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A Review of Foliar Fertilization of Some Vegetables Crops

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Author's contribution

Author DH wrote the first draft of the manuscript. Author DH collected the literature searches Author read and approved the final manuscript.

Review Article

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ABSTRACT

The main aim of this review is to provide an overview of the foliar fertilization studies in Bulgaria, comparing them with current research trends and to indicate future benefits of foliar nutrient spray investigations and their importance for agronomic science and practice. The application of foliar sprays is an important crop management strategy, which may help maximizing crop yield and quality. Foliar fertilization is used as a means of supplying supplemental doses of macro- and micro-nutrients, plant hormones, stimulants, and other beneficial substances. Observed effects of foliar fertilization have included yield increases, resistance to diseases and insect pests, improved drought tolerance, and enhanced crop quality. Plant response is dependent on species, fertilizer form, concentration, and frequency of application, as well as the stage of plant growth. Foliar applications are often timed to meet the demand of nutrients at specific vegetative or fruiting stages of growth, and the fertilizer formula is adjusted accordingly. Applications may also be used to aid plants recovering from transplant shock, hail damage, and other damaging environmental conditions. It is proposed that this treatment should be recommended in integrated plant production, because it is more environmentally friendly and may increase productivity and quality of crops. In the present paper, a brief review of the research on foliar fertilization, the advantages of this fertilization method and applied foliar fertilization of vegetables studies in Bulgaria are discussed. It is concluded that foliar fertilization has a definite place in vegetable crop production and that foliar nutrient sprays will be widely used in the future.

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1. INTRODUCTION

During the last years there is a steady trend to reduce the use of mineral fertilizers, specially soil applied nutrients such as - nitrogen (N), phosphorus (P) and potassium (K) [1]. Their use has decreased by 7 times [1]. These facts create preconditions to increase the importance of foliar fertilization as an alternative to meet plant nutrient demand during the growing season. Interest on foliar fertilization has risen as a result of the many advantages of the methods of application of foliar nutrients, such as rapid and effective response to plant needs, regardless of soil conditions [1]. Additional foliar application during the growth and development of crops can improve their nutrient balance, which may in turn lead to an increase in yield and quality [2].

According [3], interest in foliar sprays increased because of the production of high concentration soluble fertilizers and the development of machinery for spraying fungicides, herbicides, and insecticides and overhead irrigation further facilitate the application of nutrients to crops in the form of sprays. Advances in agriculture include reducing crop production costs, maintaining soil quality, use of nutrients in adequate amounts and its methods of application associated with these objectives [4]. [4] noted that foliar sprays cannot substitute soil fertilization, but that they can be used as supplement of soil applications in sustainable crop production.

In a recent review, [5] state that foliar fertilization is an agricultural practice of increasing importance in practical terms. In theory, application of nutrient sprays may indeed be an environmentally friendly fertilization method since the nutrients are directly delivered to the plant in limited amounts, thereby helping to reduce the environmental impact associated with soil fertilization. However, response to foliar sprays is often variable and not reproducible due to the existing lack of knowledge of many factors related to the penetration of the leaf-applied solution [5].

The main aim of this review is to analyze the state of the foliar fertilization studies in Bulgaria, comparing them with the latest research trends and to indicate future benefits of investigations and their importance for agronomic science and practice.

2. A SHORT HISTORICAL REVIEW OF RESEARCH ON FOLIAR FERTILIZATION

A historical overview of the development of foliar uptake basic and applied research studies was provided by [5]. The first written evidence of the ability of leaves to absorb water from the environment is from the second half of the XVII century. The absorption of nutrient elements from water solutions applicated on the leaves and their physiological effect of the plant for the first time was the subject of researches in XIX century yet. The first reports for foliar feeding are in France during 1844 year. After these first publications, numerous other studies give reason of the success of foliar fertilization. At the same time has been described the structure of the leaves. Attention has been paid to the cuticle and its properties. It has been investigated leaf gas exchange, transpiration, nutrition assimilation, leaf anatomy and physiology [5]. In the XX century, studies related to the principles and mechanisms of foliar application continued. They were aimed at clarifying the movement of water and dissolved substances in its leaves and the whole plant, using techniques with specific dyes. The role of

stomata in the process of absorbing solutions was analyzed further. The effect of adding surfactants to aqueous solutions was evaluated. The using of radioactive isotopes enabled and the development of experiments to assess the translocation of mineral nutrients in plants. New scientific information about the chemical composition and structure of the cuticle and the attention of environmental factors were also obtained [5]. Trials to identify the effects on microorganisms, leaf growth and synthesis of wax coating are conducted. Current research is focussed on the physiological and agronomic aspects of the use of fertilizers for foliar application [5].

