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SOIL QUALITY OF THE MODERN APPLE ORCHARD GROWN UNDER DIFFERENT NPK FERTILIZATION APPLICATION SYSTEMS

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1) ABSTRACT

In enhancing agricultural productivity, one of the most important determinants is to choose the best fertilizer application system. Among different application systems, fertigation can have multiple benefits on the yield and quality of crops since it can significantly reduce costs and increase the profitability. However, inadequate, excessive application of fertilizers through fertigation and irrigation may lead to soil degradation and deterioration of soil fertility, resulting in a change of some physical and chemical parameters of soil. Thus, the aim of this study was to compare the effect of fertigation and conventional fertilization on the soil chemical characteristics.

The experiment was designed to determine the effect of two different ways of fertilizer application (through two treatments: drip irrigation system-fertigation and classical way) and three different doses of NPK fertilizers on chemical parameters of chernozem soil type, in a modern apple (Red Jonaprince variety) orchard. From each treatment, bulk soil samples were taken for the determination of soil pH, mineral nitrogen (N), readily available potassium (K_2O) and phosphorus (P_2O_5). Samples were collected in the spring, before fertilizer application, to determine the initial soil condition and in the autumn, at the end of the vegetation period.

The pH in H_2O when the highest dose of fertilizer was applied by fertigation had a significantly lower value compared to the control, while in classical fertilization all three doses implicated a decrease of pH value compared to the control. The results showed that different doses of fertilizers significantly affected the content of N, K_2O and P_2O_5. Furthermore, the obtained results were strongly affected by meteorological conditions, because in some months the application of irrigation was not

necessary, due to a large amount of precipitation. To conclude, these results could serve as an indicator for further analysis of soil impact on yield and quality of apple fruit.

***Key words*: apple, irrigation, fertilization, fertigation, NPK fertilizers.**

INTRODUCTION

Apple fruits are used for various purposes: as table fruit (fresh, all year round) and as a raw material for industrial processing (production of juices, jams, dried fruits, compotes, vinegars, etc.) **(MIŠIĆ, 2004)**. Apple fruit contains 10 to 19% of dry matter; sugars 6.6 - 15.5% of total (whose structure is dominated by reducing sugars - glucose and fructose) and acids 0.4 - 0.8% of total **(NIKETIĆ-ALEKSIĆ, 1988)**. The content of mineral substances in apples is up to 0.4%, especially high is the content of potassium (280 mg / 100 g K; 26 mg / 100 g Na; 16 mg / 100 g Ca; 9 mg / 100 g Mg). 2003). Apple fruit contains up to 0.8% pectin, 0.025 to 0.27% tannin, 0.03 mg / 100 g vitamin B1 (thiamine), 0.02 mg / 100 g vitamin B2 (riboflavin), 0.3 mg / 100 g of vitamin B3 (niacin), 10 mg / 100 g of vitamin C, a significant amount of carotene, anthocyanins, amino acids and other biologically important substance-active components **(VRAČAR, 2001)**. In Serbia apple production is practiced on 23737 ha and is on the second place in terms of area, right behind plums **(KESEROVIĆ, et al., 2014)**.
Fertigation is irrigation with solution or suspension of fertilizers in the water. Fertigation enables significant savings in fertilizer use and reduces losses of nitrate forms by leaching (Mmolawa & Or, 2000). Fertigation can be reported in a variety of ways, and is most commonly performed through drip systems and rainwater systems. Fertigation is mainly done with nitrogen fertilizers due to the time of watering and the behavior of NO_3-N in the soil. The most commonly used nitrogen fertilizers for fertigation are: urea $CO(NH_2)_2$; ammonium nitrate (NH_4NO_3) and ammonium sulfate $(NH_4)_2SO_4$.

2)MATERIALS AND METHODS

The experiment was set up in a one-year-old apple orchard, of the Red Jonaprince variety, in the experimental field of the Department of Fruit Growing, Viticulture, Horticulture and Landscape Architecture on Rimski Šančevi, on chernozem-type of soil. To establish the influence of nutrient doses **(Table 1)** and types of nutrient application (fertigation and classical method), samples were taken at the beginning of vegetation, before nutrient application, as well as in autumn, at the end of vegetation. Samples were taken manually, using a probe, at three distances from the dropper (0, 15 and 30 cm) and at four depths (0 - 10 cm, 10 - 20 cm, 20 - 30 cm and 30 -40 cm).

