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Irrigation and Fertilization: A Comprehensive Analysis of Their Influences on Qualitative Indices in Two Plum Varieties

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Abstract: The chief aim of this study is to provide information regarding the value and effectiveness of localized irrigation applied to plum trees grown in nurseries; this study also emphasizes how irrigation impacts various qualitative indices in the context of different fertilization treatments. By increasing production in the nursery, the application of differentiated rules for fertilization and irrigation is expected to yield vigorous, healthy fruit tree planting material. As in the case of all cultivated plants, fruit trees in nurseries are primarily dependent on soil and climatic conditions. This research was carried out in a private fruit tree nursery in the northwestern part of Romania. The soil taxonomic unit identified on the research field was arable, weakly glaciated loamy clay on fluvial deposits. The two plum cultivars that were studied were Stanley and Cacanska Lepotica, both of which are valued for the high caliber of their fruit. This research was conducted using a $4 \times 2 \times 4$ trifactorial experiment, with irrigation acting as the primary factor, cultivar as the secondary factor, and fertilization as the tertiary factor. During this research, the fertilization treatments proved to have the most significant impact (34.50%) on stem diameter compared with irrigation (20.67%) and cultivar (5.63%), given that the cultivar had no discernible influence on the increase in the diameters of the grafted trees.

Keywords: fruit tree nursery; planting material; fertilization; irrigation; cultivar; stem diameter

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1. Introduction

In upcoming years, it is expected that fruit cultivation will emerge as one of Romania's main horticultural sectors. Fruit production will need to supply a significant amount of product to meet demand in international markets, in addition to fulfilling domestic needs. Fruit farming may considerably boost national income if adequate ecological, material, and human resources are available [1]. Obtaining tree planting material with both high biological value and favorable economic factors requires careful control of the rootstocks used in the nursery [2]. High-vigor generative rootstocks have been previously used in Romania, particularly in traditional orchards. Recently, there has been increasing demand for rootstocks with vegetative propagation due to the intensification of fruit tree plantations. Romania is currently among the European countries with exemplary achievements in vegetative rootstocks, which are requested for testing in many European nurseries. The interest in using rootstocks has increased in line with the development of fruit growing as a commercial activity, which requires the production of many trees in specialized nurseries. The cultivation of fruit trees and shrubs requires planting material meant to restore orchard areas that have been cleared by using specific replacement rate; expanding the orchard heritage by establishing new plantations; restoring the density of existing plantations by filling the gaps; promoting the production of cultivars recommended for each area and culture area; and multiplying and promoting the culture of valuable genotypes, such as newly created or imported cultivars, newly selected clones, and general materials with high biological value [3]. The recent occurrence of drought in Romania is a worrying phenomenon. In horticulture, drought causes the senescence of the leaves at the base of plants, their fall, and thus reductions in leaf surface and total transpiration. Common symptoms of more severe water deficit in plants include the loss of cell turgor, the cessation of growth, the reduction in gas exchange, and the intensification of the respiration process to the point it exceeds the intensity of photosynthesis [4]. Because water is redistributed from plant tissues, plants can survive relatively short periods of time without soil water, depending on the species. However, the effects are not severe. The water from the roots of plants is transported to the aerial organs, and the water from the apoplast penetrates through endosmosis into the cells of leaves, where it restores the turgor pressure and ensures normal conditions for the development of metabolic processes [5]. The increase in the thickness of the cuticle, the decrease in the number of stomata, and the accumulation of hemicelluloses in the form of a gel that retains water in the cell walls are additional means whereby, in times of water stress, plants can prevent significant water loss [6].

Agriculture is not only a main driver of the economy but also a provider of food for all humanity. However, climate change can have a significant impact on this domain of activity [7]. In addition, low agricultural production can be caused by the excessive fragmentation of properties and the reduction in the degree of mechanization of tasks, irrigation, and chemical treatment [8]. Plants can adapt to specific environmental conditions, which allows them to carry out their vital processes under optimal conditions and ensure the perpetuation of their species. Plant metabolism is influenced by climatic changes, which can impact plant production and quality, as well as the capacity of plants to provide a population with plant-based food sources [9]. Plants respond differently to the actions of stress factors, depending on the characteristics of the species, cultivar, etc.; from this point of view, there are species or cultivars that are either resistant or sensitive to the action of a stress factor [10]. Extended periods of drought, reduced river flow, lower lake levels, and falling water tables all have a major detrimental impact on the economy in general and on the agricultural sector in particular. Precipitation provides the water needed for agricultural crops on more than 80% of the globe's surface, but much of this surface is exposed to drought stress. Of the total cultivated land on the Earth, only about 18% is irrigated. The action of stress factors can result in losses reaching up to 40–50% of production [11]. Current climate changes increase the demand for irrigating horticultural crops and intensify the competition between agricultural and non-agricultural water needs. For these reasons, it is imperative to identify new methods for increasing the efficiency of water use in plants [12]. The rational use of water in agriculture implies the prioritization of water consumption in critical situations, the adoption of technologies with reduced water consumption, the adoption of measures that require the application of reference models, the application of innovative solutions to reduce water loss, and the quality control of water with the view of reducing environmental pollution [13]. In addition, improving irrigation technology and promoting drip irrigation are effective ways to enhance the efficiency of using the water resources [14].

Similar to other areas of agricultural production, modern fruit growing can only be imagined in the context of a water regime that corresponds to the requirements of the cultivated species and the culture system used [15]. Through strong root systems that make it possible for plants to explore a large volume of soil and due to the increased absorption capacity of roots, many fruit tree species can achieve favorable results even in areas with a lower rainfall regime or in plantations located on sloping land and on dry sands, where water is more difficult to retain [16]. However, because fruit trees are plants that have increased specific water consumption for the development of growth and fruiting processes at the appropriate level, compensating for water deficit through irrigation in fruit plantations becomes a necessary if not indispensable measure [17]. An optimal water supply level of 65–75% of the soil's total holding capacity must be ensured without creating excess moisture (>80%) through irrigation.

Due to its geographical location at the confluence of the continental and Mediterranean climates, Romania generally offers both favorable climatic and soil conditions for many fruit tree nurseries. Initially, fruit tree nurseries were concentrated in areas with greater rainfall, so that rootstock capture depended to a greater extent on the rainfall regime, with human intervention being initially limited. The uneven distribution of precipitation throughout the year, which causes prolonged periods of drought in some areas (periods longer than 10 days during the vegetation period and 14 days during the rest period when rainfall is no greater than 5 mm), is a characteristic shortcoming of our country's climatic regime and is reflected quite significantly in fruit growing. Considering these factors, along with the tendency to develop significant fruit-growing centers in normally arid regions, on zonal soils, and on sands, irrigation ought to be a top priority in Romania's fruit-growing industry. However, the specifics of this concern vary based on the pedo-climatic zone, kind of rootstock, etc. [18].