According to [6], and [7], combined soil and foliar applications should be recommended to increase both plant productivity and yield quality.

[8,9] and [10] pointed out that foliar application of fertilizers is becoming more prevalent as practice in agricultural crop production, because it is more purposefully, and potentially more friendly to the environment in contrast to soil fertilization.

As noted by [11] knowledge on nutrient absorption mechanisms by above-ground plant parts is crucial to optimize foliar fertilization. Other main factors influencing relevant for successful foliar application are environmental conditions, properties and quality of the solutions as well as some biological characteristics related to specific botanical species and varieties, structure, size, morphology of leaves, nutrient balance of plants and phase of development [5,11].

3. ADVANTAGES OF FOLIAR APPLICATION OF FERTILIZERS

Foliar fertilization has several main advantages. It can be applied throughout the growing season, which enables to spray with small quantity and composition of the nutrient solution, appropriate to the specific requirements in different phases of the crop development [1,4,5, 8,9,10,12].

Foliar applications may sometimes facilitate to the rapid absorption of mineral elements, avoiding the occurrence of soil interactions that may limit root uptake due to e.g., nutrient immobilization in the soil. Additionally, foliar fertilization may stimulate the capability of the root system to absorb nutrients from the soil solution [1,4,5,8,9,10,12].

Nutrient uptake via the foliage may be much faster as compared to soil nutrition [1,4,5,10,13,14].
Foliar nutrient applications can very quickly correct physiological disorders caused by nutrient deficiencies, as well as help to overcome various stress conditions [1,10,12,15,16]. [5] noted that one of the traditional applications of foliar application is to correct nutritional deficiencies in plants.

According to [4] foliar fertilization could be included like a part of the technology for growing different kinds of vegetable crops.

Fertilizers successfully mixed with most commercial pesticides may often improve the performance of foliar fertilizers, and enhance the effectiveness of the pesticides hence reducing plant protection costs [10,16,17]. In this regard are investigations of [18,19], which explored the possibilities a foliar application as tool for integrated pest management for the production of vegetables.

In most cases foliar fertilizers are 100% water soluble. They do not contain impurities that could damage plants, and lead to the accumulation of toxic residues in the productions [1,10]. [3,4,20] indicate the great potential of foliar fertilization as a means of reducing soil and ground water pollution.

[21] shows the positive economic effect of foliar fertilization in growing vegetables, having a direct impact on increasing yield. The economic viability of foliar application is also demonstrated [22] and [23]. Despite all the advantages of foliar application of fertilizers, some authors such as [3] and [4] draw attention into the possibility of causing leaf injury and plant damage after foliar spraying.

[24] pointed out that many new applications of foliar fertilizers have been recommended and implemented in agriculture and horticulture. This development encouraged the progressive production of foliar fertilizers in many countries for local use as well as for export. There is a real chaos in the market. For example in Egypt, during the period of five years (1990 – 1995), 554 numbers of new fertilizers were registered. Out of them, 285 are indicated as foliar fertilizers and over 200 soluble fertilizers for drip irrigation, which are partially used as foliar fertilizers. Quality control of foliar fertilizers is a much more difficult issue than with soil used fertilizers. The efficiency of foliar fertilizers is depending on much many more different variables than soil fertilizers, thus making quality criteria much more complex to approach.

According [24] most countries do not have special regulations in their legislation specifically related to foliar fertilizers and thus, there are no special quality criteria for this kind of fertilizers. It could be highly recommendable to study the situation and legislation in some countries and to make specific suggestions about the quality criteria, which should be considered for the registration of foliar fertilizers in different regions and that should be made clear to the customers.