Table 1. Total applied doses during the vegetation period (April-September) (kg/ha)

kg/ha	N	P_2O_5	K_2O
N1P1K1	50	30	60
N2P2K2	100	59,8	100
N3P3K3	150	80,6	140

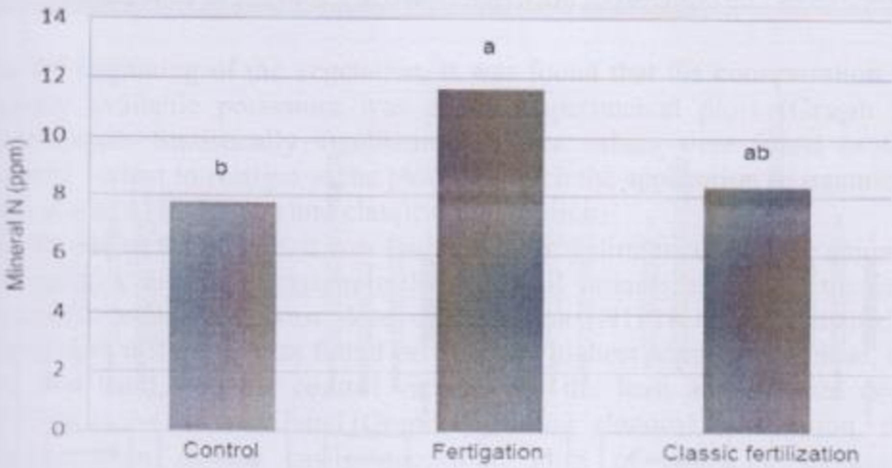
Nitrogen, phosphorus and potassium were applied in the form of AN, MAP and KNO_3 fertilizers. During the research, the following parameters were studied: the amount of mineral nitrogen in the soil, the amount of available potassium in the soil, the amount of available phosphorus in the soil and the reaction of the soil (active and substitution acidity).
The soil analysis were performed in the laboratory for testing the soil and fertilizers at the Faculty of Agriculture in Novi Sad. Standard methods have been applied to determine the chemical properties and content of nutrients. Active and substitution acidity were determined by potentiomeric method, with the help of a pedometer. The amount of readily available phosphorus (mg P_2O_5 / 100 g) was determined by the Al method **(EGNER & RIEHM, 1958)** with a reading on a spectrophotometer, and the readily available potassium (mg K_2O / 100g) was also determined by the AL method with a reading on a flame photometer. Determination of mineral nitrogen in the soil (NH_4 + NO_2 + NO_3) -N) was done according to the **BREMNER (1965).**
In data processing was used software Statistics. Analysis of variance was performed according to the split-plot model based on average means. The comparison of mean values was done using the LSD test.

4) RESULTS AND DISCUSSION

4.1. The amount of readily available nitrogen in the soil

At the beginning of the vegetation season, the measured amount of mineral nitrogen differed in all applied treatments **(Graph 1).** The largest was on the plots where the application of fertigation was planned (11.61 ppm) and the smallest on control plots (8.31 ppm N). Statistical significance was between the average values of nitrogen on the control plots and the plots intended for the application of fertigation.

Graph 1. The amount of mineral form of nitrogen in the soil at the beginning of vegetation at a depth of 0-40 cm (ppm)

