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A Review of Uncontrolled Soil Fertilization in Greenhouses and its Harmful Effects

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Abstract: ***Although when it comes to greenhouses, a key factor for profitable production is primarily the choice of location where they will be built, the quality of the soil is a main prerequisite for their long-term sustainable production. In these production units, it is common practice to add large quantities of natural or artificial fertilizers in order to maintain intensive production. Unfortunately, in many countries around the world, greenhouse crop growers add natural or artificial fertilizers by "rule of thumb." This practice, in many cases, results in an excessive loading of the soil with nitrogen, phosphorus, potassium, humus, and other substances. Such excessive and often uncontrolled fertilization of the soil has numerous undesirable consequences: an unplanned increase in other nutrients, problems with their solubility and availability to plants, soil salinization, contamination of the soil with toxic substances, reduced yields and product quality, eutrophication of waters, and even harmful effects on human health. Therefore, the only way to plan an accurate fertilization strategy is through regular agrichemical soil analysis. This approach is the best indicator of soil fertility and directly indicates the need for an additional, scientifically based nutrient input in order to achieve high-quality yields and protect the environment.***

Keywords: greenhouses, natural and artificial fertilizers, uncontrolled fertilization, effects

1. Introduction

In recent decades, the cultivation of horticultural crops in greenhouses has been on a significant rise [1], due to numerous advantages that result in a higher and better-quality yield [2]. Historically, the initial idea for greenhouse production was the result of the need to grow heat-requiring species during the winter, as greenhouses (as permanently enclosed spaces) provide higher temperatures, protection from wind, and natural rainfall.

At the same time, compared to open-field plant production, greenhouse technology allows for the cultivation of a wide variety of species. Although the choice of crops depends primarily on the final economic outcome, horticultural crops are most often cultivated: tomato (Solanum lycopersicum), pepper (Capsicum annuum), cucumber (Cucumis sativus), onion (Allium cepa), garlic (Allium sativum), carrot (Daucus carota), eggplant (Solanum melongena), and others, species that generally grow during the warm period of the year. However, due to the need to maintain profitable production, it is common practice in these production units to add large quantities of natural or artificial fertilizers, which often overload the soil with an increased accumulation of nutrients [1].

2. Results with Discussion

Soil Quality in Greenhouses and the Need for Its Fertilization

In greenhouses, managing soil fertility is of primary importance for achieving optimal plant production and its long-term sustainability, which largely depends on the complex interactions among the soil's biological, chemical, and physical properties. Many of these soil properties naturally change relatively slowly, but under greenhouse conditions (especially in greenhouses established in warm regions), the changes occur rapidly as a result of the high temperatures and high inputs of water and fertilizers. Regardless of whether the plants are grown directly in the greenhouse soil or in pots or containers, it must have characteristics adequate for the development of horticultural crops. Unfortunately, in many countries around the world, greenhouse growers add natural or artificial fertilizers by "rule of thumb," a practice that in many cases results in an excessive buildup of nitrogen, phosphorus, and potassium in the soil. Therefore, to find an optimal solution for the nutrition of the crops being grown, it is necessary to understand which processes in the plants are sensitive to nutrient concentrations and how these affect the development, yield, and quality of the plant production.

The decision on whether to fertilize the soil must be based on the answers to the following questions:

- Is the soil, with its available nutrients, suitable for the plants growing on it?
- What are the critical values of the essential plant nutrients?
- How effective would the application of natural or synthetic fertilizer be, and consequently how much should be applied?

The only way to accurately plan a soil fertilization strategy is to conduct an agrichemical soil analysis right at the start of crop planting. Such an analysis is the best indicator of soil fertility, i.e., its current capacity and the level of available nutrients. It directly indicates the need for the scientific-based application of natural or synthetic fertilizers in order to achieve high-quality yields and protect the environment [3]. In the Republic of Macedonia, this is regulated by the Regulation on Rules and Procedures for Organic Production of Plants, according to which, before each use of fertilizers, and then every three years thereafter, an agrichemical soil analysis is required to determine the content of available quantities of N, P, K, organic matter content, and the pH and EC values. Then, based on the findings and the fertilization recommendation from the laboratory where the agrichemical analysis was performed, a decision is made on the use of soil fertility maintenance or improvement measures [11]. Only in this way can nutrient deficiency or excess in the soil be avoided, and the correct fertilization rate for each crop can be determined [1]. Necessary elements for plant growth and development and their availability in greenhouse soils. Since plants autonomously synthesize all the organic compounds needed for their development, they require only certain inorganic substances. A total of 16 inorganic elements is essential for plant growth and development, and they are shown in Table 1.

