doi:10.14720/aas.2024.120.4.16352 Original research article / izvirni znanstveni članek

Growth and quality of 'Gulfblaze' plums subjected to fertigation

Vinício Grezele FOCHESATTO [1], Wendel Paulo SILVESTRE[1, 2, 3], Katiúscia Fonseca dos Santos STRASSBURGER [4], Carine COCCO [1]

Received October 12, 2023, accepted October 14, 2024
Delo je prispelo 12. oktober 2023, sprejeto 14. oktober 2024

Growth and quality of 'Gulfblaze' plums subjected to fertigation

Abstract: This work aimed to evaluate the effect of applying different doses of fertilizers through fertigation on the production, fruit quality, and nutritional status of the plum tree' Gulfblaze'. The experiment was conducted in Antônio Prado, RS, during the 2019/2020 harvest in a 'Gulfblaze' plum orchard established in 2014, with a density of 800 plants per hectare. The treatments applied were T1: Irrigation only, without fertilizer application; T2: Fertigation with 50 % of the dose recommended by CQFS-RS/SC; T3: Fertigation with 100 % of the recommendation; T4: Fertigation with 150 % of the recommendation, and T5: Fertigation at 200 % of the recommendation. A randomized block experimental design was used, with five treatments and three replications, with each plot consisting of 26 plants, and of these, five were used for evaluations. The diameter, length, and average mass of fruits increased as the fertigation doses increased. The firmness of the fruit pulp, as well as the leaf area of the plant, performed better at doses of 150 % and 200 % of the recommended amount. The highest and lowest fertigation doses promoted a higher soluble solids content and SS/AT ratio, indicating an improvement in the qualitative parameters of the plums.

Key words: fruticulture, nutrition, plant growth, Prunus salicina, soluble solids

Rast in kakovost sliv 'Gulfblaze' obravnavanih s fertigacijo

Izvleček: Namen raziskave je bil ovrednotiti učinke različnih odmerkov gnojil pri fertigaciji na obrod, kakovost plodov in stanje prehranjenost sliv 'Gulfblaze'. Poskus je potekal v Antônio Prado, RS, v rastni sezoni in obiranju 2019/2020 v nasadu sliv 'Gulfblaze', ki je bil osnovan 2014, z gostoto 800 dreves na hektar. Obravnavanja so bila sledeča: T1- samo namakanje, brez dodatka gnojil; T2 –fertigacija s 50 % odmerkom, kot jih priporoča CQFS-RS/SC; T3- fertigacija s 100 % odmerkom, kot je priporočeno; T4- fertigation s 150 % odmerkom priporočenega in T5- fertigation z 200 % odmerkom priporočenega. Uporabljen je bil naključni bločni poskus s petimi obravnavanji in tremi ponovitvami, kjer je vsak blok sestavljalo 26 dreves, od katerih je bilo pet uporabljenih za ovrednotenja. Premer, dolžina in poprečna masa plodov so naraščali z naraščanjem odmerka gnojil v fertigaciji. Čvrstost pulpe plodov in listna površina dreves sta bili boljši pri odmerkih 150 % in 200 % priporočene količine. Največji in najmanjši odmerki v fertigaciji so povečali vsebnost topnih snovi v plodovih kot tudi razmerje SS/AT, kar kaže na izboljšanje kakovostnih parametrov sliv.

Ključne besede: sadjarstvo, prehrana in rast rastlin, Prunus salicina, topne snovi

1 University of Caxias do Sul, Course of Agronomy, Caxias do Sul, RS, Brazil.
2 University of Caxias do Sul, Postgraduate Program in Process Engineering and Technologies (PGEPROTEC) and Laboratory of Studies of the Plant-Environment System, Caxias do Sul, RS, Brazil.
3 Corresponding author. E-mail: wpsilvestre@ucs.br
4 Federal University of Pelotas, Department of Agronomy, Pelotas, RS, Brasil.

1 INTRODUCTION

The plum tree is a plant that is part of the botanical family Rosaceae and the genus *Prunus*. Commercially, two species of this plant stand out: *Prunus salicina* Lindl., known as the Japanese plum, and *Prunus domestica* L., known as the European plum. However, the Japanese variety is more common in Brazil due to its adaptability to milder climates (Dalbó et al., 2021), while the European hexaploid variety (2n = 48) requires colder climatic conditions to thrive (Mayer et al., 2019; Castro et al., 2008).

In Brazil, it is not known precisely when this crop was introduced (Eidam et al., 2012), but it has been gaining prominence in recent years due to consumers' good acceptance of the fresh fruit (Castro et al., 2008). Data from IBGE (2017) show that the country produced 45,614 t of plums in an area of 3,837 ha. Of this production, 76.6 % is concentrated in the South region. The State of Rio Grande do Sul is the largest national producer, with 21,097 t produced in an area of 1,623 ha. In the state, the municipality of Caxias do Sul is the leading producer, responsible for 7,949 t, followed by Antônio Prado and Ipê, which produce 3,143 t and 1,326 t, respectively.

Among the most important cultivars is 'Gulfblaze', an early maturing cultivar, generally beginning to mature in mid-November. The plants require cross-pollination and are semi-vigorous, with an open growth habit and low winter cold requirements. The fruits are round and medium in size, around 49 mm in diameter, with an average mass of 50–65 g. The pulp is yellow, and the skin is red, with a sweet-acid flavor but with acidity and bitterness in the skin (Dalbó et al., 2021; Simonetto et al., 2007).