Where annual precipitation is less than 500 mm, fruit trees need irrigation; in regions where annual precipitation is between 500 and 700 mm, additional irrigation is used [19]. As is the case with all cultivated plants, fruit trees in nurseries grow primarily in response to the soil and climate in which they are placed [20]. An amount of 75–85%, and occasionally even more, of the weight of the tree's various organs is composed of water [21]. In addition to the fact that water ensures the circulation of fertilizing elements from the soil to the plant, water is an essential element in synthesizing all the organic substances that make up the tissues of rootstocks and trees. Trees need water so that their growth processes might occur as intensely as possible [22].

The fertilization system in nurseries includes long-term activities aimed at ensuring improvement in the physical and chemical properties of the soil and increasing its fertility, ensuring that the demand for assimilable nutrients is met in accordance with the needs of the species, rootstocks, and cultivar/rootstock associations in relation to age and the vegetation phases of plants [23].

Practicing intensive horticulture requires significant investment; thus, production must be neither mediocre nor fluctuating. This requires more professional competence; permanent supervision; and control over vegetation factors, among which the nutritional ones play a predominant role. The system for applying fertilizer consists of a set of guidelines and procedures that deal with setting fertilizer doses; applying them annually and in a full rotation (or off-rotation for non-rotating species); and applying organic fertilizers and minerals in a way that is coordinated with the biological characteristics of each species, the properties of the soil, technological advancements, and economic factors, emphasizing the ways in which fertilizers are administered for each crop [24]. Since each harvest removes a certain amount of mineral and organic matter from the soil, the fertilizer application system in nurseries needs to address issues such as replenishing the soil's reserve of readily assimilated nutrients in a balanced ratio to meet the needs of seedlings and rootstocks [25], which otherwise have to compete with higher plants for mineral nutrition. In addition to the above, fertilizers provide soil microflora with organic matter [26]. The following features need to be considered when designing the nursery fertilizer application system: the soil's hydro-physical characteristics; the differences in nutrients according to rootstocks, species, cultivar, the stage of vegetation, harvest level, weather (temperature, rainfall, and light intensity); the unique technological characteristics of every species; the agrochemical properties and content of the applied fertilizers; the optimal selection of the technique for determining fertilizer dosage and managing the condition of nutrient delivery; establishing the appropriate financial and administrative frameworks for the use, storage, and supply of fertilizers [27–29]. To increase the synthesis of organic matter and achieve large, cost-effective production with superior quality indices, fertilizers are used to optimize nutritional conditions without polluting the environment or weakening plants' resistance to disease and pest attack [30].

Water is directed to the area where it can be most effectively consumed by the plant and easily dosed according to plant requirements, thereby achieving water economy. Losses due to infiltration and evaporation are also nearly eliminated in this process. At the same time, harmful salts are transported to the surface soil beneath the root zone by drip irrigation. A faster growth rate is observed as a direct effect on the plant, leading to earlier harvests than those obtained by other methods of irrigation [31]. Some benefits of localized irrigation include avoiding soil settlement by allowing machinery to move freely during maintenance tasks, minimizing the need for weed-control treatments, and using significantly less energy than with sprinkling (one bar at the end of the irrigation pipe). The drip irrigation method has an additional advantage over the conventional sprinkler irrigation method, in that it can lower the amount of disease treatments and modify the humidity ceiling [4].

Based on the research carried out so far, it can be concluded that watering only along the rows of trees does not harm the development of the root system. Under such conditions, roots are grouped in a narrower space without reducing too much of the total length, so that the absorption capacity is practically not hindered. The ability to use mineralized irrigation water is another benefit of the drip irrigation technique. It has been discovered that salts migrate from the supply point to the boundaries of the wetting zone, resulting in small amounts of salts being found in the root system development zone in the greatest quantities [32–34]. On the other hand, the concentration of salts in the moistened root zone is kept lower due to the maintenance of high humidity throughout the irrigation period. Thus, plants find better conditions for development in salinized soils. The danger of salinization when using mineralized water is also reduced since a smaller volume of water is used per hectare compared with other irrigation methods. The above-mentioned advantages justify the efforts to increase the irrigation capacity. However, it must be remembered that these are potential advantages that can materialize only if rational irrigation is applied, considering the plants' requirements and the soil's physical properties [35]. When comparing the amount of water used for irrigation with that obtained from precipitation and groundwater intake, it becomes evident that crops need to be irrigated. Conversely, a similar comparison can be made with the production obtained in slightly rainier years or between irrigated and non-irrigated crops. To determine whether irrigation is necessary, one must consider not only the amount of precipitation but also the evolution of temperature, relative air humidity, frequency, and wind intensity. This is because the damaging effects of drought are exacerbated during dry spells that are marked by high temperatures, low relative air humidity, and hot and dry winds. In these situations, there is atmospheric drought in addition to soil drought [36,37].

Irrigation is a technique meant to supplement precipitation-derived water supply when this is inadequate for crop needs, in the context of weather conditions characteristic of Romania. It is a way to address a natural factor that causes significant variations in harvest from one year to another. The goal of irrigation is to achieve production that is as stable as possible, nearing the plants' potential for productivity under the specific phytoclimatic conditions. Research conducted in our country revealed that there are years when harvests are severely reduced, even compromised, because of insufficient rainfall during certain periods.

This research addresses an important and current issue, namely, the production of quality fruit tree planting material associated with economically efficient activity at the level of nurseries, which requires considering both the pedo-climatic conditions in the area where the fruit tree planting material is produced and the elements of applied technology. This research aimed to obtain information about the necessity and efficiency of applying localized irrigation in plum culture in a nursery against the background of different fertilization treatments.

2. Materials and Methods

2.1. Location of the Experimental Field

This research was completed in a private nursery in Girișu de Criș, Bihor County, Romania.

Girișu de Criș is a commune situated in the lower area of the Crisurilor Plain. The low plain is the result of hydrographic networks that drift down from Bihor County's higher region as a result of accumulation and erosion.

In the region of Girișu de Criș, the plain is predominant, which determines a uniform distribution of meteorological values throughout the year. The rivers that drain the plain have shallow beds and are not accompanied by terraces.

The low area of the Crișurilor Plain has an average altitude of 110 m.

The annual precipitation was higher (636 mm) in 2020 and lower (498 mm) in 2021, given that during a period of three years, the annual precipitation was lower than the multi-year average. In 2020, the monthly precipitation showed a variation of 114.9 mm, from 12.7 mm in October to 127.6 m in July. For the year 2021, the level of precipitation registered a variation (110.6 mm) was close to that of the previous year, against the background of high precipitation of 119.3 mm in June and very low of only 8.7 mm in February. The amplitude of the variation in monthly precipitation in 2022 was higher (119.7 mm) than in the previous period, varying between 13.5 mm in January and 133.2 mm in July. The amount of precipitation in the April–September vegetation period recorded values between 337.5 mm in 2020 and 370.1 mm in 2022 (Figure 1).

