

Enhancing the fruit yield and quality in pears using irrigation and fertilisation

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Abstract

The links between fertilizer dosages and irrigation guidelines on the one hand, and the changes they cause to the soil, leaves, and fruit production on the other, are discussed in this study based on experimental results conducted on the pear species, Lucas cultivar. The study was carried out on an area in the northwest part of Romania. Six fertilization and four irrigation versions were used in the tests. The variants were placed in randomized blocks, in four repetitions for the variants involving different types and dosages of boron and NPK fertilizers, and in three repetitions for the variants involving irrigation regime. The application of NPK in pear cultivation has improved the concentration of these elements in the soil and leaves, leading to a 30–48% increase in yield and evident cost-effectiveness in trees fertilized with NPK. Compared to trees with a boron deficiency, fertilizing with a 0.5% boric acid solution enhanced production by 71% on average over five years, and all fertilized trees produced fruit of a higher quality (55–60%).

Keywords: orchard, biological potential, pear cultivar, fertilizer level, watering norm.

Introduction

An essential technological way for boosting the biological potential of species and variants is tree fertilization. According to the needs of the species, rootstocks, and cultivar/rootstock associations in relation to the age and vegetation phases of the plants, the fertilization system consists of long-term activities that are intended to improve the physical and chemical characteristics of the soil and increase its fertility [1].

The main elements of the fertilization system include: the accumulation of organic matter in the soil through crop rotations and the incorporation of special plant residues for green fertilizers; the administration of mineral fertilizers with nitrogen, phosphorus and potassium [2]. The levels, terms and methods of fertilizer application are established differently for each sector depending on the agrochemical properties of the soil and the requirements of the cultivated plants.

The use of fertilizers in tree cultivation becomes necessary to renew the reserve of nutrients consumed by plants or leached into the soil, then to improve the physical state, chemical composition, and overall fertilization state of the soil [3]. The most important principle of the efficiency of the fertilization system consists in the maximum utilization and correct combination of fertilizers on horticultural lands [4]. In the soil fertilization system, fertilizers are considered an element of the greatest importance. They constitute the main source of providing plants with nutrients during the vegetation period of horticultural plants. It should be taken into consideration that the application of fertilizers should not favour the decrease in the resistance of trees to critical natural factors (diseases, pests, wintering conditions, etc.) or reduce the lifespan of trees. Such an orientation leads to the conclusion that fertilization should be done differently according to species and cultivar, grafts, rootstocks, or groups thereof, the eco-climatic and eco-pedological particularities of the area, the crop system, the age period and the physiological state of the plants, the productive and quality potential that is to be maintained or created [5].

For rational fertilization in fruit plantations, it is necessary to know the physical-chemical state of the soil in the plantations and the level of supply with nutrients easily accessible to plants. At the same time, to know the specific consumption requirements for macro and microelements of the trees, variable according to the

influence of modifying factors [6]. In modern fruit growing, fertilization is one of the most important technological links. By their nature, fruit plants occupy the same area of land for a long time, develop their root system to a significant depth and, due to the high productivity they achieve, extract from the soil, together with the harvest, appreciable quantities of nutrients [7]. Under these conditions, it is necessary to intervene every year, in several rounds, with fertilizations that ensure, on the one hand, the achievement of a certain level of production, and on the other hand, a certain level and ratio of nutrients by restoring the quantities of easily accessible nutrients extracted with the harvest in order to maintain, in this way, soil fertility in accordance with the age of the plantation and the level of production [8].

Quantitative and qualitative knowledge of the nutrients extracted by fruit plants per unit area is very important for the rational application of fertilizers. This knowledge requires prior information, based on laboratory chemical analyses, on the qualitative and quantitative presence of various nutrients in the soil [9]. The use of fertilizers is done with the aim of optimizing nutritional conditions to increase the synthesis of organic matter and achieve large, economical productions, with superior quality indices, without weakening the resistance of plants to the attack of diseases and pests and without polluting the environment [10]. Fertilizers make their optimal contribution to increasing fruit production only to the extent that they are included in a system of well-ranked technological measures, and the levels used are correlated with the plant, the soil, climatic factors, and the culture technology.

