Recent Techniques in Nutritional Management of Walnut Plant

Bülent Topcuoğlu

***Abstract*—A number of walnut varieties adapted to different climatic regions in the world are widely produced, and there have been significant differences in the walnut varieties produced from the past to the present. Today, it is seen that the commonly grown Walnut varieties have higher values than the varieties grown in previous years in terms of fruit weight, fruit yield and total nutrient removal per unit area. In walnut cultivation, it has become possible to obtain high quality, standard and abundant Walnuts with advanced irrigation and plant nutrition and plant protection techniques, and advanced production patterns have started to spread rapidly. Today, due to its superior efficiency in plant nutrition, current fertigation and foliar fertilizer applications are more demanded than conventional classical fertilization methods in the nutrition of walnut plants. Assessment of specific nutrition doses for the variety in fertilization management is still among the issues to be determined. The fertilization program recommended according to soil and leaf analysis in integrated plant nutrition applications of walnut plants is considered necessary for an effective nutrition management.**

***Keywords*— Walnut, Nutrient Requirement, Fertilization.**

I. Soil Requirements And Nutrient Consumption Of The Walnut Plant

The walnut plant develops well in deep, sandy loam-textured, well-drained and organic-rich soils. The walnut plant has adapted to soils in a wide pH range (4.3-8.3) and grows ideally at the pH level of 6-7.2. Walnut plant is sensitive to high sodium, chlorine and boron concentrations in terms of specific ion toxicity. It has been reported that the ideal places for Walnut in terms of growth development are cool river sides, slopes and areas with cold air currents in production and areas where excessive rainwater accumulates. The walnut plant has a strong root system that can reach a depth of 2-4 m. In the cultivation of the walnut tree either for wood or for its fruit, the root system of the plant can develop well in soils with a depth of 3-4 m or more.

The nutritional consumption of the walnut plant is in a wide range among the varieties adapted to many different regions in the world. An average of 50-75 kg/tree or 5-7.5 tons/ha of walnut products can be obtained from trees (10-15 years old) of today's high commercial value walnut varieties, which is much higher than the yield values in the past. The average product amount and fruit weights of the varieties that are widely cultivated in the world are compared in Table 1, and the average mineral nutrient content of the fruits of local (Anatolia region, Turkey) walnut varieties are compared in Table 2. According to these data, it is understood that there are differences in the consumption of nutrients between local and current commercial walnut varieties.

TABLE I. AVERAGE PRODUCT AMOUNTS OF DIFFERENT COMMERCIAL WALNUT VARIETIES IN FRUIT HARVEST [1]

Varieties	Average yield (ton/ha)	Average fruit weight, g	Average kernel weight, g
Chandler	5,3	12,4	6,9
Franquette	2,71	12,6	5,9
Fernette	3,37	12,6	6,7
Fernor	3,19	12,7	5,9
Pedro	3,39	12,4	6,5
Adams	2,10	13,5	6,5

TABLE II. AVERAGE MINERAL CONTENT OF DIFFERENT LOCAL WALNUT VARIETIES AT FRUIT HARVEST [2]

	K, %	Ca, %	Mg, %	Fe, ppm	Mn, ppm	Zn, ppm	Cu, ppm
Şebin	0,359	0,2	0,156	37	43	29	16
Bilecik	0,389	0,202	0,165	36	39	30	16
Kaman 1	0,366	0,149	0,126	32	48	35	15

Plant nutrients removed from the soil by the walnut plant with each ton of fruit product are given in Table 3. Although nutrient consumption varies according to varieties, considering only the average nutrient amount lost from the fruit product and the soil, it is understood that the nutrient consumption is more than many other fruit plants taken into culture. However, assessment of specific mineral nutrition doses for a commercial specific variety in fertilization management is still among the issues to be determined.