Farmers have adopted new technologies in their cultivation to meet consumer market demand and improve fruit production and quality. These innovations have proven especially relevant to mitigate the challenges arising from climate fluctuations observed in recent years (Junges et al., 2020). In Rio Grande do Sul, a state known for its high levels of rainfall, it is typical for periods of drought to occur due to the irregular distribution of rainfall, especially in crucial phases of the cultivation cycle, such as the growth until complete maturation of the fruits, harming fruit quality (Nachtigall & Hawerroth, 2023).

Water scarcity during fruit growing can affect fruit size, bud formation for the following year, and nutrient absorption (Nachtigall et al., 2012). Therefore, when the amount of water from rainfall is insufficient relative to potential evapotranspiration, it becomes essential to resort to irrigation to provide the water necessary for the crop cycle (Vélez, 2012). This practice ensures adequate availability of moisture, which is essential for plant development and fruit quality (Cechinel et al., 2022; Testezlaf, 2017).

Aiming to optimize the use of this system, many producers have adopted the fertigation technique, which consists of applying fertilizers with irrigation water (Pramanick et al., 2022; Septar & Stoli, 2019). This technique improves cultivation efficiency and contributes to the preservation of the environment, promoting sustainability in agriculture. Furthermore, fertigation represents a relevant alternative to dealing with the labor shortage in the field (Nachtigall, 2016; Soto & Parra et al., 2016).

Coelho et al. (2011) emphasize that localized irrigation, frequently used in fruit growing, restricts the root system of plants to the area wetted by the emitter. Therefore, it is necessary to provide nutrients to maintain production regularly. In this sense, fertigation stands out, as it allows the application of fertilizers to be divided into parts and more effective distribution in the area with a greater concentration of roots, reducing losses compared to the conventional system.

Furthermore, according to Silva et al. (2016), in the States of Rio Grande do Sul and Santa Catarina, the determination of nitrogen, phosphorus, and potassium doses is based on the levels present in the leaves and the expected productivity. However, Brunetto et al. (2011) highlight some drawbacks, such as not considering the increase in planting density and the nutritional requirements of the plants, the effects on the chemical and physical characteristics of the fruits, and the recommendation of fixed doses for productivity ranges when considering specific aspects of the location, like previous cultures. According to Mayer et al. (2019), the trend in contemporary fruit growing is to increase planting density in orchards, significantly increasing productivity. However, it is important to highlight that few studies in the specific literature are dedicated to adapting fertilizer levels, especially in high-density orchards. These factors can reduce the efficiency of applied fertilizers and exceed the plant's nutritional needs, which can increase production costs and cause future problems in the orchard.

Agricultural practices that combine irrigation and nutrition offer significant potential to increase productivity and quality, making production viable even in areas with low soil fertility and limited water availability. However, despite its evident benefits, its use is restricted due to inadequate technical training. Furthermore, farmers frequently have doubts regarding the economic return on this investment (Nachtigall, 2016).

In this context, the objective was to evaluate the effect of applying different doses of fertilizers, using fertigation, on fruit quality and nutritional status of the plum tree cultivar 'Gulfblaze' located in the Serra Gaúcha region, Southern Brazil.

2 MATERIAL AND METHODS

The experiment was conducted from July to November 2019 in a commercial orchard located in the municipality of Antônio Prado, in the ecoclimatic region of the Serra do Nordeste of Rio Grande do Sul, Southern Brazil (geographical coordinates are 28º50' S and 51º24' W, with an altitude of 673 m). The climate of this region is characterized as subtropical of the Cfb type, with mild summers, cold winters, and uniform rainfall throughout the year. The average annual rainfall is 1,700 mm, and the average temperature is 16.6 °C (Wrege et al., 2012).

The plum cultivar used was 'Gulfblaze', also known as Fla, in a five-year-old orchard on Okinawa rootstock. The plants were spaced 5.0 m between rows and 2.5 m between plants, with a planting density of 800 plants per hectare, cultivated in a cup system. The pollination system was based on using the Polli Rosa pollinator cultivar, implemented in a proportion of 10 %, being used exclusively as a pollinator. The orchard's production was intended for fresh consumption.

The following treatments were evaluated: T1 – Irrigation only, without fertilizer application; T2 – Fertigation with 50 % of the dose recommended by CQFS-RS/SC (2016); T3 – Fertigation with 100 % of the dose recommended by CQFS-RS/SC (2016); T4 – Fertigation with 150 % of the dose recommended by CQFS-RS/SC (2016); T5 – Fertigation with 200 % of the dose recommended by CQFS-RS/SC (2016). The experimental design was in randomized blocks with five treatments and three replications. Each plot consisted of 26 plants; five were used for evaluations. In these, two branches per plant were previously marked for later evaluations.