[25] considered foliar fertilization as an integral part of the whole system for feeding plants They point out, that foliar application is not an alternative to soil fertilization, but that it may be useful to supply part of the necessary nutrients and stimulate nutrient absorption by the root system. In this regard, [25] claim that foliar application may change the concentration of some metabolites in the root zone, and consequently help to improve the solubility of mineral elements in the soil.

These conclusions are in agreement with the results of [3], who showed the large effect of foliar application of relatively small amounts of macro-and micro-nutrients on plant productivity, due to the increased physiological activity of the roots.

4. FOLIAR FERTILIZATION ON SOME VEGETABLES: CASE OF BULGARIA

In Bulgaria, at the beginning of the 1970's liquid fertilizers of the Wuxsal series (8%N, 8%P_2O_5, 6%K_2O, 0,004%Cu EDTA, 0,02%Fe EDTA, 0,012%Mn EDTA, 0,01%Mo EDTA and0,004% Zn EDTA; Aglukon Ltd., Germany) were used. Their application was limited to field production of tomatoes and peppers, and of green-house production of tomatoes and cucumbers [26]. The good results motivated the development and production of liquid fertilizers of the Bulgarian series Fixal (9%N, 9%P_2O_5, 7%K_2O and micro element 0,004%Cu EDTA, 0,02%Fe EDTA, 0,012%Mn EDTA, 0,01%Mo EDTA and0,004% Zn EDTA; Sipro Treiding Ltd., Bulgaria) and Laktofol (21%N, 5%P_2O_5, 10%K_2O,0,020%B, 0,014%Cu, 0,250%Fe, 0,002%Mn, 0,002%Mo and 0,018% Zn; Ekofol AD., Bulgaria) and their recommendation and use in agricultural production [27].

[25] summarized the results of twenty years of research on foliar fertilizers in Bulgaria. The foliar fertilizer Laktofol (21%N, 5%P_2O_5, 10%K_2O,0,020%B, 0,014%Cu, 0,250%Fe, 0,002%Mn, 0,002%Mo and 0,018% Zn; Ekofol AD., Bulgaria) proved effective in terms of helping to increase growers economic returns, reducing soil contamination and contributing to lowering of soil applied fertilizer concentrations hence contributing to the rational use of fertilizers.

At the same time, the use of foliar fertilizers reduced chemical contamination of soil due to agricultural production. Growing some vegetables, it is found that the use of Laktofol (21%N, 5%P_2O_5, 10%K_2O, 0,020%B, 0,014%Cu, 0,250%Fe, 0,002%Mn, 0,002%Mo and 0,018% Zn; Ekofol AD., Bulgaria) reduced soil fertilization rates. There is less information available on the effect of the foliar fertilizers Fitona (7.20%N. 5.20%K_2O,1.5%Ca 0.9%Mg. 0.1%Fe. 0.1%B, Cu, Zn, Mn, Mo. Fitotech Ltd., Bulgaria) and Hortigrow (20%N 20%P_2O_5 20%K_2O, 0.06%Fe, 0.02%Zn, 0.01%Mn, 0.01%Cu, 0.02%B, 0.001%Mo and 1% amino acids, Hortiland Ltd,. Nederland). They are mineral products containing pure, highly concentrated nutrients with added amino acids and phyto-hormones. [28] study the influence of Fitona (7.20%N. 5.20%K_2O,1.5%Ca 0.9%Mg. 0.1%Fe. 0.1%B, Cu, Zn, Mn, Mo. Fitotech Ltd., Bulgaria) and Hortigrow (20%N 20%P_2O_5 20%K_2O, 0.06%Fe, 0.02%Zn, 0.01%Mn, 0.01%Cu, 0.02%B, 0.001%Mo and 1% amino acids, Hortiland Ltd,. Nederland) on biological behaviors of eggplant. The author demonstrates that combined soil and foliar applications affect vegetative habits, productivity and physiological status of the treated plants. These results give proof of the use of foliar application of eggplant as an environmentally friendly crop fertilization strategy leading to positive economic and environmental effects.

