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Some Current Issues to Be Considered for the Rehabilitation of Citrus Growing

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Abstract

This paper presents a literature review of the subtropical zone of Georgia. Due to its climatic conditions and soil diversity, Adjara is a region of particular importance. Subtropical crops are primarily cultivated on acidic soils, which vary in fertility. Different types of mineral fertilizers are characterized, with particular emphasis on nitrogen fertilizers. The application of increased doses of nitrogen fertilizers significantly increases the weight and size of citrus fruits. A summary of data on the long-term effectiveness of mineral fertilizers indicates that nitrogen fertilizers play the primary role in increasing citrus fruit mass, while phosphorus and potassium have a considerably smaller effect.

The factors determining citrus fruit quality are described, including peel and pulp content, color, and fruit size. Climatic conditions, particularly the hydrothermal coefficient, are also of great importance for fruit storability and transportability and for obtaining high-quality yields. This coefficient is calculated by dividing the sum of active temperatures (above +10°C) during the growing season by the total amount of atmospheric precipitation. This indicator can be used to predict the storability and transportability of citrus fruits grown in specific areas. Based on these indicators, appropriate decisions should be made regarding the transportation and marketing of fruit over short or long distances, using transport vehicles equipped with suitable environmental control systems. The harvested crop should be directed appropriately, either for fresh-market sales or industrial processing. The application of rational industrial processing technologies makes it possible to produce competitive products.

In this regard, our institute alone has developed more than 60 technologies for producing a wide range of nutritious and value-added food products suitable for both small- and large-scale enterprises. We can provide interested entrepreneurs with relevant recommendations and assistance in identifying and utilizing appropriate production equipment and facilities.

Keywords: Citrus, soil, subtropical zone, mandarin, climate, mineral fertilizers.

Introduction

Citrus cultivation has been, and must once again become, one of the leading sectors of Georgia's subtropical agriculture. This is supported by decades of high-level scientific research and organizational and practical work, taking into account the agrobiological characteristics of citrus plants and the environmental conditions of the region.

Within the territory of the former Soviet Union, Georgia was one of the principal citrus-producing regions, accounting for 97.7% of the total citrus orchards and 99% of citrus fruit production. Georgia also accounted for 98% of canned products manufactured from citrus fruits. It should also be noted that the country had planned to produce 700,000 tonnes of citrus fruits by 2000 and 800,000 tonnes by 2010. The primary focus was, of course, on Georgia. These figures indicate that Georgia had, and continues to possess, the potential not only to produce citrus fruits in such quantities but also to process and market them.

Taking into account the principles of a market economy and the current global state of citrus production - which stands at 74 million tonnes, exceeding total demand by 20 million tonnes - it might appear that Georgia cannot withstand the intense competition in this market. However, this would be an incorrect approach to the problem, since proximity to consumer markets gives our country a competitive advantage precisely under market economy conditions. Although leading citrus-producing countries enjoy advantages in terms of the range and quality of industrially processed citrus products, Georgia's advantages in the fresh-fruit market are indisputable, provided that the primary focus is placed on improving the marketable appearance of the fruit produced and bringing it into compliance with international standards.[1]

Although the agronomic and technological practices involved in citrus fruit production have been studied relatively extensively in our country, concerns regarding quality indicators were less pressing within the unified Soviet economic system. The centralized procurement and marketing system purchased and sold the fruit produced at fixed prices without competition. Consequently, producers suffered relatively little financial loss even when the fruit they supplied was of poor quality. This situation was further reinforced by the fact that collective farms and state farms were well supplied with essential production resources, including fertilizers, pesticides, transportation, and scientific and technological advances. The private sector, in turn, was able to benefit from these resources at virtually no cost, and the quality of the fruit produced generally met the requirements of the standards in force at the time.

Today, following the dismantling of this system, farmers have been confronted directly with the economic and political realities created by the transition to a market economy. Radical reforms have therefore become necessary, both in organizational and structural terms and in terms of production technologies. Implementing such reforms is almost impossible without appropriate government support and a strategic approach. The assumption that the market economy will regulate everything on its own is fundamentally flawed. One reason is that, given their biological requirements, citrus plantations cannot wait indefinitely for market mechanisms to begin

[1] Chkhaidze, G. Subtropical Crops. Batumi: Adjara Publishing House, 1996, pp. 6–29.

operating in their favor. As practical experience has shown, recent years have witnessed a clearly discernible and alarming decline in existing citrus plantations, accompanied by a deterioration in product quality. As a result, traditional markets are being lost.