Before implementing the experiment, soil samples were collected in the 0–20 cm and 20–40 cm layers and were sent for chemical and fertility analysis. These analyzes presented the following average results: pH in water: 6.7; SMP Index: 6.5; H + Al: 2.5 $cmol_c{\cdot}dm^{-3}$; H: 2.46 $cmol_c{\cdot}dm^{-3}$; organic matter content: 3.2 % w/v; clay: 29 % w/v; P: 230.7 $mg{\cdot}dm^{-3}$; Na: 11.0 $mg{\cdot}dm^{-3}$; K: 279.0 $mg{\cdot}dm^{-3}$; Ca: 12.9 $cmol_c{\cdot}dm^{-3}$; Mg: 1.9 $cmol_c{\cdot}dm^{-3}$; Al: zero; base saturation: 15.6 $cmol_c{\cdot}dm^{-3}$; effective cation exchange capacity (CTC): 15.6 $cmol_c{\cdot}dm^{-3}$; CTC at pH 7: 18.03 $mg{\cdot}dm^{-3}$; base saturation (V): 86.4 %; Al saturation (m): zero; S: 7.4 $mg{\cdot}dm^{-3}$; Cu: 2.3 $mg{\cdot}dm^{-3}$; Zn: 22.0 $mg{\cdot}dm^{-3}$; B: 0.5 $mg{\cdot}dm^{-3}$; Mg: 1.2 $mg{\cdot}dm^{-3}$; Ca/Mg: 6.7; Ca/K: 18.2; Mg/K: 2.7; Ca/CTC: 71.8; Mg/CTC: 10.7 and K/CTC: 3.9. The nutrient doses for fertigation were defined based on the results of the soil analysis and the recommendations of the Soil Chemistry and Fertility Commission of Rio Grande do Sul and Santa Catarina (CQFS-RS/SC, 2016) for the plum tree. The dose recommended by CQFS-RS/SC (2016), based on organic matter content in the soil, and, thus, N content, was 80 $kg{\cdot}ha^{-1}$ N, 60 $kg{\cdot}ha^{-1}$ K, 40 $kg{\cdot}ha^{-1}$ P, 30 $kg{\cdot}ha^{-1}$ Ca, and 10 $kg{\cdot}ha^{-1}$ Mg, corresponding to a 100 % dose (T3).

Fertigation was carried out every two weeks from August 4, totaling eight applications, 14 days apart, and the fertilizers were distributed equally in each application. The sources of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) used were mono ammonium phosphate – Krista MAP (61 % P_2O_5 + 12 % N); potassium sulfate – Krista SOP (51 % K_2O + 18 % S); calcium nitrate – Calcinit (18 % Ca + 15.5 % N); magnesium nitrate – Krista MAG (11 % N + 9.3 % Mg) and mixed mineral fertilizer – Krista K (43 % K_2O + 12 % N + 1.0 % S + 1.0 % Mg).

The orchard had a drip irrigation system with two hoses per row and a spacing of 0.50 m per dripper. Irrigation management was carried out based on soil moisture, measured using two tensiometers installed at 0–20 cm, 20–40 cm deep, and 50 cm away from the plants. Irrigations occurred when the average soil water tension was lower than -10 kPa. The average water tension in the soil was considered to be between zero and -10 kPa, suitable for the crop, and irrigation was not carried out when it was within these established limits.

Phytosanitary treatments (fungicides, insecticides, and acaricides) were applied during the production cycle and based on weekly monitoring. Winter pruning was carried out in June, and manual fruit thinning was carried out in October, aiming to maintain 700 fruits per plant.

Evaluations were carried out during the experiment until fruit harvest, covering the period from October to November 2019. Two fruits were selected and identified on previously marked branches, totaling ten fruits per plot, for weekly evaluation of the diameter and length of the fruits after harvesting. Winter pruning was carried out in June, and manual fruit thinning was carried out in October, aiming to maintain 700 fruits per plant. The fruits' longitudinal and sagittal diameters and length were measured with a digital caliper, expressing the results in millimeters (mm). The daily fruit growth rate was calculated as the difference between the final and initial values divided by the number of days passed, and the results were expressed in millimeters per day ($mm{\cdot}day^{-1}$).

Plant tissue samples were collected on November 22, 2019. One hundred complete leaves were collected per treatment from previously marked plants in the middle portion of the branches emitted during the year on the four legs of the plant. Subsequently, the samples were sent to the Soil Chemistry and Fertility Laboratory of the University of Caxias do Sul to verify the levels of macro and micronutrients in the leaf tissue according to the methods described by Tedesco et al. (1995).

Thirty complete leaves were collected per treatment from previously identified plants to determine the average leaf area. These leaves were selected from the middle part of the branches that grew in the year in question on the four legs of each plant. Leaf area measurement was carried out by digitizing leaf images using an AM350 leaf area meter. The results obtained were expressed in square millimeters (mm^2).

A representative sample of ten fruits per plot was collected for fruit quality analyses on November 25, 2019. With a precision electronic scale, the average mass obtained was evaluated by the quotient between the mass and the number of 10 fruits, with the data expressed in grams per fruit ($g \cdot fruit^{-1}$).

The firmness of the pulp was determined using a digital penetrometer with an 11 mm tip. After removing the epidermis with a superficial cut of two discs of approximately 1.0 cm in diameter on diametrically opposite sides in the equatorial portion of the fruit, the reading was carried out, and the results were expressed in kilograms-force (kg f). The diameter and length of fruits were measured with a digital caliper, positioning the fruits in a vertical position to measure length and horizontally for diameter. The results were expressed in millimeters (mm).

Afterward, the fruit juice was extracted with an electric centrifuge to determine soluble solids (SS), titratable acidity (TA), and SS/TA ratio. The soluble solids content was determined with an analog refractometer, and the data were expressed in degrees Brix (°Bx). The titratable acidity was determined by titrating 2.0 ml of the sample juice diluted in 50 ml of distilled water and adding three drops of phenolphthalein indicator to acquire a pink color, proceeding to titrate the sample with sodium hydroxide solution (NaOH 0.1 N), with a glass burette until reaching pH 8.1 (turning point) and the results were expressed as a percentage (% w/v) of malic acid. The ratio was calculated as the quotient between the soluble solids content and the titratable acidity. The determinations followed methods described by the Instituto Adolfo Lutz (1985).

The data obtained were subjected to analysis of variance (ANOVA), and the means were compared using the Scott-Knott test, with a significance level of 5 % probability of error, using the statistical program System for Analysis of Variance (SISVAR).

3 RESULTS AND DISCUSSION

The data regarding the growth rates of plum fruits depending on the fertigation doses applied are compiled in Figure 1.