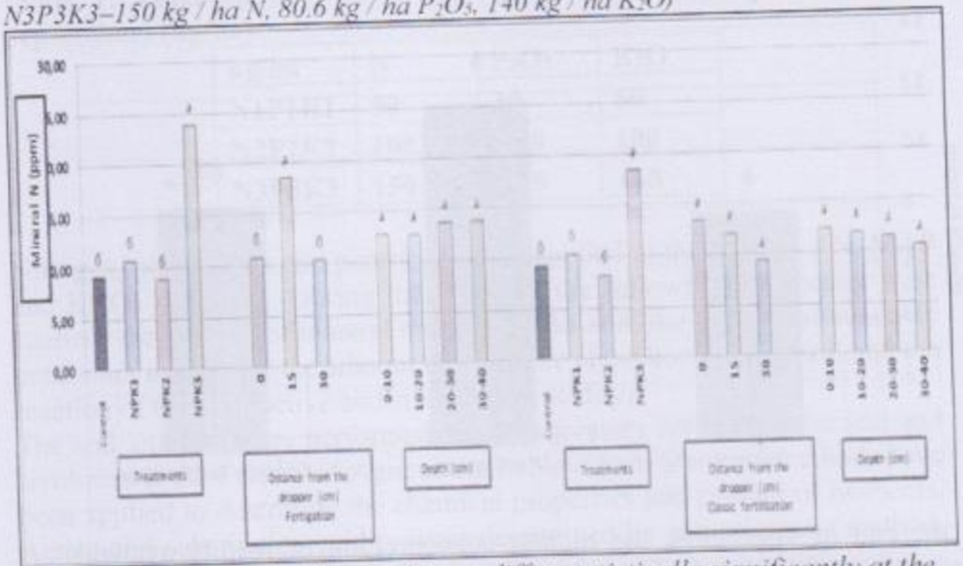


At the end of vegetation, the highest concentration of readily available nitrogen was with the highest dose of fertilizer (N3P3K3), on both applied treatments (classical fertilization and application of fertigation), and was statistically significantly different from control and all applied doses of NPK fertilizer (N1P1K1 and H2; 2). The amount of mineral form of nitrogen in the soil, when the highest dose of fertilizer applied with fertigation (N3P3K3), was 61.48% higher compared to the control, 54.97% higher than the first treatment (N1P1K1) and 62.85% higher than the second (N2P2K2).

The amount of mineral form of nitrogen in the soil when applying the classical method of fertilization, at the highest dose (N3P3K3) was higher by 49.84% compared to the control, respectively 53.86% and 55.27% compared to the other two smaller doses of NPK fertilizer (N1P1K1 and N2P2K2, respectively). Also during fertigation, when applying the highest dose of NPK fertilizer, a higher concentration of readily available nitrogen was measured, compared to the same dose of fertilizer (N3P3K3) in the classical fertilization method (23.96 ppm and 18.40 ppm, respectively).

Graph 2. Amount of mineral form of nitrogen in the soil at the end of vegetation (ppm)

(Control without fertilizer application; N1P1K1–50 kg / ha N, 30 kg / ha P_2O_5, 60 kg / ha K_2O; N2P2K2–100 kg / ha N, 59, 8 kg / ha P_2O_5, 100 kg / ha K_2O; N3P3K3–150 kg / ha N, 80.6 kg / ha P_2O_5, 140 kg / ha K_2O)



** Values marked with different letters differ statistically significantly at the level of 5% ($p < 0.05$)*

In relation to the distance from the drippers, the highest concentration of mineral nitrogen was at 15 cm, and was statistically significantly higher in relation to the distance of 0 cm and 30 cm, while in the classical application of fertilizers an even distribution of mineral nitrogen was established.

Approximately the same values of easily accessible nitrogen concentration were found at all four examined depths, in both applied treatments (classical fertilization and fertigation).

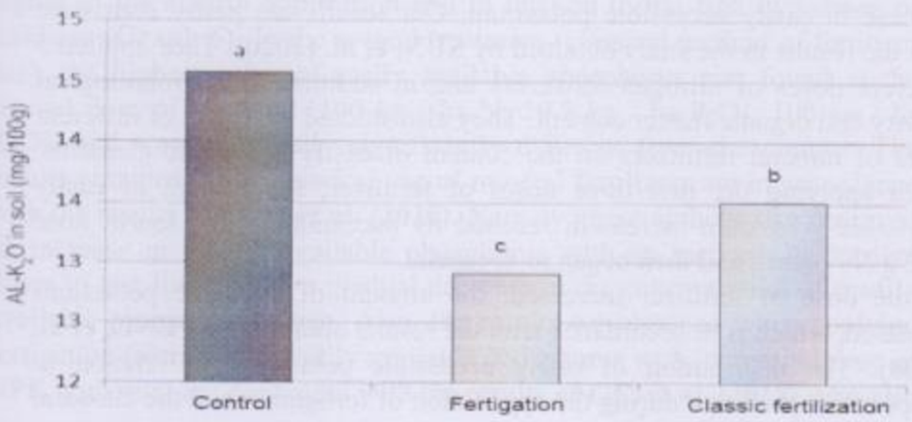
Increased concentration of readily available nitrogen in the soil was also obtained by **GE, et al. (2018)** who studied the influence of fertilization with mineral fertilizers and a combination of mineral fertilizers and organic fertilizers on soil pH, organic matter content, C / N ratio and concentration of easily accessible macroelements (N, P and K). The obtained results are in agreement with the results of **SUN, et al. (2020).** The mentioned authors, by studying the influence of different doses of nitrogen fertilizers on soil characteristics (microbiological activity, organic matter content, content of easily accessible elements) found that the use of nitrogenous mineral fertilizers increases the content of easily accessible nitrogen in the soil, but did not find a statistically significant difference between different applied doses of nitrogen fertilizers.