Scientific interest in these problems has also declined considerably within the domestic research community. Now, more than ever, there is an urgent need to conduct comprehensive research into the effects of ecological, climatic (heat, light, water, and air), soil (physical, chemical, and biological properties), and orographic factors (altitude above sea level, terrain, and aspect) on the key characteristics of citrus fruits, particularly their storability and transportability. Accordingly, research has been conducted into the classification of harvested citrus fruits according to their intended use.

The development of a new standard has also become a pressing issue. Priorities include the large-scale application of biological methods for protecting plants against pests and diseases; the preliminary prediction of fruit quality indicators; and the development of technologies for grading, processing, storage, transportation, and marketing that are accessible to groups of farmers as well as individual farmers.

Since the 1990s, the socioeconomic and political processes taking place in the country have fundamentally transformed the previously established unified system of the national economy. Nevertheless, consumer demand for these highly beneficial fruits has remained unchanged. From a global and regional perspective, Georgia continues to be an important producer of subtropical crops. Therefore, abandoning this strategic sector is not an option; rather, its preservation and further development are essential. It is particularly important that Georgia produces citrus fruits of exceptional quality and flavor, while one of the largest consumer markets for these products is located relatively close to the country.

1. Natural Conditions for Citrus Production and Factors Determining Fruit Quality in Georgia's Subtropical Zone

1.1. Climatic Characteristics of Georgia's Subtropical Zone

Georgia's humid subtropical zone, the northernmost such zone in the world, almost entirely meets the soil and climatic requirements of citrus plants. The warm Black Sea basin and the high Caucasus mountain ranges extending along its coast contribute to the region's warm and humid climate. Nevertheless, the region is not immune to the influx of cold air masses in certain years. As a rule, approximately once every ten years, individual districts experience a critical winter characterized by frost and snow cover, causing substantial damage to citrus crops. Such winters occurred in 1921, 1924, 1928, 1950, 1984, and 1985, when air temperatures dropped to –8°C or –9°C in some districts and, in isolated locations, to as low as –12°C. The varied terrain of Georgia's subtropical zone gives rise to differences in climatic conditions. In general, slopes have a warmer

climate than low-lying areas. At the same time, the growing season in lowland areas is shorter than that on slopes.

The principal citrus-producing areas are the coastal districts of Abkhazia and Adjara, as well as certain localities in the Ozurgeti, Zugdidi, Khobi, Senaki, and Lanchkhuti districts.

Adjara, an autonomous republic situated in the most south-western part of Georgia along the Black Sea coast, is the country's most extensive citrus-growing region. Its territory is protected on three sides by high mountains and opens toward the warm Black Sea basin, creating the warm and humid climate characteristic of the region. Adjara is predominantly characterized by complex terrain and an exceptional diversity of natural conditions. The territory of Adjara encompasses a geographical zone where the longest day lasts 15 hours and 16 minutes, while the shortest lasts 9 hours and 7 minutes. Annual sunshine duration in Georgia exceeds 2,000 hours, with Adjara being an exception: in some locations, this figure ranges from 1,800 to 1,900 hours. Total annual solar radiation increases with elevation above sea level, amounting to 120 kcal/cm² in lowland areas and 150–154 kcal/cm² in upland areas.

The principal climatic characteristic of the Adjara region is its high mean annual temperature, which reaches 14–15°C. January is the coldest month. According to data from recent years, the minimum and maximum temperature amplitudes recorded in the Kakhaberi area are 3.8°C and 9.4°C, respectively, while the warmer months are characterized by higher temperatures.[2]

1.2. Soil Conditions and Their Influence on Citrus Nutrition

Adjara is a distinctive region in terms of soil conditions. Its vegetation cover is also characterized by exceptional diversity. According to Professors N. Nijaradze and N. Jibuti, the soil-forming processes occurring in Adjara are zonal in nature; therefore, the main soil types are distributed according to vertical zonation.