For the growth rate regarding the diameter of the longitudinal and sagittal axis of the fruits, the plants subjected to the fertigation dose of 200 % of the recommendation by CQFS-RS/SC (2016), presented higher values than the other treatments, followed by treatment 150 % of recommendation. However, the lowest daily growth rate values were observed in plants that did not receive any fertilization throughout the production cycle. The daily fruit growth rate for length was higher at the two

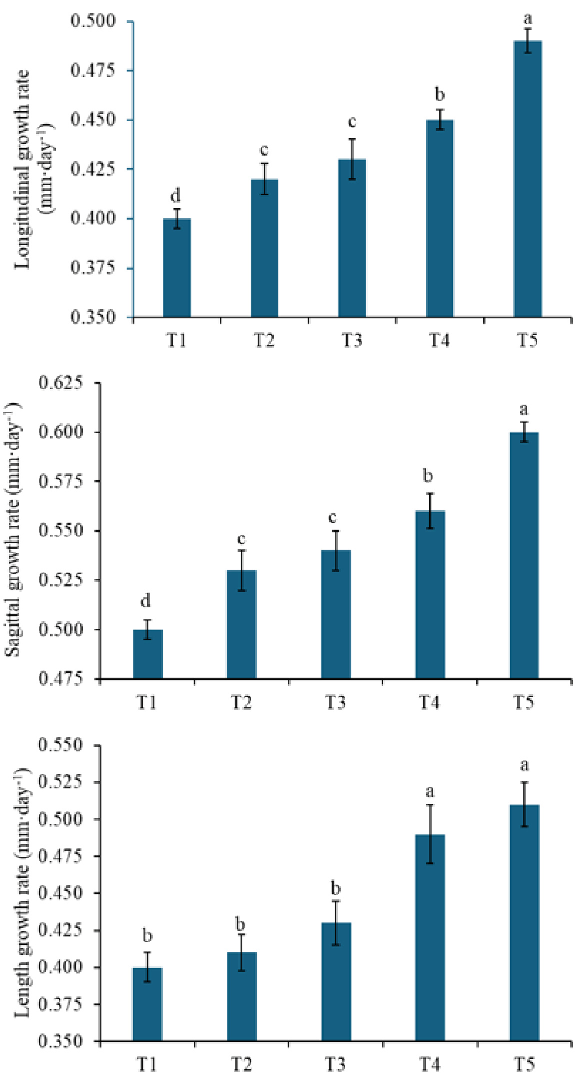

Figure 1: Daily growth rate of ‚Gulfblaze' plum fruits subjected to different doses of fertigation during the 2019/2020 cycle, Antônio Prado, RS. Means followed by the same lowercase letter do not differ statistically using the Scott-Knott Test at a 5 % error probability. T1 – control; T2 – 50 % of the recommendation; T3 – 100 % of recommendation; T4 – 150 % of recommendation; T5 – 200 % of recommendation. Coefficient of variation: Longitudinal: 3.14 %; Sagittal: 2.93 %; Length: 4.37 %.

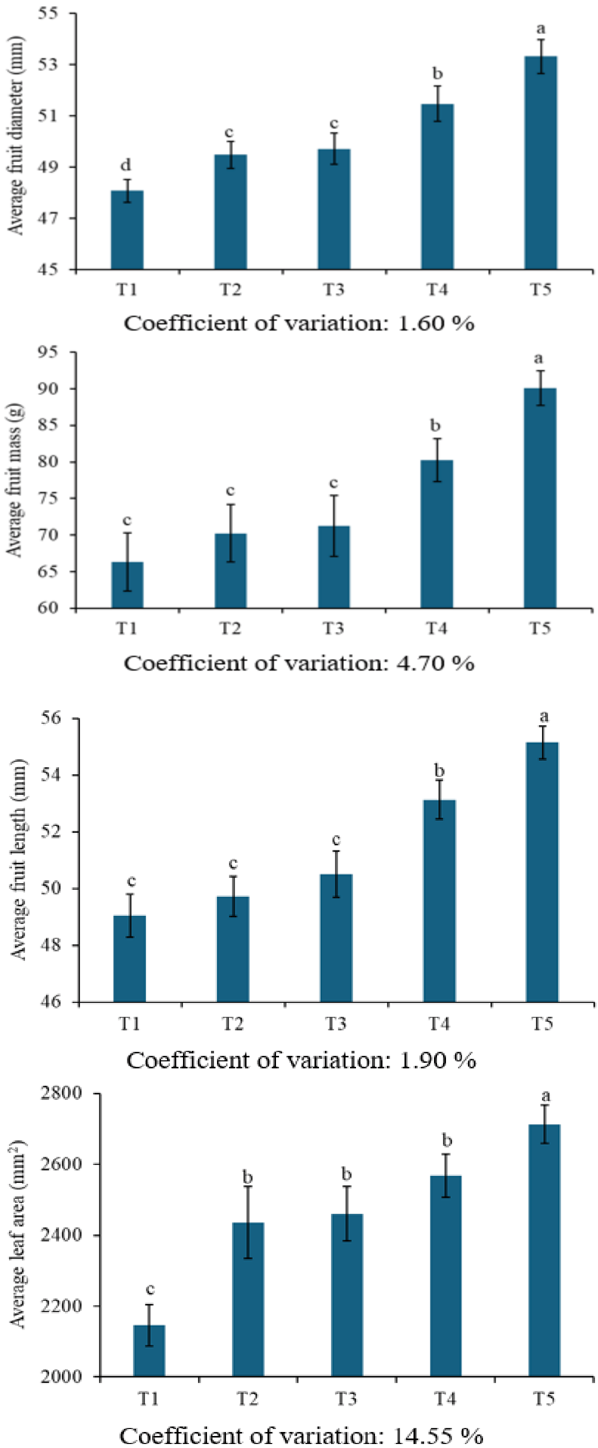

Figure 2: Biometric parameters of plums and leaf area of 'Gulfblaze' plum trees subjected to different doses of fertigation during the 2019/2020 cycle, Antônio Prado, RS. Means followed by the same lowercase letter do not differ statistically using the Scott-Knott Test at a 5 % error probability. T1 – control; T2 – 50 % of the recommendation; T3 – 100 % of recommendation; T4 – 150 % of recommendation; T5 – 200 % of recommendation.

highest doses, with 0.51 mm·day^{-1} and 0.49 mm·day^{-1}, respectively. In the control, doses of 50 % and 100 % of the recommendation showed the lowest growth rates.