4.2. The amount of easily accessible potassium in the soil

At the beginning of the vegetation, it was found that the concentration of readily available potassium was on all experimental plots **(Graph 3)** heterogenic. Statistically significantly higher values were found in the control variant in relation to the plots on which the application of treatment was planned (fertigation and classical fertilization).

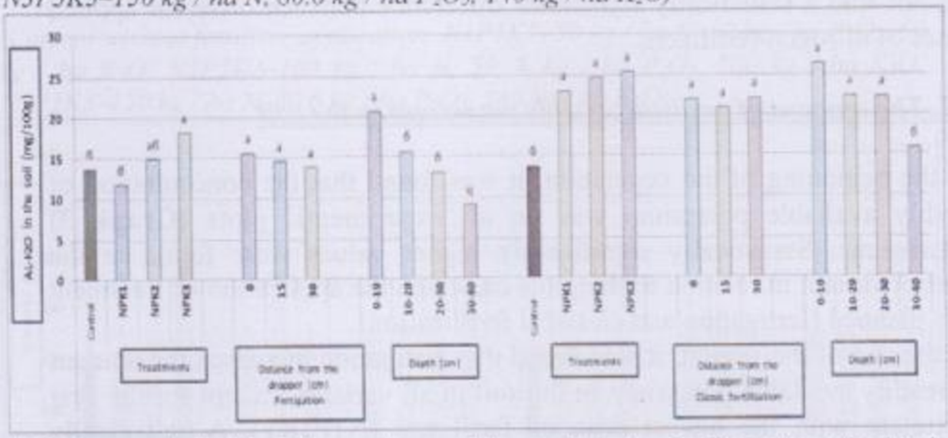
At the end of the season, it was found that fertigation increased the amount of readily available potassium in the soil in all variants, except for the first treatment with the lowest dose of fertilizers (N1P1K1). A statistically significant difference was found between the highest administered dose, on the one hand, and the control variant, and the least administered dose (N1P1K1), on the other hand (Graph 4). During classical fertilization, the concentration of the easily accessible form of potassium increased statistically significantly with all three applied doses of fertilizer (N1P1K1, N2P2K2, N3P3K3).

Graph 3. Amount of easily accessible form of potassium at the beginning of vegetation at a depth of 0-40 cm (mg K_2O / 100 g of soil).



Graph 4. Amount of easily accessible form of potassium at the end of vegetation (mg K_2O / 100 g of soil)

(Control-without fertilizer application; N1P1K1–50 kg / ha N, 30 kg / ha P_2O_5, 60 kg / ha K_2O; N2P2K2–100 kg / ha N, 59.8 kg / ha P_2O_5, 100 kg / ha K_2O; N3P3K3–150 kg / ha N, 80.6 kg / ha P_2O_5, 140 kg / ha K_2O)



* *Values marked with different letters differ statistically significantly at the level of 5% ($p < 0.05$)*