In the lowland zone, alluvial soils predominate. These include non-calcareous, calcareous, and acidic alluvial soils found in the basins of the Chorokhi, Korolistskali, Kintrishi, and Choloki rivers. Peaty and marshy soils occur in the Kakhaberi and Choloki lowlands. Moderately waterlogged alluvial soils, sandy soils, and gravelly soils are also found in this zone. Red soils predominate on the slopes.

Thus, the subtropical zone of Georgia, where citrus fruits are cultivated, is characterized by several principal soil types. In upland areas, these include brown forest soils, humus-rich red soils, and yellow soils. In lowland areas, the main types are alluvial, meadow-podzolic, and waterlogged soils. All these soil types differ in fertility and consequently influence the nutritional regime of citrus plants, which, in turn, affects the principal quality indicators of the harvested fruit, particularly its storability.[3]

[2] Gamkrelidze, I. The Fertilization System for Citrus Orchards. Moscow: Kolos Publishing House, 1971, pp. 70–79.

[3] Marshania, I., and Mikeladze, Z. "The Effect of Ammonium Nitrate, Urea, and Ammonium Sulfate on the Growth of Young Washington Navel Orange Plants." Proceedings of the Fourth Conference: Issues in Improving the Effectiveness of Scientific Research and Strengthening Efficiency in Subtropical Agriculture. Sukhumi, 1981, pp. 6–9.

Citrus plants are predominantly cultivated on soils with an acidic reaction. The scientific literature does not present a unanimous view regarding the optimal soil parameters for citrus crops. Local researchers, including Sarishvili, Goletiani, Sokolov, and others, investigated the factors responsible for the optimal acidity levels of soils in Georgia's subtropical zone. They reached a common conclusion that the high acidity of these soils is attributable to elevated concentrations of exchangeable aluminum and iron ions. Kampi and Godziashvili considered a pH of 5.0–5.5 to be optimal for citrus crops. The high acidity of soils in Georgia's subtropical zone is associated with hydrogen ions and climatic influences.

Furthermore, the annual application of physiologically acidic fertilizers further increases soil acidity. It has been established that citrus fruits grown on sandy and light-textured soils have a higher sugar content than those grown on heavy-textured soils. This pattern is observed regardless of the different forms and application rates of mineral fertilizers used.

Based on the results of our research and an examination of the relevant scientific literature, we can confidently conclude that soil conditions rich in plant nutrients may act as a limiting factor affecting the storability and quality of citrus fruits.

1.3. The Effects of Climatic and Agronomic Factors on the Biological Properties and Quality of Citrus Fruits

Climatic conditions, particularly the availability of sunlight, play a fundamental role in plant growth and in the development of fruit quality. Citrus fruits cultivated in hilly and undulating terrain, especially on south-facing slopes, tend to accumulate higher concentrations of anthocyanins, essential oils, and other biologically active substances than those grown on lowland agricultural land or north-facing slopes. These differences contribute to the superior storability and transportability of fruit harvested from more favorable locations.[4][5]

In Adjara's subtropical climate, citrus plants growing at elevations of 5 to 50 meters above sea level begin their growing season on April 17 and April 25, respectively. Increased vegetative activity is also associated with more advanced fruit maturation, a greater abundance of biologically active compounds, and a more pronounced aroma compared with fruits cultivated in tropical regions. In his comparison of the chemical composition of Italian and Georgian mandarins, F. Tserevetianov identified advantages in the Georgian fruit.

These findings, together with other research results, demonstrate the importance of both genetic characteristics and environmental conditions in determining sugar concentrations and the content of other biologically active substances. These factors also substantially influence additional quality parameters, particularly the ability of citrus fruits to withstand storage and transportation.

[4] Mikeladze, Z. "The Influence of Nitrogen Fertilizer Forms and Application Rates on the Frost Resistance of Young Washington Navel Orange Plants." Journal of Subtropical Crops, 1982, No. 1, pp. 80–83.

[5] Bzhalava, J. "The Influence of Nitrogen Fertilizer Forms and Application Rates on the Growth and Yield of Georgian Lemon and Meyer Lemon." Abstract of a dissertation submitted for an academic degree. Sukhumi, 1983, 214 pp.