The research undertaken on this topic is numerous and varied in approach and results obtained, with the most notable at the current stage being those that promote the application of moderate levels of organic and chemical fertilizers. These fertilizers aim to satisfy the need for fertilizing elements by maintaining the balance between the soil content in food and water, which is transmitted to the tree through the normal composition of the leaves and the size of the harvest corresponding to the demands of consumers and the satisfaction of producers.

The aim of this study is presenting the connections between fertilizer dosages and irrigation practices and the alterations they cause in soil, leaves, and fruit production for the pear species.

Material and Method

The research was conducted in a pear orchard, with Lucas cultivar, established in 2010, on a previously shaped plot. The fruit is medium-sized, 150 g, ovoid, yellow-green with a little red on the sunny side. The pulp is white-cream, without sclereids. Six fertilization and four irrigation versions were used in the tests. The variants were placed in randomized blocks, with four repetitions for variants involving different types and levels of boron and NPK fertilizers, and three repetitions for variants involving irrigation regime. Samples of plant material (leaves) and soil were gathered for laboratory examinations. Descriptive statistics were used to process the results.

Results and Discussion

The change in the content of mobile phosphorus and potassium under the influence of the irrigation regime, after 5 years of fertilization with $N_{180}P_{180}K_{120}$ kg/ha is shown in Table 1.

Table 1. The content of mobile phosphorus and potassium under the influence of the irrigation norm

Variant	P ₂ O ₅		K ₂ O	
	mg/100 g	%	mg/100 g	%
Unirrigated	10.2	100	8.7	100
Irrigated 30% RH	12.3	119	9.5	109
Irrigated 50% RH	12.4	120	8.7	100
Irrigated 70% RH	12.8	124	9.0	103

The data in table 1 show that mobile phosphorus increased by 19-22% in the irrigated variants, which is explained by better solubilization of the water administered through irrigation. The same is not true for potassium, which is maintained at a level close to the non-irrigated variant and in those irrigated at 30, 50 and 70% of the relative humidity range. The close potassium values show that the water from the precipitation was sufficient to solubilize this element administered in the form of potassium salt. If the level of mobile phosphorus in the soil changes depending on the irrigation rate, increasing as a larger volume of water is administered, the situation is more evident when different levels of fertilizers are used. This fact is highlighted in the data in Table 2, where it is found that the progressive application of NPK fertilizers modified the soil P₂O₅ content from 9.5 mg/100 g solution in the unfertilized variant to 20-23 mg when the $N_{100}P_{100}$ and $N_{100}P_{100}K_{100}$ levels were applied and to over 26 mg when the phosphorus level was doubled.

Table 2. The content of mobile phosphorus and potassium under the influence different fertilization levels

Variant	In soil			In leaves		
	pH (in H ₂ O)	mobile P ₂ O ₅	mobile K ₂ O	N%	P%	K%
V ₁ standard	5.45	9.5	8.3	1.99	0.15	1.26
V ₂ N ₁₀₀	5.09	10.1	7.0	2.12	0.14	1.29
V ₃ N ₁₀₀ P ₁₀₀	5.31	19.7	12.0	2.11	0.16	1.65
V ₄ N ₁₀₀ P ₁₀₀ K ₁₀₀	5.23	23.8	10.5	2.03	0.16	1.56
V ₅ N ₂₀₀ P ₁₀₀ K ₁₀₀	5.12	2.08	13.4	2.17	0.15	1.71
V ₆ N ₃₀₀ P ₂₀₀ K ₁₀₀	5.04	26.1	10.0	2.27	0.15	1.64

Regarding potassium, increased levels of fertilizers only slightly change its level in the soil, from 8 mg/100 g solution in the unfertilized version to 10.5 mg/100 g solution in the fertilized version N100P100K100 and to 13.4 mg when the applied potassium level is doubled. Similar to the situation in Table 1, mobile potassium changes slightly under the influence of increased fertilizer levels, capping in the case of sands at 10-13 mg/100 g solution. Capping at these values makes it unnecessary to increase potassium levels to raise its level in the soil, proving that these soils can be well and very well supplied with mobile potassium when its level reaches 10-13 mg/100 g solution. The above results are also supported by the relationship between the soil content of mobile potassium and the potassium content of leaves, the leaves having an increasing potassium content, reaching the level of 1.7%, considered normal (optimal) for hair when its level in the soil reaches 12-13 mg/100 g solution. Regarding boron nutrition, an important microelement in the normal development of metabolic processes in hair, research has highlighted the occurrence of deficiency and its removal through root and extra-root fertilization with borax and boric acid, results presented in table 3.