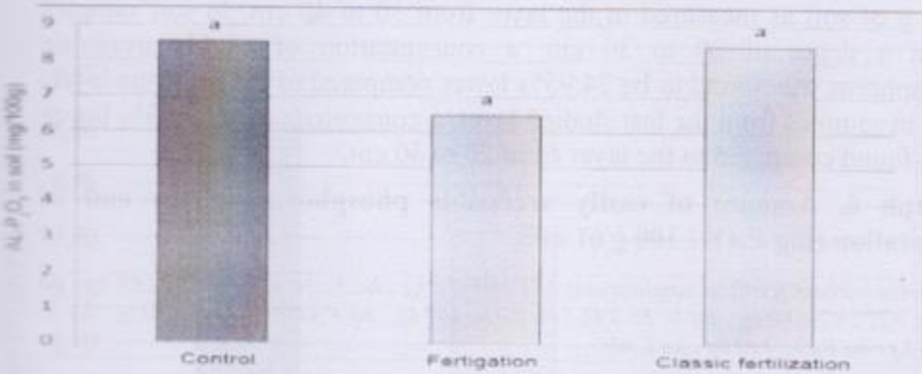
The results obtained with the application of fertigation are in agreement with the results of **GE, et al. (2018)** who studied the impact of long-term application of different combinations of fertilizers on soil properties and the content of easily accessible nutrients. They also found that on the control variant, where no fertilizers were applied, there was a decrease in the content of easily accessible potassium in the soil, and that on the plots where treatment was applied (different types of fertilizers) there was an increase in easily accessible potassium. Our results are partly consistent with the results in the study obtained by **SUN, et al. (2020).** They applied 5 different doses of nitrogen fertilizers and in addition to microbiological activity and organic matter content. They also studied the effect of different doses of mineral fertilizers on the content of easily accessible elements. When applying the first three doses of fertilizer, the content of easily accessible potassium increased, reached its maximum at the fourth dose (352 g N / plant), and then began to decrease.

As the dose of fertilizer increased, the amount of available potassium increased, which is in accordance with the results obtained by **PENG, et al. (2008).** The distribution of easily accessible potassium in relation to drippers was the same during the application of fertigation and the classical method of fertilization and with the depth of the sample, the concentration of easily accessible potassium decreased in both applied treatments. During fertigation, the amount of readily available potassium was lower by 48.98% at the first dose of fertilizer, 39.55% at the second dose of fertilizer and 28.26% at the third dose of fertilizer.

4.3 Amount of readily available phosphorus

At the beginning of vegetation, the content of easily accessible phosphorus in the soil, on all plots (control, where fertigation is applied and where classical fertilization is applied) was uniform and there was no statistically significant difference between the average values of easily accessible phosphorus **(Graph 5).**

Graph 5. Amount of easily accessible phosphorus at the beginning of vegetation at a depth of 0-40 cm (mg P_2O_5 / 100 g of soil).



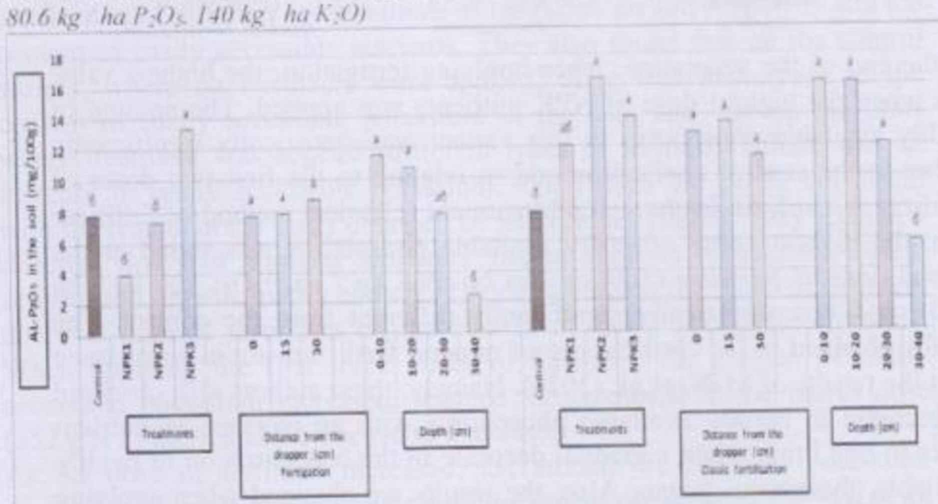
At the end of the vegetation, when applying fertigation, the highest value was when the highest dose of NPK nutrients was applied. The amount of readily available phosphorus in this variant was statistically significantly higher in the control application and in relation to the first two doses of fertilizer **(Graph 6).** In the second treatment (classical method of fertilizer use), the highest value of easily available phosphorus was found at the second dose of fertilizer (100 kg / ha N; 59.8 kg / ha P_2O_5; 100 kg / ha K_2O), and was statistically significantly different from the control. The results obtained in the classical use of mineral fertilizers are in accordance with the results of **SUN, et al. (2020).** Namely, these authors also observed an increase in readily available phosphorus with an increase in nutrient doses to one limit, when a gradual decrease in the concentration of readily available phosphorus began. Also, the results we obtained when applying fertigation (increase in readily available phosphorus with increasing dose of NPK nutrients) are consistent with the results of **GE, et al. (2018)** who also found a constant growth of readily available phosphorus due to the use of different combinations of nutrients.