The increase in the concentration of mineral nutrients, combined with the water availability provided by drip irrigation, increased the fruit growth rate. This phenomenon appears to be directly linked to the increase in the photosynthetically active surface of the plant, that is, to the expansion of the leaf area, which, in turn, resulted in greater production and availability of photoassimilates for the growth of plums (Pramanick et al., 2022). Data relating to biometric parameters of fruit diameter and length, average mass, and plant leaf area are compiled in Figure 2.

At harvest time, the fruit diameter, length, and leaf area variables were affected by fertigation treatments. For all these variables, it was observed that the increase in nutrient doses applied via fertigation increased these variables, positively affecting them. The fertigation treatment with 200 % of the dose recommended by CQFS-RS/SC (2016) was superior to the others. The control had a smaller fruit diameter and length at harvest than the other fertigation treatments, with 48.08 mm and 49.05 mm, respectively. On the other hand, the performance of 200 % and 150 % doses were 10.9 % and 7.1 %, higher than the control for fruit diameter and 12.4 % and 8.3 % for length, respectively. Chagas (2008) reported, for the cultivar ‚Gulfblaze', 48.3 mm in diameter and 46.1 mm in length of fruits in the 2007/2008 cycle in Jundiaí, SP, when characterizing cultivars with low cold requirements for subtropical regions of the state. For diameter, this result was greater than that observed in the control but lower than the treatments subjected to fertigation.

Fertigation treatment with 200 % of the dose recommended by CQFS-RS/SC (2016) resulted in the largest average leaf area (2,713 mm^2). In contrast, in the irrigation-only treatment, the plum trees had a smaller leaf area (2,146 mm^2). There was no difference between treatments with 50 %, 100 %, and 150 % doses. These results demonstrate a directly proportional relationship between leaf area and the quality parameters of fruit diameter and length, considering that an increase in leaf area was associated with an increase in the values of these parameters. Such a result may be related to the greater leaf area per plant, which may have provided greater availability of photoassimilates for the fruits. According to Franganito (2014), the leaf area and the functioning of the stomata influence productivity, as the first determines the interception of light, and the second controls the absorption of CO_2, an important drain of water and nutrients for the fruits.

However, contrary to what was observed in the present study, Chagas et al. (2016), when evaluating the effect of irrigation and fertigation on the leaf area of ‚Maxi Gala' and ‚Fuji Suprema' apple trees in the 2015/2016 harvest using conventional fertilization as treatments; conventional fertilization plus irrigation; irrigation plus fertigation and fertigation, no significant difference was observed between the treatments applied. Ferreira et al. (2018), when evaluating the effect of nitrogen fertilization (zero, 30 kg·ha^{-1}, 60 kg·ha^{-1}, and 120 kg·ha^{-1}) on peach trees ‚Cascata 1543' and ‚Cascata 1067' in an experiment conducted between 2012 and 2015 in the municipality of Pelotas, RS, found that the increase in nitrogen application promoted an increase in leaf area, being observed at a dose of 120 kg·ha^{-1} the largest average leaf area (1,882 mm^2) compared to the control (1,230 mm^2).

The leaf area is important for understanding photosynthesis, respiration, nutrient use, flowering, fruiting, and productivity (Demirsoy et al., 2004). Nitrogen is the nutrient most plants require, and those that most influence this variable since it is incorporated into the plant in the form of amino acids once absorbed from the soil solution. Thus, as the supply of this nutrient increases, proteins synthesized through amino acids promote leaf growth, increasing the photosynthetic area. Furthermore, nitrogen is involved in chlorophyll synthesis, and its deficiency decreases this synthesis. In situations with nutrient deficiency, there are losses in the photosynthetic process, reducing the efficiency of using sunlight and, consequently, the execution of essential functions, such as nutrient absorption (Dechen & Nachtigall, 2007).

From the results, it can be seen that, with the increase in the amount of nutrients made available to the plants, an expansion of the leaf area was obtained due to the greater photosynthetic area, resulting in a greater capacity to reallocate photosynthates and provide nutrients to the fruits, promoting greater potential for their growth.

For the variable average fruit mass, it was found that the plants that were subjected to fertigation doses of 200 % and 150 % of the recommendation had a mass increase of 35.8 % and 28.2 %, respectively, relative to the control (66.35 g·fruit^{-1}), which did not differ from the recommended doses of 50 % and 100 % (Figure 2). These results were superior to those obtained by Oliveira et al. (2019), who found fruits with an average mass of 60.0 g and 41.1 g, evaluating plum trees in Veranópolis, RS, classified plums with an average mass of less than 50 g as small, fruits with an average mass between 50–65 g as medium and fruits with an average mass of more than 65 g as large. With this classification, the fruits of the present study were considered large.