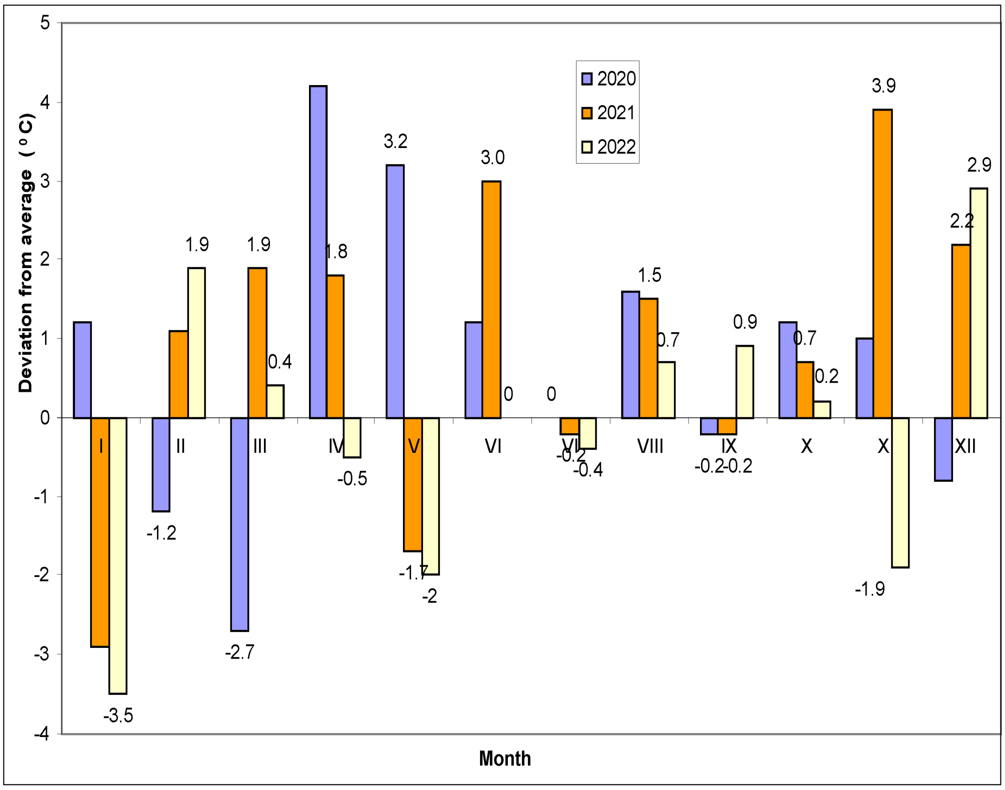

Figure 1. Variations in monthly average rainfall from 2020 to 2022 compared with multi-annual average monthly temperatures in Girişu de Criş.

To give a thorough account of the climatic conditions during the research period, a number of aridity indices were used (Table 1). According to the UNEP aridity index (IAU), Girişu de Criş's area falls into the dry–sub-humid climate class, with average values for the vegetation period over the three years ranging from 0.52 in 2020 to 0.59 in 2021. This index shows that the driest months in 2020 and 2021 were August and September, and July and August, respectively.

Table 1. Hydroclimatic characterization of conditions in Girişu de Criş during 2020–2022.

Year	Month							
	Index	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**Average**
2020	IA_U	0.50	0.48	0.63	1.00	0.25	0.26	0.52
IA_{TH} = 46.16	IA_{DM}	17.88	23.27	32.15	47.85	12.99	9.54	23.95
2021	IA_U	0.74	1.00	0.94	0.16	0.08	0.39	0.55
IA_{TH} = 39.55	IA_{DM}	23.69	51.19	43.38	8.26	4.06	14.24	24.14
2022	IA_U	0.32	0.75	0.96	0.97	0.21	0.34	0.59
IA_{TH} = 33.41	IA_{DM}	8.80	29.39	40.60	50.58	10.48	12.87	25.45

IA_U—UNEP aridity index; IA_{DM}—Martonne aridity index; Bh—water balance; IA_{TH}—Thornthwaite aridity index.

According to Formula (1), the values of the Martonne index (IADM) for the three years (23.95–25.45) characterize the climate of Girişu de Criş as semi-humid. Thus, during the 2020 vegetation period, July (IADM = 47.85) was considered the wettest month, and September (IADM = 9.54) was the driest one. Under the conditions of 2021, May and June (IADM = 43.38–51.19) were the wettest months, and July and August (IADM = 4.06–8.26) were the driest ones. In 2022, the index had values between 8.8 in April and 50.58 in July, according to Formulas (2) and (3).

According to the Thornthwaite aridity index (IATH), Formula (4), the climate in Girişu de Criş in 2021 and 2022, with values between 20 and 40, was considered semi-arid, while the climate in 2020, with a value of 46.16, was considered arid.

Following the analyses, the soil taxonomic unit identified was arable, weakly glaciated loamy clay on fluvial deposits, having the profile Ap-A0-AC-Cg. The depth of groundwater was 2–3 m.

2.2. Experimental Design

This research was carried out based on a trifactorial experiment of the $4 \times 2 \times 4$ type, organized in five repetitions, with plots comprising four trees planted in 0.7×0.25 m, with irrigation as the primary factor (a1—non-irrigated; a2—10 mm irrigation; a3—20 mm irrigation; a4—30 mm irrigation), the cultivar as the secondary factor (b1—Stanley; b2—Cacanska Lepotica), and fertilization as the tertiary factor (c1—$N_0P_0K_0$; c2—$N_8P_8K_8$; c3—N_{16} P_{16} K_{16}; c4—$N_{24}P_{24}K_{24}$). The PAST 4.10 program was used for statistical interpretation.

Regarding the technology applied, the first field of the nursery was prepared by deep plowing (35 cm) in August 2020, followed by the leveling work by discus and harrowing in October.

The planting of rootstocks in Field I was carried out in the fall of 2020. In 2021, two mechanical slings between rows and two manual slings per row were applied in Field I. Additionally, phytosanitary treatments using the insecticide Decis (0.02%) and fungicide Dithane (0.2%) were carried out. The complex fertilizer 16:16:16 (Azomureş) was applied concurrently with the mechanical nets in the following amounts (kg/ha): 50 kg for $N_8P_8K_8$; 100 kg for $N_{16}P_{16}K_{16}$; 150 kg for $N_{24}P_{24}K_{24}$. An irrigation control system was installed to measure the amount of water used (Figure 2).

To ensure that the moisture requirement of the soil was met, watering was performed one time in July and three times in August in accordance with amounts related to the three experimental variants, i.e., 100 m^3/ha, 200 m^3/ha, and 300 m^3/ha, respectively. The grafting took place in August 2021.

In the second field of the nursery, the cutting of the cone was carried out in the spring of 2022, followed by the dragging of two mechanical harrows between rows and four manual harrows per row. Also, the weeding out of wild plants was performed four times and the pinching of side growths two times (Figure 3).

Figure 2. Irrigation control system in the nursery for measuring the amount of water used.

Three treatments were applied with the fungicide Dithane (0.2%) and the insecticide Fastak (0.02%) to combat diseases and pests (Figure 4). In August, the soil water deficit was compensated for by applying irrigation three times in accordance with amounts related to the three experimental variants, namely, 100 m^3/ha, 200 m^3/ha, and 300 m^3/ha, respectively. The complex fertilizer 16:16:16 was used in the amounts (kg/ha) of 50 kg for $N_8P_8K_8$, 100 kg for $N_{16}P_{16}K_{16}$, and 150 kg for $N_{24}P_{24}K_{24}$ to obtain the NPK doses associated with the fertilization treatments.