Agronomic practices for the cultivation and maintenance of citrus plants have been studied extensively by local scientists. However, given the circumstances prevailing at the time, agricultural researchers were often less concerned with the storability of harvested fruit when pursuing maximum yields. This was the position adopted by the authorities, and it was the perspective encouraged among scientists from the 1970s onward. It is particularly noteworthy that, even before this period, when citrus production volumes were relatively modest, considerable attention was devoted to delivering fruit to consumers with minimal losses. Despite limited technical resources, research efforts focused on improving harvesting practices, organizing the collection and handling of fruit, and optimizing transportation and marketing.

Accordingly, agricultural scientists recognized the need to ensure the successful production and distribution of these perishable fruits. Simple storage facilities for citrus fruits were systematically constructed on collective and state farms. In short, the initial approach was forward-looking and well considered. One outcome of this approach was that approximately 40%, and sometimes an even greater proportion, of the citrus fruits produced reached consumers as standard-quality products.[6]

During the 1980s, large-scale operations were undertaken to preserve citrus fruits using sulfitation. Concentrates and various other products were manufactured from stored and non-standard fruits. Of particular importance was the widespread introduction of zero-waste processing technologies, together with the supply of large quantities of sugar to the processing industry at low prices - equivalent to approximately half the price of mandarins.

At the present stage, revitalizing citrus cultivation and establishing it once again as one of the principal branches of subtropical agriculture require a comprehensive transformation of the entire infrastructure, encompassing production and processing, storage and transportation, and marketing. Achieving this objective demands a fundamentally new approach, reflected in the systematic implementation of large-scale, integrated measures across the entire value chain.

1.4. The Influence of Mineral Fertilizers on Citrus Fruit Quality

The scientific literature contains substantial evidence demonstrating that various agricultural practices can improve the storability and other quality characteristics of citrus fruits. These practices include regulating the chemical, physical, and biological processes in the soil through appropriate soil management measures, such as tillage, irrigation, and the removal of excess groundwater. They also include the balanced application of mineral and organic fertilizers, the rational use of entomophagous organisms (natural enemies of insect pests), and other agronomic practices tailored to the agrobiological requirements of citrus plants. As is well known, the principal indicators of citrus fruit quality include fruit size, color, peel-to-pulp ratio, and chemical composition.

[6] Marshania, I. Fertilizers for Citrus Crops. Sukhumi: Alashara Publishing House, 1970, p. 412.

Unfortunately, insufficient attention has been paid to such important characteristics as storability and transportability, which are essentially the result of the combined effects of all other quality parameters. These characteristics are particularly important for individual farming operations, effective marketing, and the successful sale of abundant harvests.

Numerous scientific studies clearly demonstrate that mineral and organic fertilizers influence not only citrus yields **b**ut also the quality characteristics of the harvested fruit. The application of increased fertilizer doses can raise fruit weight and size. Similar findings have been reported by American researchers, who observed that higher nitrogen fertilizer application rates positively affected mandarin fruit size in years with sufficient rainfall. However, during dry years, particularly when drought occurred during flowering and fruit set, increasing fertilizer application rates produced negative results in terms of fruit growth.

According to published research, nitrogen fertilizer application positively affected the average weight of 'Washington Navel' orange fruits. However, further increases in application rates significantly reduced this indicator because the overall yield increased substantially, generally resulting in a greater proportion of smaller fruits.

Among the nitrogen fertilizers studied, ammonium sulfate demonstrated a notable advantage over urea and ammonium nitrate. The researcher attributed this effect to the sulfur content of ammonium sulfate and its physiologically acidic reaction. These characteristics improved the availability of phosphorus, calcium, and other micronutrients to plants. These findings further emphasize the importance of optimizing plant nutrient availability to achieve desirable citrus yields while maintaining high fruit quality.