TABLE III. AT THE END OF THE DEVELOPMENT PERIOD OF THE WALNUT PLANT, THE FRUIT PRODUCT AND THE NUTRIENTS REMOVED FROM THE SOIL [3]

	N	P	K	S	Ca	Mg
Removel nutrients (kg/ton ürün)	26	3,5	4,4	1,3	1,1	1,6
Removel nutrients (kg/ha)	104	14	17,6	5,2	4,4	6,4

II. Nutritional Management Of The Walnut Plant

Achieving efficiency and quality in walnut production depends on sufficient and balanced fertilization to a great extent. In order to obtain high yields from walnut plants, an appropriate fertilization planning should be made by considering the soil conditions, the variety selected and other cultural practices to be applied. Selection of fertilizers, nutritional level, application form and time, etc. considerations

Bülent Topcuoğlu, is with the Akdeniz University Vocational School of Tech. Sciences, 07058, Antalya, TURKEY.

can vary greatly according to the agricultural climatic regions and the varieties taken in culture and other cultural practices.

With the efficient fertilization of the walnut plant:

- Creating a healthy and strong plant structure resistant to diseases and pests,
- Increase in the total amount of product and the amount of quality fruit with high marketing value,
- Storage properties are improved.

The nutrients to meet the nutritional requirement of the walnut plant, which is growht in a wide soil volume with a deep root structure, should be presented to the plant in sufficient and easily available forms in accordance with the plant's phenological stages. In Walnut phenology (Figure 1.), which consists of *dormancy, blooming, fruit development and post-harvest stages*, the amount and proportional intake of plant nutrients differ according to the periods; fertilizer applications are applied according to *dormancy, pre-flowering, after fruit set, fruit development and pre-harvest* periods.

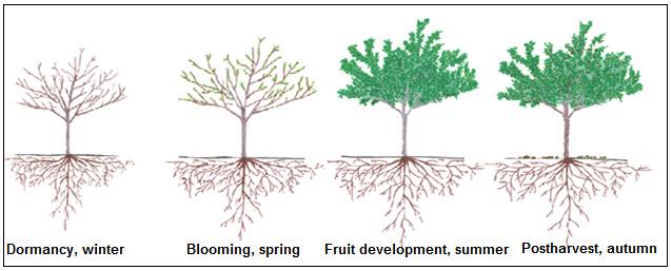

Fig. 1. Phenological periods of walnut plant

In many studies, it has been evaluated that the classical Walnut plant with full fruit yield needs nutrients at the a wide range of 400-800 g N, 250-450g P2O5 and 350-600g K2O/plant depending on the soil conditions and the cultivar. The range values given regarding the nutritional requirement may vary depending on the adapted and high yield varieties used today, the production patterns and the planting measurements in the orchard. Fertilizers containing other nutrients such as Ca, Mg, S and micronutrients required according to soil specific properties and available plant nutrients levels are also applied as required.

III. Fertilization Methods

In the nutrition of the walnut plant, fertilizers and their amounts determined according to soil characteristics, cultural cultivation form and conditions, nutrition form and plant requirement can be applied in various ways.

1) Fertilizers can be applied in certain growth periods with base and top dressing. In base dressing, fertilizers are concentrated at a suitable distance from the stem to reduce possible fixation losses, to the band under the soil, and in top dressing, the fertilizers are divided into phenological periods, spreaded by sprinkling and applied to the surface in the projection of the plant crown.
2) Fertilizers can also be applied by fertigation method. In fertigation applications, nutrients are applied directly to the root area in the form of salts dissolved with irrigation water in the appropriate nutrient amounts for the relevant phenological period and provide an effective feeding.
3) Fertilizers can also be applied by spraying the leaves as a solution. In the application, which is mostly used for micronutrients taken from the soil in less amounts by plants during critical periods, macronutrients can also be applied.

Care should be taken to ensure that the timing of fertilizer applications in walnut cultivation is adapted with the soil and climatic conditions and the phenological stages of the plant. While all of the phosphorus fertilizers are applied during the dormant period of the plants in the usual base/top dressing applications; Nitrogen and potassium fertilizers are divided and applied according to the phenological stages that the plant needs the most of them during the vegetation period. The fertilizer material of other necessary nutrients can be applied as base fertilizer during the dormant period or as top dressing during the vegetation period.

Fertilizers of nitrogen and potassium nutrients with faster mobility are applied at short intervals in accordance with the phenological periods. In fertilization, in light textured soils and in regions where precipitation is intense, frequent applications of nitrogenous fertilizers by dividing are important in terms of minimizing losses in nutrition. Fertilizers containing phosphorus nutrients with relatively limited mobility in the soil are applied once or twice in a year in semi-tropical regions; The frequency of application can be significantly reduced by the use of slow release fertilizer forms if the soil properties are suitable.