The amount of easily accessible phosphorus was higher on plots on which fertilization was applied in the classical way than on those fertilized by fertigation at all three applied doses of fertilizer. Among the samples taken from different distances from the dropper, no statistical significance was found in both applied treatments, but there was more readily available phosphorus in the application of classical fertilization than in the application of fertigation.

As the depth increased, the amount of readily available phosphorus decreased, with both applied treatments. During fertigation, the concentration of readily available phosphorus decreased from 11.54 mg P_2O_5 / 100 g, as recorded in the surface layer (0-10 cm), to 2.1 mg P_2O_5 / 100 g of soil as measured in the layer from 30 to 40 cm. In soil samples from a depth of 20 to 30 cm, a concentration of readily available phosphorus was found to be 24.95% lower compared to the previous layer, and in samples from the last studied layer, a concentration of 51.73% lower was found compared to the layer from 20 to 30 cm.

Graph 6. Amount of easily accessible phosphorus at the end of vegetation (mg P_2O_5 / 100 g of soil)

(Control-without fertilizer application: N1P1K1–50 kg/ha N, 30 kg/ha P_2O_5, 60 kg/ha K_2O; N2P2K2–100 kg/ha N, 59.8 kg/ha P_2O_5, 100 kg/ha K_2O; N3P3K3–150 kg/ha N, 80.6 kg/ha P_2O_5, 140 kg/ha K_2O)

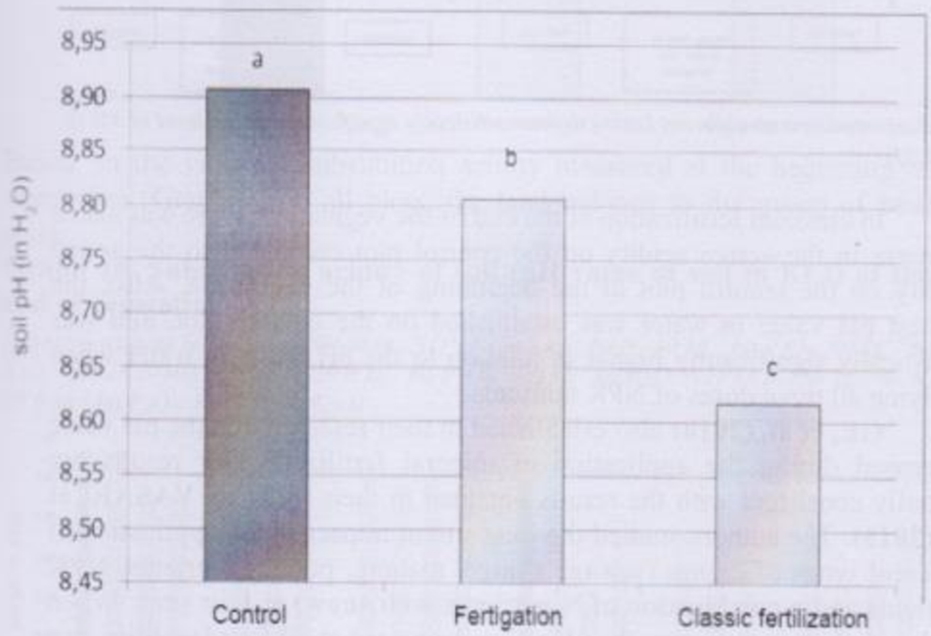


** Values marked with different letters differ statistically significantly at the level of 5% (p <0.05).*

4.4. Soil reaction

As with the previously studied parameters, the property of active soil acidity (acidity extracted from the soil by water) was found to be very heterogeneous at the beginning of vegetation between the examined plots (Graph 7). On the control plot, the pH in the water was 8.91, on the plot where the application of fertigation was planned, the pH was 8.81, and on the plot where the classical fertilization was applied, the lowest pH value in the water was recorded (8.62). All pH values according to the soil classification in relation to the pH in the water indicate the soil reaction class of the base reaction.