The foliar fertilizer Hortigrow (20%N 20%P_2O_5 20%K_2O, 0.06%Fe,0.02%Zn,0.01%Mn, 0.01%Cu,,0.02%B,0.001%Mo and 1% amino acids, Hortiland Ltd,. Nederland) has been studied in pepper with is another economically important vegetable crop in Bulgaria. [29] tested different doses of foliar fertilizer on vegetative development and productivity of pepper. He found that its use increased plant productivity and improved product quality. The positive effects achieved are due to the balanced development of vegetative growth in plants. With increasing dose of Hortigrow, the effect on vegetative growth decreased, but remained higher than in untreated control plants.

[30] studied the effect of Hortigrow (20%N 20%P_2O_5 20%K_2O, 0.06%Fe,0.02%Zn,0.01%Mn, 0.01%Cu,,0.02%B,0.001%Mo and 1% amino acids, Hortiland Ltd,. Nederlands) on some physiological parameters in pepper. Their results showed that spraying plants with Hortigrow induced significant changes in leaf gas exchange, the content of plastid pigments and intensity of photosynthesis.

The aim of the experimental work carried out by [31] was to analyze the influence of foliar fertilization with Laktofol (21%N, 5%P_2O_5, 10%K_2O,0,020%B, 0,014%Cu, 0,250%Fe, 0,002%Mn, 0,002%Mo and 0,018% Zn; Ekofol AD., Bulgaria), Hortigrow (20%N 20%P_2O_5 20%K_2O, 0.06%Fe, 0.02%Zn, 0.01%Mn, 0.01%Cu, 0.02%B, 0.001%Mo and 1% amino acids, Hortiland Ltd,. Netherlands), Agroleaf (20%N, 20%P_2O_5 20%K_2O, 0,14%FeDTPA, 0.07%Zn EDTA, 0.07%Mn EDTA, 0.07%Cu EDTA, 0.03%B, 0.001%Mo, Scotts Company, Netherland) on the feeding, growth and productivity of radish, and also searching for opportunities to optimize nutrient supply. Their use as part of the agricultural production activities in the cultivation of radish may increase the yield and quality of horticultural commodities.

[32] investigated the effectiveness of foliar Laktofol "O"(21%N, 5%P_2O_5, 10%K_2O, 0,020%B, 0,014%Cu, 0,250%Fe, 0,002%Mn, 0,002%Mo and 0,018% Zn; Ekofol AD., Bulgaria) in zucchini squash variety Biserka (*Cucurbita pepo* L, *var, giromontia*). The Researcher found that the levels of mineral fertilization: 0, 8, 12, 16 kg N, P_2O_5 and K_2O, in a 1:1:1 ratio with foliar fertilizer suspension Laktofol "O" (21%N, 5%P_2O_5, 10%K_2O, 0,020%B, 0,014%Cu, 0,250%Fe, 0,002%Mn, 0,002%Mo and 0,018% Zn; Ekofol AD., Bulgaria) additionally increased yield from 32,0 to 65,6 kg.ha^{1}. The highest additional increase in yield (14.2%) with the lowest rate of NPK was determined. When decreasing ratio of NPK with 25% and 50%, crop yield and vegetative mass decreased. However, in foliar fertilization, differences between yields of plants fertilized with $N_{16}P_{16}K_{16}$ and those with reduced rates NPK are statistically unproven.

From 1996 to1997, [33] investigated the influence of foliar fertilizer Laktofol "Fe" (17%N, 8.5%K_2O, 2,8%MgO. 0,020%B, 0,010%Cu, 1,3%Fe, 0,010%Mn, 0,001%Mo and 0,007% Zn; Ekofol AD., Bulgaria) under field conditions on the variety Biserka (*Cucurbita pepo* L, *var, giromontia*) and fertilization with 0, 8 and 16 kg N, P_2O_5 and K_2O in the ratio 1:1:1 with and without foliar application The results indicate that the highest yield is obtained by fertilization with $N_{16}P_{16}K_{16}$ + Foliar feeding - 7,059 kg.da^{-1} or 41.3% more than in control – non fertilized. The effect of foliar application was significantly higher for 50% reduction in standards of NPK. Interesting from an economic point of view is the option that is conducted only foliar application. Individual application of the foliar fertilizer also increases the yield. The good results are probably due to the fact that when spraying Laktofol, zucchini plants grew better and provided more assimilates to the growing fruits.