Fertigation application is a continuous nutrition process in which each nutrient is applied in different proportions in accordance with the plant development periods within the specified time interval. In the application made with the pressurized irrigation system, it is based on giving the determined amount of fertilizer through the irrigation system. Base fertilization can also be recommended before planting, taking into account the soil properties in terms of supporting the development period in practice. Fertigation can reduce the costs of fertilizer application by eliminating the need for technically high operation. In addition, by applying plant nutrients when the plant needs it, nutrient utilization efficiency is achieved, and luxury nutrient consumption by plants can be reduced by fixation, leakage or gaseous nutrient losses in the soil.

While the roots of plants can easily absorb most mineral nutrients, leaves and other plant tissues can also absorb ionic nutrients. The wide area of the walnut leaves and the many pores on it are especially suitable for the introduction of micronutrients and allow them to be used as a supportive nutrition channel. Foliar application of nutrients ensures fast and effective intake of nutrients and, when timed correctly, can prevent the hidden hunger that occurs in plants and especially severe deficiencies in micronutrients. However, due to the high consumption of primary macronutrients by the plant compared to other nutrients and the low absorption rate, it is not sufficient to meet the macro nutrient requirement of the plant through foliar fertilization in a production period.

Since photosynthesis products begin to move from the plant body to the fruits in large amounts, especially in the fruit formation phase of walnut production, high nutrient availability is important to support the needs of the plant until harvest. Hidden hunger syndrome, which occurs when plant roots cannot provide certain nutrients in these critical stages of growth, can

sometimes occur even in fertile soils. Foliar fertilization may be necessary as any limitation in the nutritional of the walnut plant during the critical periods of development that adversely affects the fruit size and quality.

Foliar fertilizers under the following conditions provide a high level of nutrient availability to target organs, reducing stress conditions and providing important advantages for walnut growers as a supportive application in plant nutrition:

- When there is a lack of nutrients in the soil, when they need plant nutrients whose availability is reduced by fixing in the soil and/or their availability is limited due to ion interaction,
- When nutrient deficiencies are detected in the plant in the advanced stages of plant growth and a rapid correction is required,
- In case root activity is hampered by external pressures such as low soil temperature, insufficient aeration, parasitic organisms or damage by cultivation machinery.

IV. Fertilizer Material

In the selection of the fertilization material, the soil and climate characteristics and the fertilization method to be applied (base / top dressing, fertigation and foliar application), the phenological periods of the plant and the nutritional state during the growing period are determinants. Base fertilizers are used in solid form and relatively slow-acting, while top fertilizers are easily dissolved and used quickly. Soluble forms of solid fertilizers and liquid fertilizer preparations, which are widely used today, are successfully used in fertigation applications. Solid fertilizers with water-soluble macro and micro nutrients and liquid fertilizers with appropriate composition can be used in foliar fertilization.

In the presence of problems restricting the availability of nutrients according to the specific characteristics of the soil (high/low pH, high lime/active lime, high nutrient buffering index, ion toxicity, etc.), success in plant production is achieved by solving existing problems at an acceptable level with soil improvement methods and applying regulatory preparations when necessary in plant nutrition. Today, many foliar fertilizers marketed for commercial purposes are successfully applied, especially in eliminating micronutrient deficiencies. These preparations may contain a single nutrient or contain more than one nutrient. In practice, it is generally recommended to adopt targeted preparations in terms of cost effectiveness and ecological safety.

V. Nutritional Management Based On Soil, Water And Leaf Analysis

Determination of soil and water production tools and climate suitability before the walnut garden facility is the basis for production. The availability of the soil and water resources quality of the production site and the elimination of the identified problems affect the success, sustainability and costs of the production. If the conditions are favorable, fertilizer expenditures have an important place in total costs in plant nutrition practices.