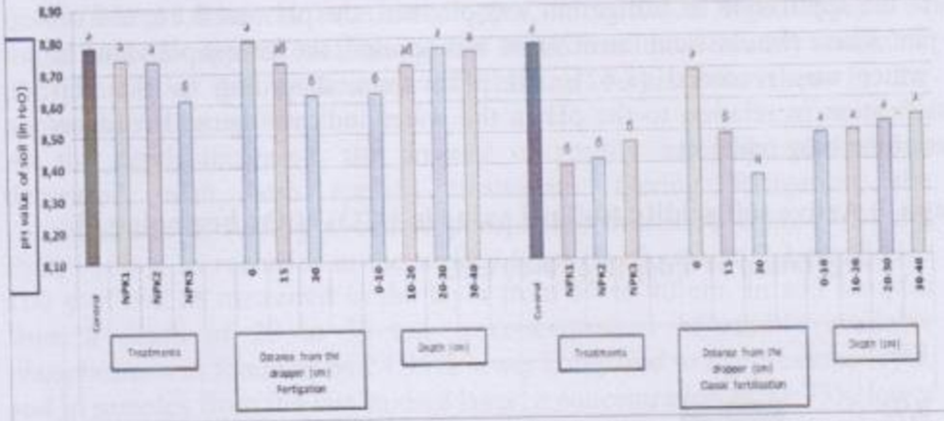
Graph 7. Active soil acidity (soil pH value in H2O) at the beginning of vegetation at a depth of 0-40 cm.



At the end of vegetation, during the application of fertigation, there was a decrease in the value of active acidity in relation to the beginning of vegetation. The highest value was recorded on the control, and it was statistically significantly different only in comparison with the application of the highest dose of nutrients **(Table 8).**

Table 8. Active soil acidity (soil pH value in H2O) at the end of vegetation

(Control-without fertilizer application; N1P1K1–50 kg / ha N, 30 kg / ha P_2O_5, 60 kg / ha K_2O; N2P2K2–100 kg / ha N, 59.8 kg / ha P_2O_5, 100 kg / ha K_2O; N3P3K3–150 kg / ha N, 80.6 kg / ha P_2O_5, 140 kg / ha K_2O)



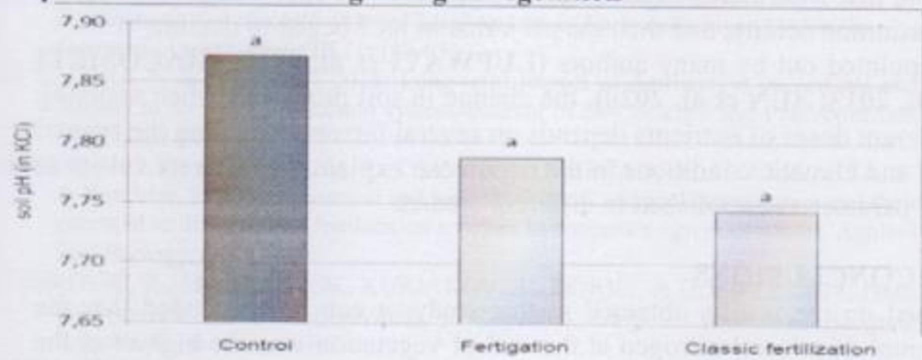
* *Values marked with different letters differ statistically significantly at the level of 5% (p <0.05)*

In classical fertilization at the end of the vegetation, there was also a decrease in the active acidity on the control plot compared to the active acidity on the control plot at the beginning of the vegetation. Also, the highest pH value in water was established on the control plot, and was statistically significantly higher in relation to the pH value in water when applying all three doses of NPK nutrients.

GE, et al. (2018) also established in their research that the pH value decreased during the application of mineral fertilizers. Our results are partially consistent with the results obtained in their study by **VASAK, et al. (2015).** The authors studied the long - term impact of the application of different types of cranes (sewage sludge, manure, pure N nutrients, NPK nutrients and a combination of N nutrients with straw) at four sites. When applying organic nutrients, the pH value decreased at all four localities, but it was not statistically significant. Pure mineral fertilizers (N and NPK), as well as a combination of pure nitrogen and straw, led to a decrease in pH at three of the four studied sites.