Figure 3. Second field of the nursery.

Figure 4. Second field of the nursery.

2.3. Calculations

Throughout the study, descriptive statistical analysis was employed. The data were gathered, analyzed, and summarized by the authors. The following aridity indices were calculated in order to describe the weather during the study period:

- UNEP aridity index (1992):

$$IA_U = P/FTE \quad (1)$$

where P—precipitation (mm); ETP—potential evapotranspiration (mm).

According to this index, the climate varied from hyper-arid ($IA_U < 0.03$) to humid ($IA_U > 65$).

- Martonne aridity index:

$$\text{annually:}AIDM = P/(T + 10); \quad (2)$$

$$\text{monthly:}AIDM = 12p/(t + 10); \quad (3)$$

where T—average annual temperature (°C); t—mean monthly temperature (°C).

This index allows for the determination of the degree of aridity of a region for certain periods (a year or a month), with climatic variations from hyper-arid (IADM = 0–5) to humid (IADM > 30).

- Thornthwaite aridity index:

$$IATH = 100 \times \Sigma(P - ETP)/\Sigma ETP; \quad (4)$$

This index characterizes a climate as arid at values above 40 and as semi-temperate at values of 0–10.

To determine water consumption directly, the soil water balance was established according to the soil water reserve at the beginning and end of each month from April to September. Soil moisture was determined by the gravimetric method; for this, soil samples were collected from the field at the beginning and middle of each month. These were weighed before and after having been dried in an oven. By using the following formula, which considers the difference between the two weighing instances, soil moisture was calculated:

$$W = 100 \times (B - A)/A \quad (5)$$

where W—soil moisture (%); A—mass of sample with wet soil (g); B—mass of sample with dry soil.

The soil water reserve (R) was established with the following formula:

$$R = 100 \times DA \times H \times W \quad (6)$$

where DA—apparent density (t/m^3); H—depth of active soil layer (m); W—soil moisture (%).

The minimum ceiling—the lowest level of humidity that is readily accessible to plants—was determined to establish the exact moment at which irrigation was required to provide water to the soil. The minimum ceiling (%) for medium soils—which includes the soil from the experimental land—was determined by using the following formula:

$$Pmin = CO + ½(CC - CO) \quad (7)$$

where CO—withering coefficient (%); CC—field capacity for water (%).

The minimum volumetric ceiling (m^3/ha) was calculated with the following formula:

$$Pmin.vol. = 100 \times DA \times H \times Pmin \quad (8)$$

As regards the version watered with the amount of 10 mm, the moment for applying irrigation was established in relation to the time when the minimum ceiling was reached. In this sense, watering was performed several times in some months, based on the three amounts discussed in this study.

Potential evapotranspiration was estimated using the Thornthwaite method, so as to determine water consumption indirectly. This method estimates potential evapotranspiration as a function of air temperature by using the following formula:

$$ETP = 160\left(\frac{10 \cdot t}{I}\right)^{a} \cdot K \tag{9}$$

where *ETP*—potential monthly evapotranspiration (m^3); *tn*—average monthly temperature for which ETP is calculated (°C); *I*—annual thermal index, determined as

$$I = \sum_{n=1}^{n=12} i = \sum_{n=1}^{n=12} \left(\frac{t_n}{5}\right)^{1.514} \tag{10}$$

a—empirical coefficient, which is determined as

$$\mathrm{a} = 0.000000675\mathrm{I}^2 - 0.000077\mathrm{I} + 0.01279211\ \mathrm{I} + 0.49239 \tag{11}$$

K—brightness coefficient depending on latitude of land (for the period April–September: 1.135, 1.3, 1.32, 1.133, 1.225, 1.045).

The effective precipitation (Pe) during the vegetation months was calculated according to the total precipitation (Pt) that fell in that month, using the USBR method:

$$\mathrm{Pe} = \mathrm{Pt}\ (125 - 0.2\ \mathrm{Pt})/125, \text{ when Pt} < 250 \text{ mm} \tag{12}$$

$$\mathrm{Pe} = \mathrm{Pt}(125 + 0.1\ \mathrm{Pt})/125, \text{ when Pt} > 250 \text{ mm} \tag{13}$$

For each combination of the three factors (irrigation × cultivar × fertilization), determinations were made in relation to the morphological characteristics below, which are connected to the stem diameter (cm).

The growth rate for different characteristics under the effect of different watering amounts and fertilization doses was determined based on an exponential function represented by the following equation:

$$y = \alpha \cdot e^{\beta x} \tag{14}$$

where α—initial value; x—time; y—growth rate.

The accuracy of the respective estimates was evaluated by means of the coefficient of determination (R^2).

3. Results

3.1. Analysis of Variance

The statistical analysis of the factors under investigation revealed significant effects on the stem diameter. The fertilization treatments had the highest impact (34.50%) on this characteristic, compared with irrigation (20.67%) and cultivar (5.63%). In addition, the combination of the three factors showed a significant influence on the stem diameter, but this was considerably lower than their separate effects. The interaction between cultivar and fertilization was highlighted by a major effect of 5.03%, followed by the irrigation x cultivar interaction. At the level of experience, the obtained results were influenced to a degree of 16.6% by other sources of variation not included in the experimental device (Table S1).

3.2. Main Effects of Watering, Cultivar, and Fertilization on Stem Diameter

Considering the unilateral effect of irrigation, it was observed that the stem diameter registered a variation of 2.46 cm, with values between 7.09 cm in the non-irrigated version and 9.55 cm in the situation where 30 mm watering was used (Table 2).

Table 2. Stem diameter under main effects of watering, cultivar, and fertilization.

Irrigation	Mean (cm)	Cultivar	Mean (cm)	Fertilization	Mean (cm)
0 mm	7.09 c	Stanley	8.09 b	$N_0P_0K_0$	6.51 d
10 mm	7.98 b	Cacanska Lepotica	8.45 a	$N_8P_8K_8$	7.90 c
20 mm	8.47 b			$N_{16}P_{16}K_{16}$	8.93 b
30 mm	9.55 a			$N_{24}P_{24}K_{24}$	9.74 a
LSD5% = 0.56		LSD5% = 0.36		LSD5% = 0.54	

Means with different letters are significant at $p < 0.05$.

As such, the three watering amounts showed major and strongly statistically assured influences, determining progressive increases in the diameter of the stem between 12.59 and 34.75%.

Changing the watering amount from 10 to 20 mm had a negligible impact linked to an increase in diameter of only 6.17%. Instead, an increase in this characteristic of 12.73% was found when irrigation was increased from 20 to 30 mm.

Regarding the individual effect of the cultivars, the stem diameter registered a variation of 0.36 cm and low variability, from 8.09 cm in the case of Stanley seedlings to 8.45 cm in the case of Cacanska Lepotica (Table 2).

Therefore, over the course of the entire experiment, it was confirmed that the cultivar had no discernible impact on the seedlings' diameter increase under the 2020 climate.