Table 1: Essential nutrients and the form in which they are taken up by plants (Soil fertility and plant nutrition-GAP)
Macronutrient Chemical form Micronutrient Chemical form

Macronutrient	Chemical form	Micronutrient	Chemical form
Carbon (C)	Co2	Iron (Fe)	Fe2+
Oxygen (O)	H2O	Manganese (Mn)	Mn2+
Hydrogen (H)	H2O	Zinc (Zn)	Zn2+
Nitrogen (N)	NO3-, $NH4^{+}$	Copper (Cu)	Cu2+
Phosphorus (P)	$H2PO4^{-}$, $HPO4^{2}$	Boron (B)	H3BO3
Sulfur (S)	$SO4^{2-}$	Molybdenum (Mo)	$MoO4^{2-}$
Potassium (K)	K+	Chlorine (Cl)	Cl-
Calcium (Ca)	Ca2+		
Magnesium (Mg)	Mg2+		

Like all soils, the soils in greenhouses contain natural reserves of these micronutrients and macronutrients, but only a small portion of them is readily available to the crops. These are mainly the nutrients in the soil solution (nitrates, magnesium, potassium, and sulfates), but their concentration is often low and insufficient for greenhouse crops that have high nutritional requirements [1]. Therefore, "super" intensive greenhouse production regularly necessitates the application of fertilizers by the growers themselves [4]. However, the added natural or artificial fertilizer represents an external input of nutrients and can have a dual effect: a positive one (maintaining and increasing the soil's production capacity), but also a negative one (contamination of the soil with toxic substances).

Potentially good indicators of the total nutrient content in greenhouse soil are the amounts of nitrogen, phosphorus, calcium, magnesium, and potassium.

Unlike open areas, in greenhouses the lack of rainfall disrupts the natural nitrogen cycle, so atmospheric deposition of nitrogen is almost negligible as a source for its input into the soil. Therefore, the most important source of nitrogen in the soil is organic matter, to which more than 90% of the soil nitrogen is bound. Although crop residues are also a source of nitrogen, they are rarely left in greenhouses to avoid the risk of disease, so in these ecosystems, only the remains of plant roots contribute to replenishing soil nitrogen. This is especially true for the roots of leguminous plants. Therefore, manure is a very important source of soil nitrogen, which is why most greenhouse owners regularly add it to the soil. The amount of nitrogen it provides varies depending on the type of livestock (age, diet), rearing conditions, the rate, and the method of application. For example, cattle manure can contain 5-18 kg of N per ton, nearly half of which is very quickly converted into nitrogen forms that are readily available to plants. Furthermore, due to the higher temperatures in greenhouses, these transformations occur much faster compared to open-air fields, which is another reason for its frequent use [1].

Phosphorus is an essential element for energy metabolism, particularly for the processes of photosynthesis, respiration, and nucleic acid biosynthesis in the plant. Because it is easily mobile in plants, its deficiencies immediately affect the appearance and structure of the leaf. The soil contains numerous organic and inorganic phosphorus compounds, with the inorganic forms accounting for 50–75% of the total phosphorus and being associated with aluminum and calcium compounds [1]. Phosphorus requirements for plants during the rapid growth phase range from 0.3-0.5 kg/ha per day [9], while in greenhouses, the requirements are even greater due to the intensive plant growth. Although phosphorus is abundant in cultivated soils (around 1100 kg/ha), most greenhouse owners add phosphorus-rich preparations or manure several times a year, which raises its concentrations in the soil to maximum levels [1].

Potassium plays numerous regulatory roles in plant growth and development (lignin and cellulose synthesis, regulation of photosynthesis, formation of cellular structures, and as a cofactor in the activation of more than 50 enzyme systems). Therefore, plants have high nutritional requirements for it, so it is often added to the soil and supplied from external sources. Because it is easily mobile within plants, its deficiency immediately affects leaf appearance (leaf necrosis) and the flavor of the produce.

Consequences of Uncontrolled Soil Fertilization

There are numerous examples confirming the overuse of natural and artificial fertilizers to improve soil characteristics. For example, in a study on the use of fertilizers and their impact on the soil in China, it was found that the application of nitrogen and phosphate fertilizers was as much as 5 times higher than the actual needs of the crops, and over 35% of greenhouses applied >1000 kg N/ha [8].

Data in the literature indicate that in greenhouses, the concentrations of nitrogen, phosphorus, potassium, and the amount of humus increase in parallel with the number of years of crop cultivation, and their peak is observed after 5-10 years [7]. This is certainly due to their continuous "external" input, without monitoring their consumption by the plants.

Excessive and uncontrolled fertilization of the soil has numerous negative consequences. Thus, the use of combined artificial fertilizers can help supply the soil with one nutrient, but it can also result in an unwanted increase of other nutrients. At the same time, the excessive use of natural and synthetic fertilizers leads to soil salinization, which is particularly harmful to young plants, causing the root system to dry out and reducing its ability to absorb water [5].

The frequent practice of adding large quantities of nitrogen fertilizers increases nitrate concentrations in plant parts used in the human diet, as well as their levels in groundwater to amounts harmful to human health. Therefore, determining the correct nitrogen application in greenhouses is one of the biggest challenges for the owners of these production units. For example, a correct application of nitrogen would include applying 20-40 kg N/ha at the time of planting, followed by several more applications during the growing period [1]. Furthermore, to protect groundwater from nitrates originating

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from agricultural sources, the use of manure must not exceed 170 kg N/ha annually [11].

