafting, so that by shortening the period of the production, it is possible to reduce production costs to a large extent.

The efficiency of photosynthesis is essentially determined by the chlorophyll content, which increases the yield, growth processes and plant resistance through the production of higher amounts of asimilates. Increasing their quantity can also contribute to more efficient production.

Based on this experiment, it can be said that, in the reference plantations, the chlorophyll content of treatment stock significantly differed from the control stock when iron and flavonoid preparations were used alone or in combination. For the physical parameters measured, the sole use of Flavo Plant and the treatment combination of Flavo Plant and Bistep had the best effect on the longitudinal growth of the nursery-gardens. In all cases, the combination of humic acid-based and flavonoid-containing formulation proved to be the best treatment in terms of trunk circumference increase compared to the control stock.

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