1.5. Citrus Fruit Quality Indicators and Standards

One of the principal indicators of compliance with citrus fruit quality standards is the average fruit weight and size. Under the existing standards, the minimum acceptable diameters for quality fruit are 50 mm for oranges, 38 mm for mandarins, and 42 mm for lemons, measured across the widest part of the fruit. Despite these requirements, the proportion of non-standard fruit remains relatively high, frequently ranging between 28% and 30%. Moreover, this proportion tends to increase in line with the overall harvest volume. Minimum size requirements should be revised to promote the production of larger fruits. In the case of mandarins, the minimum diameter should be no less than 45 mm. Accordingly, we believe that the existing standards should be revised and their requirements made stricter.

In our view, such changes may initially have a negative impact on citrus farmers. In the longer term, however, they would encourage producers to devote greater attention to growing high-quality fruit and to follow scientific recommendations. This would help improve farmers' economic circumstances and restore Georgian citrus fruits to their former prestige in commercial markets.

Color is another essential quality requirement for citrus fruits. A yellowish-orange color, free from blemishes and physical damage, enhances the fruit's marketable appearance and contributes to a higher selling price. In this respect, the existing standards are also relatively permissive, allowing up to one-third of the fruit surface to remain yellow and permitting blemishes caused by diseases. In practice, however, such fruit is rarely accepted by buyers for commercial sale, and when it is accepted, the prices offered are generally very low.

As evergreen, remontant plants, citrus trees have specific environmental requirements. They require a cumulative sum of active temperatures of approximately 4,200–4,500°C, a threshold that is not reached every year in Georgia. Consequently, the fruits do not always attain full biological maturity. Because of the risk of impending rainfall, growers are often compelled to harvest them at the stage of technical maturity. As a result, the harvested fruits do not develop uniform coloration and differ in their ability to withstand storage and transportation.

Leading citrus-producing countries have addressed this problem successfully. In addition to having sufficient cumulative active temperatures for fruit maturation, they have developed and widely implemented artificial ripening, washing, and coating technologies using wax-based compounds.[7]

1.6. Fruit Coating Technologies: Modern Methods of Post-Harvest Commercial Treatment

In this respect, Georgia remains considerably underdeveloped. Although such technologies have been developed through our many years of research, we lack the necessary technical equipment to implement them. Despite significant progress having been made in this field, the political developments that took place in the country fundamentally transformed the entire system of citrus production, procurement, and marketing. Consequently, the approaches and technologies developed through our research became, in practice, unacceptable or inaccessible under the new circumstances.

At present, there is an urgent need to identify new, systematic approaches and technologies. Our research has focused specifically on addressing this challenge.

Returning to the issues outlined in the introduction, it becomes clear that solutions are available. The key lies in adapting agronomic practices to different production conditions and tailoring post-harvest commercial treatment technologies to the needs and capabilities of individual farming enterprises.

The nutritional regime of citrus plants has a substantial influence on fruit coloration. Among the factors that can be regulated to achieve significant improvements in this regard, the rational application of mineral fertilizers is particularly important. Both Georgian and international researchers have reached this conclusion.

The timely progression of plants through their phenological stages, the development of fruit coloration, the overall yield, and the distribution of fruits along the branches all have a

[7] Kacharava, I. "Fractional Application of High Doses of Nitrogen Fertilizers in Mandarin Plantations." Journal of Subtropical Crops, 1980, No. 3–4, pp. 165–170.

considerable influence on their final color. Appropriate fertilizer management can therefore help address some of the challenges associated with fruit coloration. Naturally, the intended use of the harvested fruit must be determined in advance. Production practices should be selected according to whether the fruit is intended for industrial processing, storage, or marketing over short or long distances. One of the important quality characteristics of citrus fruits is the ratio of peel to pulp.[89]

1.7. The Peel-to-Pulp Ratio in Citrus Fruits

The average weight of a citrus fruit may be high, but an increase in this parameter is beneficial only when it is accompanied by an increase in the proportion of pulp. At the same time, the importance and function of the peel must not be overlooked, particularly with regard to fruit storability. Therefore, achieving an optimal balance between the peel and pulp of mandarin fruits should be given considerable attention.