Artificial fertilizers rich in phosphorus, nitrogen, and potassium are a significant source of heavy metals that pollute the soil. Tests have shown that phosphate fertilizers in particular contain high amounts of As, Cd, Cu, Cr, Ni, V, and Zn, with Cd levels especially several times higher than the maximum permitted [6].

Although phosphorus does not directly affect human health, it reduces crop yields and product quality. Furthermore, its excessive concentration can cause problems with the solubility of other nutrients and their unavailability to plants. Part of the phosphorus applied through synthetic, or manure fertilizer is utilized by plants in the same year it is applied, but a significant portion accumulates in the soil as residual phosphorus, which can be used many years later. On the other hand, excessive phosphorus concentrations in the soil are a direct threat to water eutrophication, which in turn leads to the emergence of another environmental problem [9].

High potassium concentrations, according to studies, improve the taste of tomatoes, but also increase their β-carotene and lycopene content. However, its high concentration often leads to antagonistic restrictions on the uptake of calcium and magnesium [5].

High concentrations of humus in the soil affect the behavior of trace elements, particularly in terms of strong fixation of Cu, which predisposes toxic effects in livestock feed [10].

These are just a few of the numerous harmful consequences of uncontrolled nutrient inputs into the soil by humans. Today, numerous studies have clearly established the limits of the minimum and maximum required concentrations for most plant crops, with the best strategy being to maintain their presence in the soil at levels slightly above the critically sufficient values. Accordingly, to prevent the negative effects of excessive and uncontrolled fertilization of soils, balanced fertilization schemes are necessary. They must be based on an understanding of the plants' nutritional needs in correlation with soil nutrient reserves, which are determined solely through regular agrichemical soil analysis.

3.Conclusion

The cultivation of horticultural crops under greenhouses is a trend that is increasingly growing worldwide due to the numerous advantages it offers (organic production, intensive production of a variety of horticultural crops, economic benefit, etc.) This intensive production necessitates an additional input of nutrients by the growers themselves.

Greenhouse crop growers often add natural or artificial fertilizers by “rule of thumb,” which in many cases results in an excessive load of nitrogen, phosphorus, and potassium in the soil. Such excessive and uncontrolled fertilization of the soil has numerous negative consequences (undesirable increase in nutrient concentrations, soil salinization, drying of plant root systems, reduced root water uptake, eutrophication of water bodies with agricultural nutrients, and a risk to human health)

To prevent the negative effects of excessive and uncontrolled fertilization of soils, balanced fertilization schemes are necessary, which must be based on knowledge of the plants' nutritional needs in correlation with soil nutrient reserves.

The best indicator of soil fertility and the need for additional input of natural or artificial nutrients is an agrichemical soil analysis, which, on a scientific basis, would achieve high-quality yields and protect the environment.

References

[1] W. Baudoin, R. Nono-Womdim, N. Lutaladio, A. Hodder. 2013. Good Agricultural Practices for greenhouse vegetable crops. Food and Agriculture Organization of the United Nations Plant Production and Protection Division

[2] Agency for the Promotion of Agricultural Development http://agencija.gov.mk/%D0%BF%D0%BB%D0%B0%D1%81%D1%82%D0%B5%D0%BD%D0%B8%D1%86%D0%B8/

[3] Trajkova F., Zlatkovski V. (2017). Guide to Taking Soil Samples from Agricultural Lands. University “Goce Delchev” – Štip, Faculty of Agriculture.

[4] Agrotalternativa. Soil fertility control as a basis for the rational application of mineral fertilizers http://agroalternativa.info/kontrola-na-plodnosta-na-pochvata-osnova-za-ratsionalno-aplitsirane-na-mineralni-gubriva/

[5] Hochmuth, G. J (2018). Fertilizer Management for Greenhouse Vegetables. Florida Greenhouse Vegetable Production Handbook, Vol 3. IFAS Extension. University of Florida

[6] Molina,M., Aburto, F., Caldero,R., Cazanga,M & Escudey,M. (2009). Trace Element Composition of Selected Fertilizers Used in Chile: Phosphorus Fertilizers as a Source of Long-Term Soil Contamination. Soil and Sediment Contamination, 18:497–511, 2009

[7] Jing Li, Yan Xu, Hongguang Liu. (2019). Variations of soil quality from continuously planting greenhouses in North China. Int J Agric & Biol Eng Open Access at https://www.ijabe.org Vol. 12 No.1

[8] Qing Chen, Xiaosheng Zhang, Hongyan Zhang, Peter Christie, Xiaolin Li, Dieter Horlacher and Hans-Peter Liebig. (2004). Evaluation of current fertilizer practice and soil fertility in vegetable production in the Beijing region. Nutrient Cycling in Agroecosystems 69: 51–58, 2004.

[9] J.K. Syers, J.K., Johnston.A.E. & Curtin,D. (2008). Efficiency of soil and fertilizer phosphorus use Reconciling changing concepts of soil phosphorus behaviour with agronomic information. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. Rome

[10] Kabata-Pendias,A. (2001) Trace elements in soils and plants. Third edition. Boca Raton London New York Washington, D.C.

[11] Official Gazette of the Republic of Macedonia No. 27 (2014) Regulation on Rules and Procedures for Plant Organic Production.