The greater average fruit mass increased fruit production and productivity, as observed in treatments with 150 % and 200 % of the CQFS-RS/CS (2016) recommendation. Considering the commercial scale of production, the average size of the fruits plays a crucial role in the viability of an orchard, as it directly impacts productivity and profitability. This is due to the potential to increase production per plant and positively influence the prices negotiated for larger caliber fruits on the market (Petri et al., 2016).

Considering that the average quantity of fruits kept on the plant after manual thinning is 700, it is possible to estimate the average production and productivity of the treatments. Using 100 % of the fertilizer recommendation according to CQFS-RS/SC, the estimated production and productivity are 49.8 kg·plant^{-1} and 39.8 t·ha^{-1}, respectively. On the other hand, with 200 % application of the recommendation, estimated production and productivity reach 63.1 kg·plant $^{-1}$ and 50 t·ha^{-1}, respectively, increasing 10.6 t·ha^{-1}, a 26.6 % increase relative to the recommended dose (T3). This result demonstrates the high productive capacity of the ‚Gulfblaze' cultivar, providing fruits with a high caliber when subjected to increased nutrient supply and under adequate water availability.

Data on the nutrient contents in the leaf tissue of the plum trees as a function of each fertigation regime is compiled in Table 1.

It is essential to highlight the increase in leaf potassium and nitrogen content, which, in high availability,

Table 1: Contents of nutrients in the leaf tissue of ‚Gulfblaze' plum trees subjected to different doses of fertigation during the 2019/2020 cycle, Antônio Prado, RS.

Treatment	N	P	K	Ca	Mg	S	Zn	Cu	Mn	Fe	B
			g·kg^{-1}						mg·kg^{-1}		
Control – T1	29.9	2.1	28.5	26.7	6.1	1.1	27.6	81.4	81.8	116.9	64.6
50 % – T2	29.3	2.3	24.9	25.7	6.2	0.7	28.1	96.8	84.8	120.2	60.5
100 % – T3	30.8	2.0	26.5	25.1	5.5	2.0	27.3	93.4	77.0	121.3	60.5
150 % – T4	29.8	1.7	20.3	18.7	4.2	1.5	20.1	76.4	72.2	94.1	57.7
200 % – T5	31.1	2.2	31.6	23.1	5.1	1.0	33.3	99.5	101.6	148.9	62.4

are related to the increase in fruit size. This is an important qualitative characteristic, as it adds value to the product, especially for fresh consumption. According to Dechen and Nachtigall (2007), adding nitrogen increases the availability of photosynthates to the fruits, providing greater plant growth and productive potential. For this, potassium is essential, as it helps in photosynthesis and, consequently, in cellular respiration and the accumulation of carbohydrates in the plant's tissues.

Furthermore, fruit size is determined by the genetic characteristics of each cultivar. Other management factors also influence it in the orchard besides nutrition and irrigation, such as pruning and thinning practices and applying phytoregulators. It is also important to consider the environmental and climatic conditions to which the orchard is subjected (Giovanaz et al., 2014).

The results of the present work differ from those observed by Cechinel et al. (2022) in ‚Kinkas' apple trees grown in São Joaquim, SC, during the 2014/2015 productive season. When evaluating the effect of irrigation and fertigation (conventional solid fertilization; conventional solid fertilization plus irrigation; fertigation plus irrigation and fertigation), they observed no difference in the treatments relative to the average fruit mass. Similarly, Dolinski et al. (2007), when evaluating the effect of different doses of nitrogen fertilizer (40 kg·ha^{-1}·year^{-1}, 80 kg·ha^{-1}·year^{-1}, 120 kg·ha^{-1}·year^{-1}, 160 kg·ha^{-1}·year^{-1}, and 200 kg·ha^{-1}·year^{-1}) and potash (55 kg·ha^{-1}·year^{-1}, 110 kg·ha^{-1}·year^{-1}, and 200 kg·ha^{-1}·year^{-1}) in the ‚Reubennel' plum tree in the region of Araucária, PR, in three consecutive years (2003, 2004, and 2005), the variable of average mass per fruit showed no difference between the evaluated treatments, with general averages in the range from 53 – 65 g·fruit^{-1}. The authors associated the lack of response to the high concentration of potassium in the soil in the study area and the supply of part of the nitrogen demand by soil organic matter, the natural presence of white clover, and rainwater. In the present study, it was observed that, even in fertile soil, this variable was affected by the treatments applied.

Nitrogen fertilization increases growth potential by increasing individual fruit mass at maturity and total fruit production (Saenz et al., 1997). On the other hand, the primary influence of potassium fertilization on the increase in average fruit mass is poorly understood. However, this nutrient is believed to participate in metabolic activities related to synthesizing and transporting carbohydrates and water to fruits, resulting in greater fruit mass (Aular & Natale, 2013). This may explain the greater average fruit mass with increasing nutrient doses in fertigation.

The results regarding the quality parameters of the evaluated fruits are presented in Figure 3.