Matters needing attention for effective fertilization:

- It is necessary to determine the unique and dynamic properties of the soil by testing soil, to prepare an appropriate fertilization program by taking into account the inherent and dynamic soil characteristics, the characteristics and genetic yield capacity of the plant to be grown, cultivation techniques, climatic factors and other cultural processes to be applied.
- In the fertilization program, the type and application form of the fertilizer and the application dose, application method and application time should be determined optimally according to the existing data and the criteria considered.
- Based on soil analysis, the proposed fertilization program should be implemented correctly.
- In order to control the nutritional status of the plant during the vegetation period and/or to determine the nutritional or physiological problems that arise, it is necessary to make plant/leaf analyzes in the appropriate period and to provide timely solutions to the identified problems.
- Determining the suitability of irrigation water quality to be used before the facility; Due to the dynamic nature of water resources, it is necessary to control the changing quality values with periodic analyzes and to plan the irrigation method and fertilization to be used according to the water quality values.

VI. Importance Of Soil Analysis

Soil analysis is an important implementation requirement that reflects the current unique and dynamic properties of the soil and guides fertilization recommendations. The main focus in analysis-based fertilization is to maximize the efficiency of nutrient use without compromising environmental values, to increase crop production and quality, to protect soil quality and to ensure soil use sustainability.

In the content of the fertilization proposal program based on soil analysis for sustainable soil management and high vegetative productivity, the following basic issues should be included in the minimum criteria:

- If available, diagnosis of basic soil problems determined by the selected analysis parameters (unsuitable pH, high salinity, high fixation capacity and physical problems) and solution suggestions,
- Determining the available amount of plant nutrients in the soil and determining the factors limiting nutrient availability,
- Determining the organic matter requirement of the soil,
- Determining the nutritional requirement according to the physical and chemical properties of the soil and the plant variety requirement, selecting the appropriate forms of the necessary fertilizers,
- Planning the dosage and timing of the fertilizers determined in accordance with the phenological periods of the plant and the fertilizer application method,
- Specifying soil or foliar application options and required micronutrient form and dose in case of deficiency of micronutrients,
- To provide explanatory information on the application of fertilizers and special issues that may be encountered.

VII. The Importance Of Leaf Analysis And Sampling Leaf Samples In Walnut Plants

Plant nutrients must be in a sufficient concentration range for optimum development. Values outside the sufficiency range cause unhealthy growth, cost increases and losses in product potential in the plant with effects such as deficiency, ion antagonism, luxury consumption, and ion toxicity (Figure 2). Foliar analysis in the plant gives very useful results in the control of the healthy nutrition of the plant by determining the adequacy of the mineral nutrients. Some deficiency the symptoms that cannot be observed in the leaves (visible nutrient deficiency) remain as a hidden deficiency in the leaves of the plant (the plant looks like a healthy plant although there is a deficiency) and negatively affects the subsequent development and product performance of the plant at that time. In this, the predominance of the parameters that affect the nutrient availability in the soil (high/low pH, excess lime, structural defects, low organic matter, lack of chelation, etc.), the quality of irrigation water, ion interactions in the soil and special soil problems (salinity, ion toxicity, etc.).) can be effective. In this respect, leaf analysis gives very useful results in a complementary nature to the plant nutrition program based on soil analysis.

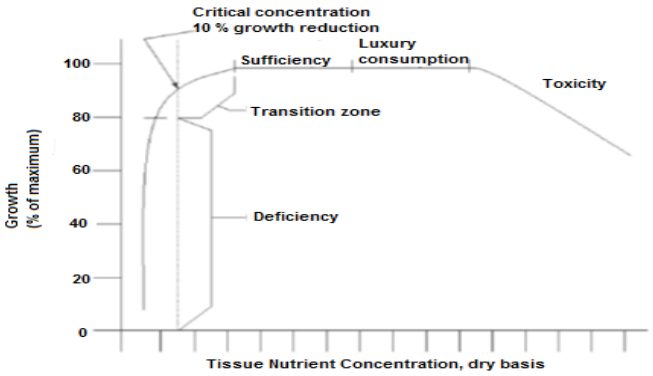

Fig. 2. Mineral nutrient applications and nutrient concentration and performance chart in the plant [4]

VIII. Temporal Changes Of Plant Nutrients In Leaves

The concentration of nutrients in plant leaves is dynamic and changes with time, and this situation progresses differently according to the nutrients (Figure 3). The periodic changes in plant physiology and related changes in the element needs and nutrient mobility in the body are effective in this, but these usual changes mostly occur in the sufficiency ranges. If the required elements are not sufficient in plant physiology during critical periods (rapid vegetative development, fruit set, fruit growth, etc.), stress factors increase, growth disorders and product losses are inevitable.