Considering the many fertilization techniques, the stem diameter showed a variation amplitude of 3.24 cm, with values between 6.51 cm under unfertilized agricultural conditions and 9.74 cm in the case where the 24 kg NPK dose was applied, with a variability of 8.49% among treatments.

The application of NPK fertilization variants led to the recording of significant increases in this characteristic of 21.51–49.79% compared with the non-fertilized agricultural conditions. The seedlings successfully used the additional fertilizer, which increased from 8 to 16 kg and from 16 to 24 kg, respectively, to produce notable gains of 9.18–12.92%.

3.3. Effect of Irrigation × Cultivar Interaction on Stem Diameter

In the case of the Cacanska Lepotica cultivar, it appears that the three watering amounts did not produce substantial changes compared with the non-irrigated variant, considering the influence of the interaction between cultivar and irrigation on the stem diameter of the seedlings. Only the application of amounts of 20 and 30 mm to Stanley cultivar seedlings led to the identification of substantial increases; the influence of the 10 mm amount was negligible and smaller than that in the Cacanska Lepotica cultivar. Considering the interaction between irrigation and the diameter of the plot for the seedlings of the Stanley cultivar, it was observed that only 20–30 mm irrigation allowed for a significant variation of 12.26–27.45%. By contrast, the influence of the 10 mm watering amount was negligible. Additionally, merely increasing the watering rate from 20 to 30 mm resulted in a notable 13.53% increase in diameter in the cultivar's seedlings (Table 3).

Under the effect of different watering amounts, the seedlings of the Cacanska Lepotica cultivar recorded a stem diameter from 6.98 cm in the case of the non-irrigated variant up to 9.93 cm in the 30 mm variant, with a variability between treatments of 20.53%.

Compared with the non-irrigated agricultural group, this cultivar's samplings successfully benefited from all three watering amounts, exhibiting notable increases ranging from 15.33 to 42.29%. When the irrigation standard was gradually adjusted by 10 mm, notable variations in this characteristic, ranging between 10.14 and 12.02%, were observed.

Table 3. Stem diameter under effect of cultivar × irrigation interaction.

	Watering Amounts					
Cultivar	**0 mm**	**10 mm**	**20 mm**	**30 mm**	$\bar{x} \pm s_{\bar{x}}$	**CV**
Stanley	z 7.20 a	yz 7.91 a	y 8.08 b	x 9.17 b	8.45 ± 0.20	21.66
Cacanska Lepotica	u 6.98 a	z 8.04 a	y 8.86 a	x 9.93 a	8.09 ± 0.18	20.53
$\bar{x} \pm s_{\bar{x}}$	7.09 ± 0.24	7.09 ± 0.21	8.47 ± 0.26	9.55 ± 0.25	8.27 ± 0.14	
CV	21.87	16.43	19.02	16.54	21.13	

Cultivar LSD5% = 0.73 cm; means with different letters (a and b) are significant at $p < 0.05$ in vertical comparisons of cultivars. Irrigation LSD5% = 0.74 cm; means with different letters (x, y, z, and u) are significant at $p < 0.05$ in horizontal comparisons of watering amounts.

When the stem diameters of the two cultivars were compared under varying watering rates, it was found that the Stanley cultivar exhibited better behavior under agricultural conditions where 20–30 mm of water was applied. This was demonstrated by a growth spurt of 8.23–9.69% (Table 3).

In the absence of irrigation, the stem diameter of the Cacanska Lepotica cultivar was reduced by approximately 3%, without this difference reaching the level of statistical significance. The two seedling types benefited from irrigation to comparable degrees, with the typical irrigation amount of 10 mm.

Regarding the Stanley cultivar, the impact of watering on the growth of seedlings could be estimated by means of an exponential regression, with a precision of 93.78%.

As a result, the value increased at an average rate of 0.07 cm/mm of watering with a variation of 7.2 cm for the non-irrigated kind, with values ranging from 0.02 to 0.11 cm/mm of watering. The relationship between the watering rate and the increase in the stem diameter in the seedlings of the Cacanska Lepotica cultivar was calculated with a precision of approximately 99.5% by means of an exponential function.

Thus, compared with the average value of 7.05 cm in the absence of irrigation, the average rate of increase in this characteristic was 0.1 cm/mm of watering, with different values among the different irrigation amounts (0.08–0.11 cm/mm of watering). It was observed that the Cacanska Lepotica cultivar benefited more from irrigation (Figure 5).

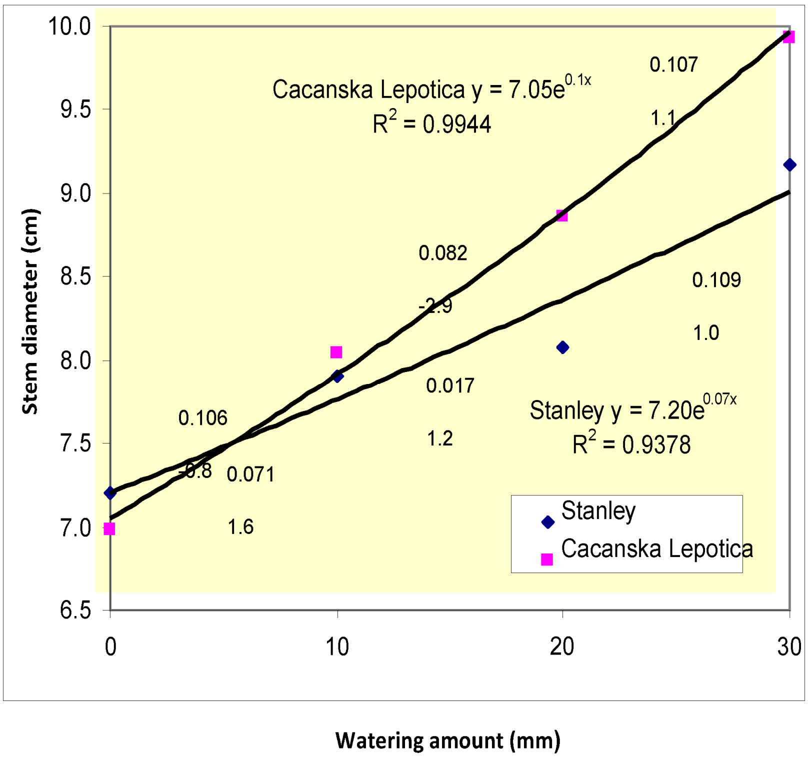

Figure 5. Variation in stem diameter for the two cultivars under effect of different watering norms.

3.4. Effect of Irrigation × Fertilization Interaction on Stem Diameter

When examining how fertilization affected the diameter increase attained at a given watering rate, the non-irrigated cultivar had the largest variation amplitude, while 30 mm irrigation displayed the lowest variation amplitude. There was small variation among NPK dosages (Table 4).

Table 4. Stem diameter under effect of irrigation x fertilization interaction.