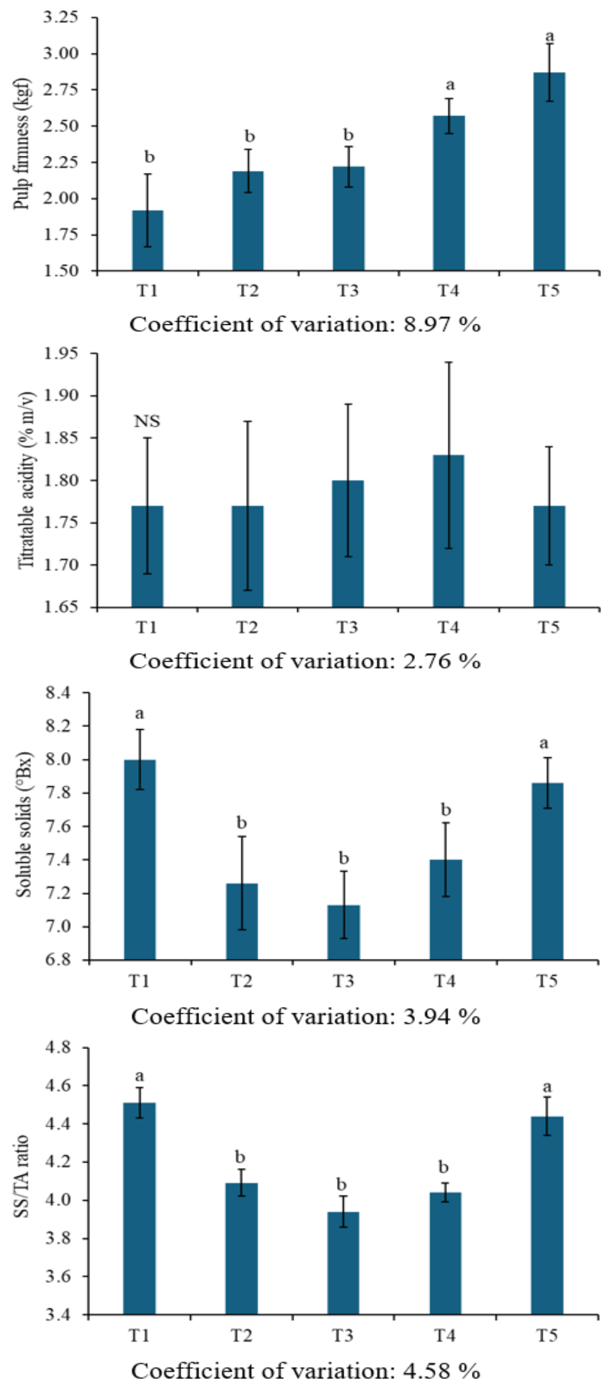

Figure 3: Results of pulp firmness, soluble solids content, titratable acidity, and SS/TA ratio of fruits from ‚Gulfblaze' plum trees subjected to different doses of fertigation during the 2019/2020 cycle, Antônio Prado, RS. Means followed by the same lowercase letter do not differ statistically using the Scott- Knott Test at a 5 % error probability. NS: not significant by the ANOVA. 1 – titratable acidity expressed as gram equivalents of malic acid per 100 ml of juice. T1 – control; T2 – 50 % of the recommendation; T3 – 100 % of recommendation; T4 – 150 % of recommendation; T5 – 200 % of recommendation.

There was no difference between treatments concerning the physical-chemical parameter of titratable acidity. However, pulp firmness, soluble solids content, and SS/TA ratio were influenced by fertigation doses. The highest values of pulp firmness were observed in 200 % fertigation treatments, followed by treatment 150 % of the recommendation, which was superior to the other treatments and did not differ from the control. The two highest doses promoted an increase of 49.5 % and 33.9 %, respectively, relative to the control. According to Crisosto et al. (2001), the minimum pulp firmness for harvesting plums is 2.65 kg f to avoid damage due to impact during handling and storage. Considering the classification and subsequent commercialization stages, fruits with pulp firmness in the 1.32–2.65 kgf range are deemed suitable. For consumption, plums must have firmness in the 0.81–1.32 kgf range, not less than 0.81 kgf.

A divergent result was observed by Branco et al. (2016), who found greater pulp firmness in the control when evaluating , Kinkas , apple trees in the 2013-2014 harvest in São Joaquim, RS, under the effect of applying the same amounts of nutrients between conventional fertilization, irrigation plus conventional fertilization, irrigation plus fertigation and in fertigation. The results were associated with the smaller fruit size in the control.

A likely explanation for the results obtained in the present study regarding pulp firmness was the observation that the control treatment was at a more advanced stage of maturation at the harvest stage. For this, the color of the fruit epidermis observed in the field during the experiment, the firmness of the pulp, and the soluble solids content obtained in the analyses were considered. Pessoa (2016) highlighted that it is natural to reduce the firmness of the pulp as the plum matures since the degradation of complex carbohydrates, such as pectic substances, cellulose, and hemicellulose, results in changes to the cell wall and causes the pulp to soften. Therefore, this quality attribute is vital for the post-harvest conservation of fruits.

Regarding the soluble solids content, the control (T1) and the dose of 200 % of the fertigation recommendation (T5) performed similarly, while the other treatments did not differ. Anzanello and Menin (2018), when evaluating the phenology, production, and quality of fruits of potential plum cultivars for the Serra Gaúcha region in the 2014/2015 harvest, reported a soluble solids content of 9.5 °Brix for the ‚Gulfblaze' cultivar, this value being higher than that found in the present study. On the other hand, in a study conducted by Vargas et al. (2017), this variable was not affected when evaluating the effect between rainfed, irrigated, fertigation A treatments (based on a nutrient extraction rate of 10 $kg \cdot ha^{-1}$, 15 $kg \cdot ha^{-1}$, and 20 $kg \cdot ha^{-1}$ of N, P, and K) and fertigation B (based on a nutrient extraction rate of 53 $kg \cdot ha^{-1}$, 13 $kg \cdot ha^{-1}$, and 55 $kg \cdot ha^{-1}$ of N, P, and K) in apples ‚Galaxy', in the Campos de Cima da Serra region, RS.