Arrangements in fertilization program in terms of controlling the adequacy of reserve nutrients It gives very beneficial results in terms of winter resistance of the plant, healthy and resistant structure and high yield in the next season.

A wide range of recommendations have been made for the critical nutrient concentrations of the walnut plant in different ecological regions in the world and in studies conducted with a large number of cultivars. Current and mostly accepted critical values are given in Table 4.

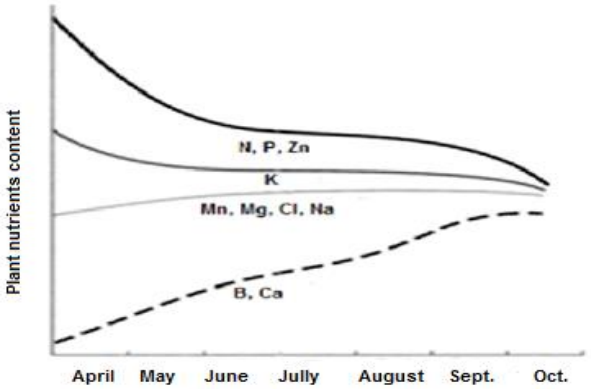

Fig. 3.Generalized concentration trend graphs within the sufficiency ranges of mineral nutrients during the growing season in walnut leaves [5]

.

TABLE IV. CRITICAL CONCENTRATIONS OF NUTRIENTS FOR OPTIMUM GROWTH IN THE LEAVES OF THE WALNUT PLANT (CURRENT AND MOSTLY ACCEPTED LITERATURE VALUES)

	Deficient	Low	Adequate	High	Excess
N	<1,8	1,8-2,2	2,21-2,5	2,51-3,2	3,2<
P	<0,11	0,11-0,14	0,14-0,45	0,45-0,55	0,55<
K	<0,5	0,5-0,8	0,8-2	2-3	3<
Ca	<0,6	0,6-1	1-2,5	2,5-3	3<
Mg	<0,18	0,19-0,24	0,25-0,5	0,5-1	1<
Fe	<40	40-50	50-400	400-500	500<
Mn	<20	20-25	25-650	650-1000	1000<
Zn	<10	10-15	15-60	60-100	100<
Cu	<2	2-4	4-15	15-100	100<
B	<25	25-30	30-75	75-100	100<
S	<0,08	0,08-0,12	0,12-0,2	0,2-0,5	0,5<
Cl		<0,1	0,1-0,3	0,3<	
Mo		<0,25	0,25-1	1<	
Na			0,1		

The most important criterion in taking leaf samples is to represent the area where the sample was taken by sampling at the right time and with the right method. The general rule considered in terms of timing in taking plant samples is to perform sampling during the period when the nutrient amounts of the plant are stable. This period reflects especially the mineral reserves of the plant and the potential required for the growth of the product (seed, fruit, green parts, etc.).

Leaf analysis of walnuts should be done every year in terms of control and revision of the plant nutrition program on days corresponding to 6-8 weeks after flowering (depending on the varieties and different climatic regions, on average, in the second half of June and the first half of July). The arrangements made in the fertilization program by repeating the same process in the first week of September in terms of controlling the adequacy of the reserve nutrients and ensuring that the plants enter the winter season with sufficient nutrients. In case of abnormal changes in the walnut garden, the plants should be analyzed immediately to solve the problems regardless of time.

IX. Walnut Leaf Sampling Time And Method

Leaf samples of the walnut plant for nutritional control should be taken from plants grown in the same age, variety, nutrition-maintenance management and soil characteristics. If there are widespread differences in these aspects in the garden, sampling should be done separately in these sections. Leaf samples should be selected from young leaf pairs (with petiole/petiole) that have completed the maturation of compound leaf groups on non-fruit shoots in the spring of that year and a total of 100 leaf samples should be taken from 25 trees, 1 leaf from 4 directions of each tree. Leaf sampling from large and old trees should be made from shoots at least 1.5-2 m above the ground (Figure 4).