	NPK Doses					
Irrigation	$\mathbf{N_0P_0K_0}$	$\mathbf{N_8P_8K_8}$	$\mathbf{N_{16}P_{16}K_{16}}$	$\mathbf{N_{24}P_{24}K_{24}}$	$\bar{x} \pm s_{\bar{x}}$	**CV**
0 mm	z 4.92 c	y 6.84 c	x 8.13 b	x 8.46 c	7.09 ± 0.24	21.87
10 mm	z 6.53 b	yz 7.45 bc	y 8.42 b	x 9.52 b	7.09 ± 0.21	16.43
20 mm	z 6.65 b	y 8.44 ab	y 8.62 b	x 10.18 ab	8.47 ± 0.26	19.02
30 mm	y 7.93 a	y 8.90 a	x 10.54 a	x 10.83 a	9.55 ± 0.25	16.54
$\bar{x} \pm s_{\bar{x}}$	6.51 ± 0.24	7.90 ± 0.17	8.93 ± 0.19	9.74 ± 0.20	8.27 ± 0.14	
CV	23.23	13.83	13.48	12.67	21.13	

Irrigation LSD5% = 1.06 cm; means with different letters (a, b, and c) are significant at $p < 0.05$ in vertical comparisons of watering amounts. Fertilization LSD5% = 1.07 cm; means with different letters (x, y, and z) are significant at $p < 0.05$ in horizontal comparisons of NPK doses.

Compared with the version without irrigation, the three watering amounts made it possible to achieve very noticeable increases in seedling growth under these conditions, with values ranging from 32.76 to 61.34%. Changing watering amounts from 10 to 20 mm did not generate significant increases, while increasing irrigation from 20 to 30 mm was connected with a notable increase in stem diameter of 19.25%.

In the absence of fertilization, the investigated watering amounts allowed for the acquisition of stem diameter values ranging from 4.92 cm under the non-irrigated agricultural conditions to 7.93 cm under 30 mm irrigation, with a variance of 21.87% between the watering amounts (Table 4).

This characteristic varied under 8 kg of NPK fertilization, ranging from 6.84 cm for the non-irrigated cultivar to 8.9 cm under 30 mm watering. When compared with the non-irrigated alternative, only the 20 and 30 mm watering amounts in this agricultural area showed statistically significant increases of 23.41–30.21%.

Furthermore, increasing the watering rate from 10 to 30 mm resulted in a significant variation of 19.50% in stem diameter, whereas changing the rate by 10 mm had no notable effect.

As a result of applying the treatment with 16 kg of NPK fertilizer, the stem diameter was between 8.13 and 10.54 cm. In this case, only the watering amount of 30 mm showed a significant positive effect of 29.58% greater growth and thickness of the seedlings compared with the non-irrigated version. Instead, employing 20 to 30 mm irrigation allowed for a significant increase of 22.29% in stem diameter.

Considering the fertilization process with 24 kg of NPK fertilizer, the application of irrigation with the three watering amounts determined a significant increase in this characteristic of 12.47–27.96%. In the case of this agricultural experiment, the differences between the watering amounts were small and insignificant; only the increase in watering from 10 to 30 mm showed high efficiency, evidenced by a 13.77% increase in diameter.

Considering the impact of fertilization on stem diameter in seedlings under different watering rates, it was observed that in the absence of irrigation, the seedlings recorded values ranging from 4.92 cm for the unfertilized variant up to 8.46 cm for the variant with 24 kg of NPK application, with a variability among treatments of 21.87%. Compared with the non-fertilized agricultural conditions, the applied treatments had significantly higher efficiency, evidenced by increases in this characteristic of 39.02–71.95%. Only the change in the dose of NPK from 8 to 16 kg was associated with significant effects of a 18.86% increase in thickness in the seedlings.

Under 10 mm irrigation, the applied fertilization options allowed for the acquisition of stem diameters ranging between 6.53 cm for the unfertilized agricultural specimens and 9.52 cm for specimens to which the dose of 24 kg of NPK fertilizer was applied, with an amplitude of variation of 2.99 cm and a variability of 16.43% among treatments.

Under these soil moisture conditions, only the application of 16–24 kg of NPK fertilizer generated significant increases in seedling diameter of 28.94–45.79% compared with the unfertilized version. Additionally, compared with doses of 8–16 kg, the treatment with 24 kg of NPK fertilizer had a significantly greater impact on stem diameter, resulting in increases ranging from 13.06 to 27.79%.

Under the effect of 20 mm irrigation, fertilization with NPK showed a significant effect on the increase in seedling diameter, associated with increases of 26.92–53.08%. The increase in NPK fertilization from 8 to 16 kg had a small and insignificant effect, but the application of 24 kg of NPK fertilizer generated significant increases of 18.1–20.62% in thickness in seedlings compared with the other two doses.

Under the circumstances where 30 mm watering was applied, the seedlings showed stem diameter values from 7.93 cm in the unfertilized variant up to 10.83 cm in the variant with 240 kg of NPK fertilizer, with a variability among treatments of 16.54%.

Compared with the unfertilized agricultural background, only the application of 16–24 kg of NPK fertilizer had significantly higher efficiency, evidenced by increases of 32.91–36.57%. The progressive modification of the dose of NPK fertilizer from 8 to 16 and 24 kg was associated with significant effects of 18.43–21.69% greater thickness in seedlings. The increase in NPK fertilization from 16 to 24 kg had a small and insignificant influence on stem diameter.

In the case of the non-irrigated version, the exponential regression indicates that the increase in stem diameter revealed a mean rate of 0.15 cm for each kg of NPK fertilizer applied, with values from 0.04 between the doses of 16 and 24 kg to 0.24 cm/kg of NPK between the unfertilized version and the 8 kg dose (Figure 6).

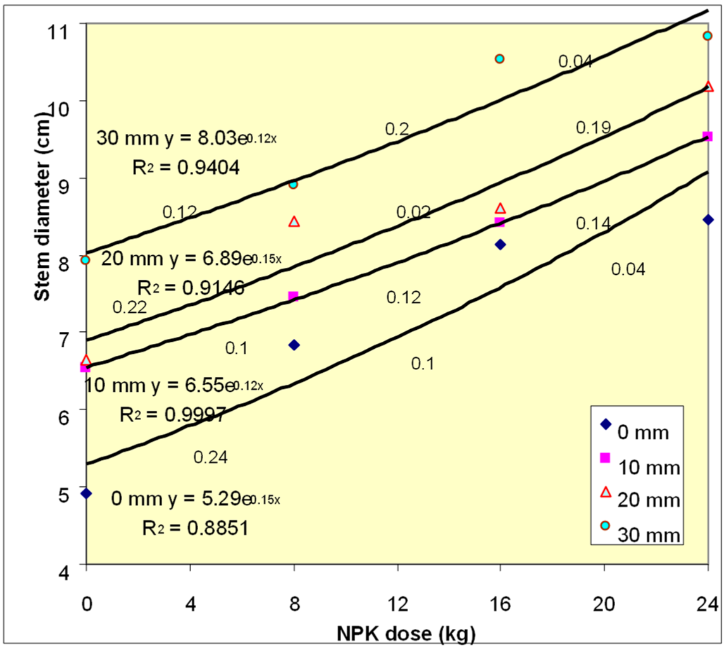

Figure 6. Variation in stem diameter under effect of different watering amounts and NPK doses.