The results of [34] led them to conclude that foliar feeding with Laktofol "O"(21%N, 5%P_2O_5, 10%K_2O,0,020%B, 0,014%Cu, 0,250%Fe, 0,002%Mn, 0,002%Mo and 0,018% Zn; Ekofol AD., Bulgaria) and Laktofol "Fe" (17%N, 8.5%K_2O,2,8%MgO. 0,020%B, 0,010%Cu, 1,3%Fe, 0,010%Mn, 0,001%Mo and 0,007% Zn; Ekofol AD., Bulgaria) help to reduce the rate of soil fertilization. This reduction may be in the range of 20-25%. Thereby, foliar fertilization proves useful to reduce chemical contamination of soil and for improving yields and increasing economic returns associated with the rational use of fertilizers.

Along with complex water-soluble mineral fertilizers, the use of organic fertilizers with high content of humic and fulvo acids are gaining scientific importance. There is an increasing interest for many Bulgarian and foreign authors to investigate the response of plants when treated with fertilizers containing potassium humate [35,36,37]. All authors indicated that treatment with fertilizers containing humic acids leads to growth promotion accelerates the development of plants, increased yield and enhanced quality of crops.

In Bulgaria, in the last years there is a significant tendency towards assessing the performance of products based on humic acids, especially potassium humate. Many researchers conducted experiments to establish the impact of humic fertilizers on biological behaviors of many crops. In the vegetable species of particular interest is foliar fertilizer Humustim (3%N 1.14%P_2O_5 7.83%K_2O 3.92%Ca, 1.1%Mg, Cu, Zn, Mo, Co, B, S. Agrospeis Ltd., Bulgaria), which influence on the growth and productivity is studied in plants - Brussels sprouts and garden beans [36], on the onions [38]; on the tomatoes [39], on the lettuce [40]. [41] reported that the yield of zucchini squash variety Izobilna after treatment with Humustim (3%N, 1.14%P_2O_5, 7.83%K_2O, 3.92%Ca, 1.1%Mg, Cu, Zn, Mo, Co, B, S. Agrospeis Ltd., Bulgaria), increased by 16-29.78% compared to control plants, and mass of fruit in 6.6-7.4%. Our studies show that the use of the complex organic fertilizer containing humic acids Humustim (3%N 1.14%P_2O_5 7.83%K_2O 3.92%Ca, 1.1%Mg, Cu, Zn, Mo, Co, B, S, Agrospeis

Ltd., Bulgaria), stimulated the vegetative growth, increased the total yield of zucchini and improved fruit quality [42,43,44].

This review outlines the growing interest in foliar fertilization as a method for stimulating the biological potential of vegetables crops. Apart from analyzing the fundamental mechanisms of absorption of nutrients through the leaves and determining the advantages and disadvantages of foliar fertilization, research efforts are directed to solving specific problems in individual vegetables to be able to provide scientifically-based recommendations to vegetable growers.

The current interest in foliar fertilization can be illustrated by several research studies carried out with vegetable crops such as: pepper - [45,46,47,48]; lettuce – [49]; head cabbage – [50]; melons [51]; tomato - [52,53]; green beans - [54, 55]; carrots - [56,57]; Onion – [58]; eggplant – [59]; Peas – [60]; okra – [61] Cucumber – [62].

5. CONCLUSION

In summary, there is a significant trend towards introducing new foliar fertilizer commercial products. In the agro-chemical catalogs and product labels are indicated the recommended rates of application, which are suggested as universal but may not be consistent with the specific characteristics of every particular vegetable and also in relation with the growing season. This information is not sufficient to ensure positive biological and economic effects after the application of foliar nutrient sprays, since potential responses to the treatments such as vegetative growth, overall productivity and yield, cannot be predicted a priori.

To optimize plant responses to foliar nutrient sprays further research on foliar fertilization of vegetable crops should be carried out in the future. Such studies may include foliar fertilization as tool to contribute to a more sustainable and environmentally friendly vegetable production.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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