In fertigation, at a greater drip distance, the pH value of the soil had the lowest value (8.63), which was statistically significantly different from the distance of 0 cm (8.80). In the classical application of fertilizers, the pH values measured at all three distances from the drippers were statistically significantly different from each other. Observed at different depths, in classical fertilization no statistically significant difference was found between pH values measured at different depths, while in surface layer fertigation the lowest pH value (8.63) was measured, which was statistically significantly lower than the values measured in the layer from 20 to 30 cm and from 30 to 40 cm **(Graph 8).**

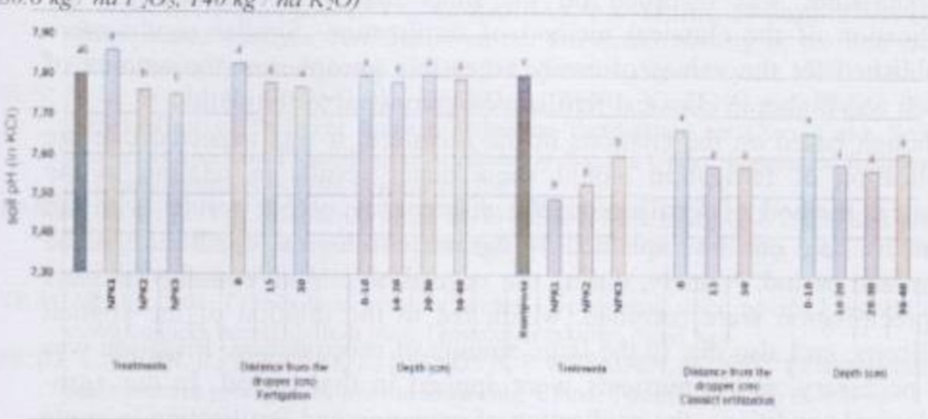
Graph 9. Substitution acidity of the soil (pH value of the soil in KCl) at a depth of 0-40 cm at the beginning of vegetation



Based on the value of substitution acidity measured at the beginning of vegetation (Graph 9) on all plots, the land belongs to the group of base soils.

Graph 10. Substitution acidity of soil (pH value of soil in KCl) at the end of vegetation

(Control-without fertilizer application, N1P1K1–50 kg / ha N, 30 kg / ha P_2O_5, 60 kg / ha K_2O; N2P2K2–100 kg / ha N, 59.8 kg / ha P_2O_5, 100 kg / ha K_2O; N3P3K3–150 kg / ha N, 80.6 kg / ha P_2O_5, 140 kg / ha K_2O)



* *Values marked with different letters differ statistically significantly at the level of 5% (p <0.05)*

In fertigation, pH (1M KCl) had a statistically significantly higher value at the lowest applied dose of NPK nutrients compared to the other two applied doses (Graph 10), while there was no statistical significance between the control and all applied doses of nutrients. In classical fertilization, the values of substitution acidity were statistically significantly lower at all three doses of nutrients, compared to the control. Our research is partly consistent with research conducted by **SAWICKA, et al. (2020).** They found that with increasing nitrogen dose, there was first a slight increase in substitution acidity, and then the pH value in KCl began to decline.
As pointed out by many authors **(LUPWAYI et al, 2012; GIACOMETI et al, 2013; SUN et al, 2020),** the change in soil properties when applying different doses of nutrients depends on several factors, including the type of soil and climatic conditions in the region can explain the different values of soil parameters established in different studies.

5) CONCLUSIONS

Based on the results obtained in this study, it can be concluded that the amount of mineral nitrogen at the end of vegetation was the highest at the highest doses of NPK nutrients, with both types of fertilizer application and statistically significantly different from the control and application of lower doses of NPK nutrients. The amount of easily accessible potassium was higher in the classical application of nutrients in relation to the use of nutrients with irrigation, but when interpreting these results it must be taken into account that the soil at the beginning of vegetation was very uneven in terms of easily accessible potassium. the amount of easily accessible form of potassium was recorded on the plots that were planned for the application of the classical method of fertilization. Similar results were established for the values of easily accessible phosphorus, the amount of which was higher in classical fertilization compared to fertigation.
Although based on the citations in the literature, it was expected that the application of fertigation would show better results in relation to the classical method of fertilization, the discrepancy of our results with the literature data can be explained by agrometeorological conditions in the examined period. Namely, during the vegetation period, extreme amounts of precipitation were recorded, which led to the dilution of the applied fertilizers, and also due to the large amount of precipitation, irrigation was not necessary, so no nutrients were applied in that period. In our agro-ecological conditions, the application of irrigation and fertilization in apple production requires agro-technical measures, and combining these two

measures provides the possibility not only of great savings, but also enables reduced contamination of the soil and the environment.

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