With a stem diameter of roughly 5.3 cm, the corresponding estimates had an accuracy of 88.5% in the absence of fertilization.

For the watering rate of 10 mm, the impact of fertilization on the thickness of the seedlings was expressed by a regression with a precision of 99.97% and indicates an average increase in this characteristic at a relatively constant rate of 0.12 cm/kg of NPK.

Under 20 mm irrigation, a variation in stem diameter associated with an average rate of 0.15 cm/kg of NPK was found, with a coefficient of determination of 91.5% and an initial value of this characteristic of 6.89 cm for non-irrigated agricultural land.

With an estimation accuracy of 94 percent, the average rate of increase in diameter under 30 mm irrigation was 0.12 cm/kg of NPK fertilizer applied, with values among doses (0.04–0.2 cm/kg of NPK).

3.5. Effect of Fertilization × Cultivar Interaction on Stem Diameter

Concerning the impact of fertilization on and the variation in the diameter of the stem, only in the Stanley cultivar, the treatments with NPK showed significantly positive influences, with small variations among the treatments. In the case of seedlings of the Cacanska Lepotica cultivar, fertilization did not significantly influence the diameter of the stem (Table 5).

Table 5. Stem diameter under effect of cultivar × fertilization interaction.

Cultivar	NPK Doses					
	$N_0P_0K_0$	$N_8P_8K_8$	$N_{16}P_{16}K_{16}$	$N_{24}P_{24}K_{24}$	$\bar{x} \pm s_{\bar{x}}$	CV
Stanley	z 5.81 b	y 7.86 a	x 9.13 a	x 9.56 a	8.45 ± 0.20	21.66
Cacanska Lepotica	z 7.20 a	z 7.95 a	y 8.73 a	x 9.93 a	8.09 ± 0.18	20.53
$\bar{x} \pm s_{\bar{x}}$	6.51 ± 0.24	7.90 ± 0.17	8.93 ± 0.19	9.74 ± 0.20	8.27 ± 0.14	
CV	23.23	13.83	13.48	12.67	21.13	

Cultivar LSD5% = 0.74 cm; means with different letters (a and b) are significant at $p < 0.05$ in vertical comparisons of cultivars. Fertilization LSD5% = 0.76 cm; means with different letters (x, y, and z) are significant at $p < 0.05$ in horizontal comparisons of NPK doses.

Considering the impact of the variant on stem diameter under various fertilization conditions, there was a variation from 0.09 cm at the dose of 8 kg of NPK fertilization to 1.39 cm for the unfertilized variant.

Considering this variation, in the non-fertilized variant of the cultivar Cacanska Lepotica, the stem diameter grew at a substantially higher rate, accounting for 23.92% of the seedling diameter. The seedlings of the two cultivars benefited from comparable levels of fertilization, with the Stanley cultivar experiencing greater gains in diameter under agricultural conditions with 16–24 kg of NPK fertilization. However, the differences between the two cultivars were not statistically significant.

In terms of how fertilization affected the increase in stem diameter in each cultivar, in Stanley plants, the results ranged from 5.81 cm for the unfertilized version to 9.56 cm when 24 kg of NPK fertilizer was applied. The three treatments significantly increased this property by 35.28–64.54% compared with the unfertilized variant. Additionally, it was discovered that a notable increase in thickness in the seedlings of 16.16–21.63% was related to the gradual increase in dosage from 8 to 16 and 24 kg. The increase in NPK fertilization from 16 to 24 kg did not significantly influence the diameter of the stem of this cultivar.

According to the results of the exponential regression, the diameter in the Cacanska Lepotica cultivar varied at an average rate of 0.11 cm for every kg of NPK fertilizer, with values from 0.09 cm/kg of NPK fertilization for initial doses and up to 0.15 cm/kg of NPK fertilization for the 24 kg dose (Figure 7).

When stems were not fertilized, the estimates showed a precision of 99.5% based on a stem diameter of roughly 7.16 cm.

The Stanley cultivar showed a stronger response to fertilization in terms of increased seedling diameter, with an average growth rate of 0.16 cm/kg of NPK fertilizer, with variations from 0.05 cm/kg of NPK fertilization between the two larger treatments and 0.25 cm/kg of NPK fertilization between the 8 kg dose and the unfertilized version.

Based on an initial value of 6.21 cm for unfertilized soil, the logarithmic regression between the fertilization dosage and the increase in seedling thickness in the Stanley cultivar showed 89.1% predictability. The difference in fertilization application among the cultivars can also be seen from the slope of the regression lines, which is higher for the Stanley cultivar (Figure 7).

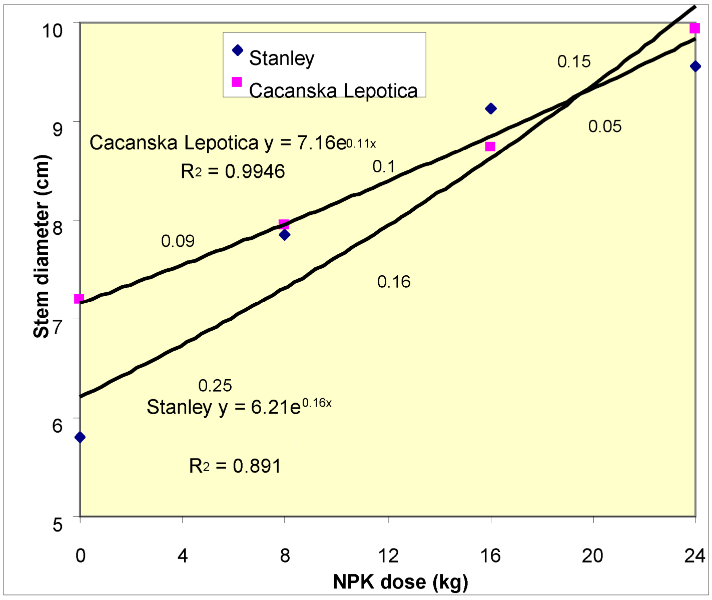

Figure 7. Variation in stem diameter under the effect of different fertilization doses.

3.6. Effect of Irrigation × Fertilization × Cultivar Interaction on Stem Diameter

The variation in Cacanska Lepotica cultivar seedling diameter was less correlated with the effects of fertilization, with a variation of 2.73 cm, ranging from 7.2 cm under unfertilized agricultural conditions to 9.93 cm at the dosage of 24 kg of NPK fertilizer. The NPK dose of 8 kg showed a small and insignificant influence of 0.75 cm on the increase in seedling diameter. Instead, the other two treatments generated significant increases of 21.25–37.92%. The addition of fertilization by progressively increasing the doses determined a significant increase of 9.81–13.75% in the development of seedlings of the Cacanska Lepotica cultivar. Considering the combined effect of the three factors, fertilization had a more pronounced effect on the diameter of seedlings of the Cacanska Lepotica cultivar, especially on non-irrigated farmland, compared with the seedlings of the Stanley cultivar (Table 6).