Fig. 4. Leaf sampling in walnut plant

X. General Recommendations For Nutritional Management Of Walnut Plant

Today, new varieties, classical, semi-dwarf and dwarf culture forms and their different production potentials in agricultural production cause the nutritional requirements of these plants to vary in a wide range in terms of quantity and timing. The complexity of the large number of new agrochemicals and fertilizer compositions introduced to the market today necessitated the development of new analysis evaluation criteria with sophisticated, comprehensive and product-specific approaches, instead of conventional fertilizer and fertilization recommendations.

In the plant production, it is of great importance in terms of productivity, sustainability and environmental health that soil and plant analyzes are carried out on time and with appropriate techniques, and fertilization is applied based on analysis.

Soil, plant and water analysis laboratories are sophisticated service organizations that have an important role in sustainable agriculture, profitable production and clean and healthy environment, have an important role in raising awareness of producers and providing them with guidance, using high-tech equipment and employing expert personnel. Agricultural developments and changes show the absolute necessity of analysis-based applications in fertilizer applications. In this context, the adaptation of analysis laboratories to scientific and technological developments, their opportunities and capabilities and service quality come to the fore.

The amount of plant nutrients removed from the soil with the harvested walnut fruit is one of the important criteria in making fertilizer recommendations. The nutrient content of the biomass produced by the plant during the vegetation period and the amounts of plant nutrients in the fruit form the basis for the planning of the fertilization program. In addition to these, the following issues are also required in the preparation of an effective fertilization program:

- Before the establishment of the walnut orchard, the suitability of the soil and water resources and genetic material to the site should be determined.
- A fertilization program should be arranged to the extent necessary, taking into account the genetic yield potential, average height and total biomass of the cultivated variety.
- Criteria such as irrigation method, planting dimensions should be taken into account in fertilization planning.
- The nutriition dose foreseen for the plant requirement should be arranged in accordance with the original and dynamic characteristics of the soil determined by current soil analyzes.
- Possible leaching, gaseous removal and fixation losses in the soil of the nutrients to be applied with fertilization should be taken into consideration, and fertilization options that will minimize losses should be adopted in application planning.
- The fertilizer material should be selected in accordance with the adopted fertilization method and soil properties, and the distribution and timing of the relevant total amounts of the determined fertilizers should be planned in accordance with the phenological stages of the plant.
- Nutritional sufficiency control should be made according to the results of the leaf analysis made in the prescribed time in the vegetation period and the arrangements should be implemented on time by making revisions with appropriate options in the fertilization planning when necessary.
- The communication between the walnut producer and the laboratory organization that provides analysis and fertilization advice should be kept open and the success criteria should be evaluated by receiving the feedback of the application.

References

[1] Mihai, B. O. T. U., Alabedallat, Y. F., Bucura, F., Geana, E. I., & Vladu, M. The Productive Capacity and Quality of Several Walnut Cultivars (Juglans regia L.) Grown in North Oltenia, Romania. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 2019, 47(3), 574-579.

[2] Yerlikaya, C., Yucel, S., Erturk, Ü., & Korukluoğlu, M. (2012). Proximate composition, minerals and fatty acid composition of Juglans regia L. genotypes and cultivars grown in Turkey. Brazilian Archives of Biology and Technology, 2012, 55(5), 677-683.

[3] Walnut nutrient removal charts, in http:www.potash-info.com/research/nutrientconc/nutrientcon.htm

[4] Hochmuth, G., Maynard, D., Vavrina, C., Hanlon, E., & Simonne, E. Plant tissue analysis and interpretation for vegetable crops in Florida, 2004.

[5] Ramos, D. E. (Ed.). Walnut production manual (Vol. 3373). UCANR publications, 1997.

Bülent TOPCUOĞLU has born in Turkey, 1966; obtained PhD degree in 1993 from the Ankara University, Turkey in Soil Science and Plant Nutrition Department.

He is currently working as a Professor on Soil Science and Plant Nutrition, Soil Pollution and Environmental Sciences topics, at the Akdeniz University Vocational school of Tecnical Sciences, Antalya TURKEY. Author has done more than one hundred research publication to his credit.

Prof. Dr. Topcuoğlu has a scientific member of many organizations and chaire of many conferences organized by IAAST, IAE, CBMSR, IICBEE, IIENG and PSRC in İstanbul and Antalya, TURKEY.