Table 3. Boron content after fertilization

Variant	In soil (mg/kg)		In leaves (mg/kg)	
		4-year average		4-year average
V1 standard unfertilised with trees not affected by deficiency	0.45	0.13	36.5	7.1
V treated with 0.25% boric acid	0.2	0.17	5.3	12.9
V treated with 0.5 % boric acid	0.15	0.21	6.2	16.0
V treated with 1.0 % boric acid	0.17	0.28	6.6	19.2

According to table 3, the boron level in the soil, of 0.45 mg/ kg of sandy solution, ensures normal nutrition of the hair with this element, a fact confirmed by its value in the leaves, of 36.5 mg/ 1 kg of leaves. This value is considered optimal by the data in the specialized literature and confirmed by this research, by the lack of specific symptoms of boron deficiency on the fruits. Over the next 5 years, the trees from the untreated variant and initially unaffected by the deficiency fully manifested this boron deficiency, with the boron level in the soil decreasing 4 times and that in the leaves 5 times, simultaneously with the appearance of deficiency symptoms on the fruits, which depreciated greatly. The demonstrated existence of close correlation between the soil content of nutrients, fertilizer levels and the level of these elements in leaves has great theoretical significance that converges towards the practical side, materialized by the reflection of these correlation on the level and quality of production.

Table 4. Fruit production

Variant	Kg/tree	T/ha	%	First quality pears
Unirrigated	34.0	17.0	100	54
Irrigated 30% RH	49.4	24.7	145	68
Irrigated 50% RH	50.2	25.1	148	79
Irrigated 70% RH	55.0	27.5	161	78

DL 5% 6.9

Table 4 presents fruit production depending on the irrigation norm in the first 5 years of fruiting.

From table 4, pear production in the first 5 years of fruiting increases as the minimum active humidity threshold is maintained higher, exceeding the non-irrigated variant by 45 - 61%, values that are statistically

significant. These yield increases are closely related to the high-water consumption which has solubilized a greater quantity of mineral salts, providing the trees with enough food, for an increased yield. Added to this is the increase in the quality of the extra and quality I fruits, which exceed the non-irrigated control by 14-25%. In Table 5, a close relationship between fertilizer levels and harvest is observed, because of increasing the NPK content in the soil and leaves.

Table 5. Fruit production obtained when applying different levels of fertilizers

Variant	Kg/tree	T/ha	%	Difference significance
V ₁ standard	36.0	18.0	100	
V ₂ N ₁₀₀	24.8	17.4	97	-
V ₃ N ₁₀₀ P ₁₀₀ K ₁₀₀	49.0	24.5	130	+
V ₄ N ₁₀₀ P ₂₀₀ K ₁₀₀	48.8	24.4	130	+
V ₅ N ₂₀₀ P ₁₀₀ K ₂₀₀	53.2	26.6	148	+
V ₆ N ₃₀₀ P ₂₀₀ K ₁₀₀	46.0	23.0	128	-

DL 5% 6.5

The average harvest for the first 12 years of fruiting increased by 28-48%. It is worth noting that the more economical and ecologically superior variant is the V₃ variant, which brings a 30% harvest increase, while V₆ increases the harvest by 28%, consuming double the level of fertilizers. Fertilization in variant V₁ remained ineffective, production being equal to that of unfertilized trees. This variant, as well as the one with very high levels of nitrogen, is not justified, being evident both in terms of the increase in harvest and in terms of costs and energy consumed. Pear production was also significantly influenced by the application of boric acid as a foliar treatment (Figure 1).