Fertilization resulted in a notable increase in the diameter of Stanley cultivar seedlings on the non-irrigated farmland of 2.64–4.13 cm, with negligible differences among the three doses administered.

When 10 mm irrigation was used, the diameter of seedlings fertilized with 24 kg of NPK increased significantly more than that of seedlings fertilized with 8 kg of NPK or the untreated cultivar. Fertilization had a smaller impact on the diameter of the seedlings when 20 mm irrigation was used. This was accompanied by considerable increments of 3.53–4.75 cm in comparison to the non-fertilized version, as well as negligible variations among the three doses. When 30 mm irrigation was applied, when comparing the treatments with 16–24 kg of NPK fertilizer to the other two fertilization methods, it was found that there was a noticeable increase in stem diameter. When 16–24 kg of NPK fertilizer was applied to Cacanska Lepotica cultivar non-irrigated seedlings, the diameter of the stem increased significantly by 2.3–3.6 cm compared with the untreated group. Furthermore, a far higher efficiency was found for the 24 kg dose compared with the 8 kg NPK dose.

In contrast to other variations, the seedlings of this cultivar demonstrated a notable increase in stem diameter under the influence of 10 mm irrigation, demonstrating an excellent utilization of the 16–24 kg NPK treatments. Only 24 kg of NPK fertilizer, with minor differences among the three dosages, enabled a considerable increase in the stem diameter by 2.3 cm under 20 mm irrigation. Under the conditions of 30 mm irrigation, the seedlings efficiently utilized 16–24 kg fertilization, registering significant increases in this characteristic of 1.6–2.6 cm compared with the non-fertilized version.

Table 6. Stem diameter under effect of irrigation × fertilization × cultivar interaction.

Watering Amount: 0 mm				
	NPK dose			
Cultivar	$N_0P_0K_0$	$N_8P_8K_8$	$N_{16}P_{16}K_{16}$	$N_{24}P_{24}K_{24}$
Stanley	y 4.63 a	x 7.27 a	x 8.76 a	x 8.12 a
Cacanska Lepotica	z 5.20 a	yz 6.40 a	xy 7.50 a	x 8.80 a
Watering Amount: 10 mm				
	NPK dose			
Cultivar	$N_0P_0K_0$	$N_8P_8K_8$	$N_{16}P_{16}K_{16}$	$N_{24}P_{24}K_{24}$
Stanley	z 6.25 a	yz 7.42 a	y 8.14 a	x 9.83 a
Cacanska Lepotica	z 6.80 a	yz 7.48 a	xy 8.70 a	x 9.20 a
Watering Amount: 20 mm				
	NPK dose			
Cultivar	$N_0P_0K_0$	$N_8P_8K_8$	$N_{16}P_{16}K_{16}$	$N_{24}P_{24}K_{24}$
Stanley	y 5.10 b	x 8.63 a	x 8.73 a	x 9.85 a
Cacanska Lepotica	y 8.20 a	y 8.24 a	y 8.50 a	x 10.50 a
Watering Amount: 30 mm				
	NPK dose			
Cultivar	$N_0P_0K_0$	$N_8P_8K_8$	$N_{16}P_{16}K_{16}$	$N_{24}P_{24}K_{24}$
Stanley	y 7.26 a	y 8.10 b	x 10.87 a	x 10.45 a
Cacanska Lepotica	y 8.60 a	xy 9.70 a	x 10.20 a	x 11.20 a

Cultivar LSD5% = 0.74 cm; means with different letters (a and b) are significant at $p < 0.05$ in vertical comparisons of cultivars. Fertilization LSD5% = 0.76 cm; means with different letters (x, y, and z) are significant at $p < 0.05$ in horizontal comparisons of NPK doses.

On non-fertilized agricultural land, the seedlings of the Cacanska Lepotica cultivar made more efficient use of 20 mm irrigation, registering a notable increase in the stem diameter compared with the Stanley cultivar. Also, in the case of 8 kg NPK fertilization and 30 mm irrigation, the diameter of the stem in the seedlings of the Cacanska Lepotica cultivar had a significantly higher value (1.6 cm higher) than the seedlings of the Stanley cultivar. There were no discernible differences between the two cultivars in this trait under the other fertilization and irrigation combinations.

4. Discussion

In the agrotechnical field of environmental protection, this research may be considered very up to date, especially in light of the apparent changes in global climate and the food and energy crises. The results of the undertaken research confirm the working hypothesis and complement the current knowledge in the field. The positive influence of the watering amounts and the doses of fertilizers on the number of plum seedlings obtained from the two analyzed cultivars has been highlighted. The current research has theoretical and practical implications in the domain of fruit growing, with regard to developing horticultural fields and increasing their productive level, ensuring the increase in economic efficiency and profit. It also provides information on obtaining fruit planting material through the application of various irrigation and fertilization doses to plum seedlings in nurseries.

In the climate context of recent years, Romania is facing the phenomenon of complex agricultural drought, which represents a climatic hazard phenomenon that induces the most serious consequences in agriculture.

Changes in climate have an impact on the rainfall regime, with the volume of annual precipitation and monthly distribution favoring the appearance of dry periods or, on the contrary, periods with excessive precipitation [38]. Global warming intensifies the processes of plant transpiration and water absorption, as well as that of water evaporation from the soil surface, and reduces the amount of water available for plants [39]. High temperatures, strong insolation, drought, and excessive irrigation also increase soil salinity, which has a negative impact on plants [40]. The simultaneous action of these stress factors induces numerous morphological, physiological, biochemical, and molecular changes in crop plants, unfavorably affecting their growth, development, and production [41].

A characteristic shortcoming of the climatic regime in Romania, which is reflected quite significantly in fruit growing, is the defective distribution of precipitation during the year, resulting in prolonged periods of drought in some areas. Considering these aspects, associated with the tendency to develop important fruit-growing centers in typically dry areas, on zonal soils, and on sands, irrigation must be a concern of prime importance for the fruit-growing sector in our country. However, the specifics of this concern vary based on the pedo-climatic zone, type of rootstock, etc.

Research on the application of fertilizer and irrigation in nurseries is limited, since most studies have focused on fruit tree orchards. The present study aims to investigate a current issue, namely, the production of quality fruit tree planting material associated with economically efficient activity at the level of nurseries, which requires considering both the pedo-climatic conditions in the area where the planting material is produced and the components of applied technology.

5. Conclusions

The results of this research show that the fertilization treatments had the highest impact on stem diameter compared with irrigation and the plant variety, considering that the cultivar did not significantly influence the increase in the diameter of grafted trees. When compared with the non-fertilized agricultural conditions, the stem diameter dramatically increased by 21.51–49.79% after various doses of NPK were applied. The combined application of irrigation and fertilization with NPK is recommended to obtain high-quality planting material production. It is also necessary to monitor the soil water reserve and apply irrigation in periods of water deficit when the trees need high levels of water. As future research directions, it is necessary to establish the influence of irrigation, fertilization, and cultivar on other morphological and physiological characteristics, as well as on the production of grafted trees and their economic efficiency.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16062496/s1, Table S1: Analysis of variance regarding the effect of cultivar, irrigation, and fertilization on stem diameter.

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