As early as the 1920s, scientists began investigating this issue. Based on extensive research conducted over many years, they established that the peel accounts for 26.7 - 38.2% of the weight of Unshiu mandarin fruits and 47.9% of lemon fruits. At the same time, nitrogen fertilizers were found to have a negative effect on the percentage of pulp in citrus fruits. However, according to data reported by Z. Gigineishvili and U. Urushadze, the application of nitrogen fertilizers did not produce adverse effects in this respect. California farmers believed that applying mineral nitrogen fertilizers in combination with potassium and lime fertilizers promoted the production of oranges with thinner peels. In contrast, research findings reported by the Australian scientist Bolus indicated the opposite effect.

A well-known American citrus specialist, drawing on farmers' observations, argued that the application of potassium fertilizers promotes the development of thicker and firmer citrus peels, making the fruits more suitable for storage and transportation.

Experimental studies recorded a lower proportion of peel in citrus fruits when organic and mineral fertilizers were applied, both in combination and separately. The researchers concluded that air temperature and soil moisture content play decisive roles in determining the peel-to-pulp ratio. The application of fertilizers was also found to reduce the peel proportion of orange fruits. However, no substantial differences in this parameter were observed between different forms and application rates of nitrogen fertilizers.

A more thorough examination of the scientific literature confirms that the rational implementation of agronomic practices can contribute not only to high and stable yields but also to improved fruit quality, storage suitability, and transportability. In this regard, particular importance should be attached to the proper organization of harvesting techniques, followed by appropriate post-harvest handling, storage, and transportation procedures.

[8] Mikeladze, Z. Agricultural Products—Food and Medicine: Practical Advice and Recommendations. National Academy of Sciences of Georgia, Tbilisi, 2014, pp. 15–30.

[9] Goletiani, G. The Influence of Mineral Fertilizers on Soil Properties and the Productivity of Tea Plants. Tbilisi, 1960, pp. 10–20.

1.8. Optimal Harvesting Times for Citrus Fruits

Optimal harvesting times have been established for different citrus varieties and forms. However, determining these parameters remains a relatively complex task, as fruit ripening is influenced not only by varietal characteristics but also by soil and climatic conditions, agronomic practices - particularly the application of mineral fertilizers - solar radiation, and other factors.

As mentioned above, citrus plants are predominantly cultivated on hills and slopes, where considerable diversity exists in both soil types and climatic conditions. Consequently, fruits of the same maturity level cannot always be obtained simultaneously, even in shaded areas or within the same plot and on the same tree. Naturally, these fruits also differ in their ability to withstand storage. Long-term research conducted by the Scientific Research Institute of Tea and Subtropical Crops has demonstrated that premature harvesting of citrus fruits leads to quantitative losses.[10]

Furthermore, prematurely harvested fruits do not accumulate sufficient quantities of biologically active substances, have an inferior marketable appearance, and, most importantly, exhibit poor storability. Delayed harvesting, although potentially improving certain quality indicators, carries serious risks associated with deteriorating weather conditions. It may also prevent the trees from completing their preparation for winter, leaving them more vulnerable to both mechanical and physiological damage.

Citrus harvesting is a highly responsible and labor-intensive operation. Consequently, established agronomic requirements are frequently not observed. In many cases, no clear plan exists for the subsequent handling and distribution of sorted and harvested produce. Delays in harvesting also create difficulties during transportation and marketing, placing considerable pressure on distributors and commercial operators. These shortcomings have contributed to the unfavorable reputation of Georgian citrus fruits in international markets. Therefore, improving organizational and marketing arrangements between producers and distributors is essential.

An attempt to address this complex and important problem is represented by our research, which uses the hydrothermal coefficient to predict the storability and transportability of citrus fruits in specific geographical zones. The findings are presented in specialized tables and are intended to support decisions regarding the subsequent processing and marketing of citrus fruits through differentiated technological approaches.

Conclusion

The harvested citrus crop should be appropriately allocated either for sale as fresh fruit or for industrial processing. The application of rational processing technologies can facilitate the production of competitive products and improve the utilization of harvested crops.

In this regard, our institute alone has developed more than 60 technologies for producing a wide range of nutritious and value-added food products suitable for both small- and large-scale enterprises. We can provide interested entrepreneurs with relevant recommendations and

[10] Chkhaidze, G. Subtropical Crops. Batumi: Adjara Publishing House, 1996, p. 11.

assistance in identifying, sourcing, and utilizing the necessary production equipment and facilities.

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