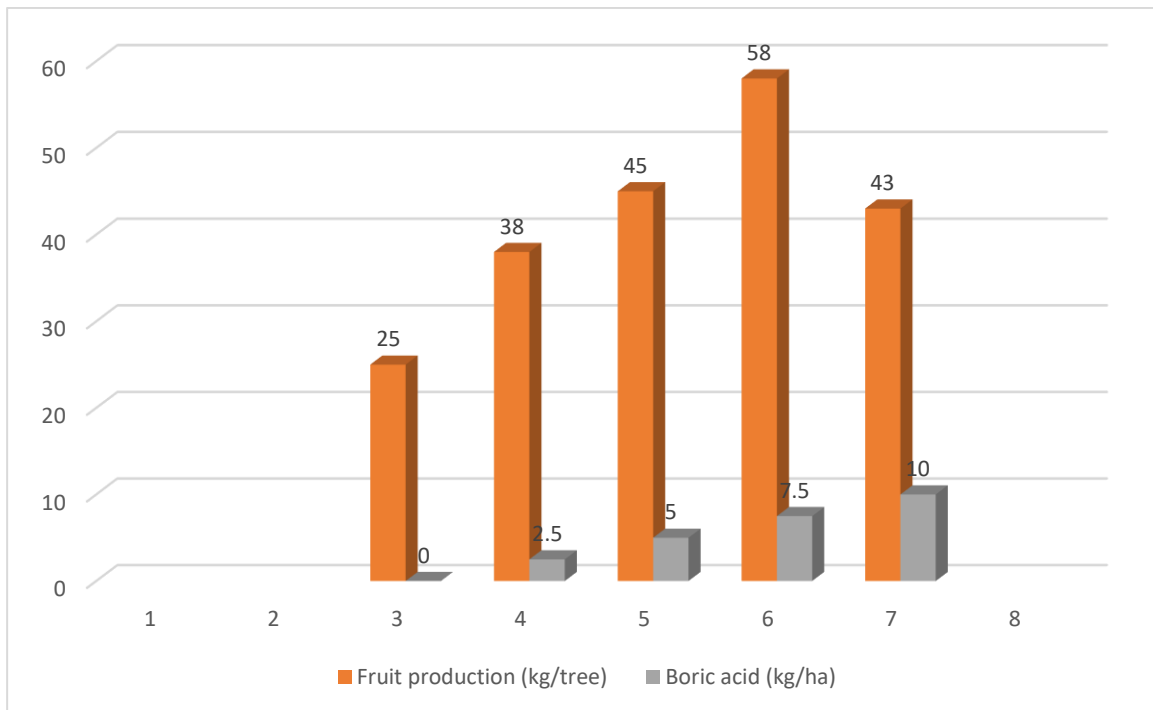


Figure 1. Correlation between boric acid application and fruit production

On average for 6 years, the harvest increased from 25 kg/tree in trees not treated with boric acid, to 58 kg/tree in trees treated with boric acid 0.55 and to 45 kg/tree at a boric acid concentration of 1%. The decrease in production by increasing the boric acid concentration to 1% was caused by the phytotoxicity phenomenon, evidenced by leaf fall in some years up to 50%, one week after treatment. Applying boric acid to deficient trees while increasing the harvest improved the quality of the pears by over 55%, the fruits being free of the cracks, a characteristic of fruits harvested from trees affected by boron deficiency.

Conclusions

The application of NPK and boron fertilizers to the pear species positively influenced the soil content of these elements, more in the case of mobile phosphorus and total boron and less in the case of potassium, which peaked at 10-13 mg/100 g solution. The content of mobile phosphorus was also positively influenced by the water applied through irrigation, its level in the soil increasing as the irrigation rate increased. Fertilized and irrigated trees respond positively by increasing the level of the analysed elements at the leaf level and maintaining them within optimal limits, while in unfertilized trees the analysed leaves contain NPK close to the critical level, and boron at the deficiency level. Fruit production responds positively to NPK and boron fertilization with statistically assured increases when levels are moderate, while unilaterally applied nitrogen does not bring yield increases.

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