The smaller leaf area in the control may have provided greater sunlight on the fruits and, consequently, greater accumulation of sugars. According to Feliciano et al. (2010), fruits with greater exposure to the sun tend to increase the soluble solids content. Another factor observed was the higher leaf potassium content in the control and the higher dose treatment (Table 1), which may have influenced this variable. K fertilization plays a fundamental role in the biosynthesis of sugars and carbohydrates, favoring an increase in the concentration of soluble solids in the fruit pulp since this nutrient helps transport carbohydrates (Jawandha et al. 2017). However, Barreto et al. (2020) did not observe any influence of increasing doses of potassium on color, pulp firmness, soluble solids, juice pH, total phenolic compounds, and antioxidant activity of peaches ‚Sensation' in soils with a high content of this nutrient.

Furthermore, the more advanced maturation observed in the control may have affected the soluble solids content since, according to Argenta (2006), as the fruit ripens, the soluble solids content increases as a result of starch hydrolysis and other reserve substances present in the fruits.

Titratable acidity was not influenced by fertigation treatments, obtaining an average of 1.8 % w/v of malic acid. Chagas (2008), when evaluating the development of cultivars with low cold requirements for subtropical regions of the state of São Paulo in the 2007/2008 harvest, obtained for the cultivar ‚Gulfblaze' 1.0 % w/v of malic acid for the same harvest time of the present study.

Similar behavior to the soluble solids content was observed for the SS/TA ratio, in which the control and fertigation treatment of 200 % of the recommendation presented superior results. In the other treatments, the lowest results were obtained, not differing. Queiroz (2014) observed higher values, reporting an SS/TA ratio of 5.98 for the ‚Gulfblaze' cultivar when characterizing plum tree genotypes in the Central Depression physiographic region of the State of Rio Grande do Sul in 2013.

The SS/TA ratio is one of the leading indicators of fruit quality, as it is related to the flavor of the fruit. This relationship indicates that the higher the value, the sweeter and less acidic the fruits are (Chitarra & Chitarra, 2005). Therefore, as the titratable acidity values were not affected by the treatments, but the soluble solids values were, the SS/TA results' behavior was arranged the same way as those found for the soluble solids content.

Therefore, it is crucial to understand the productive performance and quality of plum trees subjected to fertigation. This is because a combination of physical and chemical characteristics of the fruits supplied determines consumer acceptance and commercial value of plums. Buyers and consumers prefer larger fruits with redder skin and a sweeter flavor. Consequently, obtaining larger fruits, as observed in fertigation treatments, can result in higher profitability for the producer, making this management a crucial practice in the orchard. Furthermore, the incorporation of new driving systems and the increase in plant density in the most recent production areas indicate the need to increase the amount of fertilizers supplied throughout the Japanese plum production cycle. This aims to achieve fruits with superior caliber and high productivity. Furthermore, ensuring available water during critical periods, even in low rainfall, promotes nutrient absorption and adequate plant growth.

4 CONCLUSIONS

Increasing the dose of nutrients in fertigation for the ‚Gulfblaze' plum tree increased the daily fruit growth rate. Fertigation doses of 150 % and 200 % of the dose recommended by CQFS increased production and improved fruit quality, while plants that were not subjected to fertigation and those subjected to a dose of 200 % of the recommendation had a higher content of soluble solids and SS/AT ratio, indicating better performance concerning consumer preferences.

5 REFERENCES

Anzanello, R., & Menin, R. P. (2018). Cultivares potenciais de pessegueiro, ameixeira, pereira e quivizeiro para a região da Serra Gaúcha. Pesquisa Agropecuária Gaúcha, 24(1/2), 1-11. https://doi.org/10.36812/pag.2018241/21-11

Argenta, L. C. (2006). Fisiologia pós-colheita: Maturação, colheita e armazenagem dos frutos. In EPAGRI, A cultura da macieira (pp. 691-724). Florianópolis, SC: EPAGRI.

Aular, J., & Natale, W. (2013). Nutrição mineral e qualidade do fruto de algumas frutíferas tropicais: goiabeira, mangueira, bananeira e mamoeiro. Revista Brasileira de Fruticultura, 35(4), 1214-1231. https://doi.org/10.1590/S0100-29452013000400033

Barreto, C. F., Navroski, R., Cantillano, R. F. F., Vizzotto, M., & Nava, G. (2020). Adubação potássica na qualidade de pêssegos. Revista de Ciências Agrárias, 43(1), 64-71.

Branco, M. S. C., Nava, G., & Ernani, P. R. (2016). Crescimento inicial, produção e qualidade de frutos de macieiras submetidas a irrigação e fertirrigação. Revista de Ciências Agroveterinárias, 15(1), 34-41. https://doi.org/10.5965/223811711512016034

Brunetto, G., Melo, G. W. B., & Kaminski, J. (2011). Critérios de predição da adubação e da calagem em frutíferas. Boletim Informativo da Sociedade Brasileira de Ciência do Solo, 36, 24-29.

Castro, L. A. S., Nakasu, B. H., & Pereira, J. F. M. (2008). Ameixeira: Histórico e perspectivas de cultivo. Pelotas, RS: Embrapa Clima Temperado.

Cechinel, J. H. Ciotta, M. N., & Ernani, P. R. (2022). Influência da irrigação e da fertirrigação no rendimento de frutos de macieiras 'Kinkas'. Agropecuária Catarinense, 35(1), 67-72. https://doi.org/10.52945/rac.v35i1.1078

Chagas, P. C. (2008). Cultivares de ameixas de baixa exigência em frio para regiões subtropicais do Estado de São Paulo. [Master's thesis, University of São Paulo].

Chagas, Y. P. Zago, M. C., Roveda, L. M., Nachtigall, G. R., & Hawerroth, F. J. (2016) Área foliar em macieiras" Maxigala" e" Fuji Suprema" em função da irrigação e fertirrigação. Proceedings of the 12th Seminário Nacional sobre Fruticultura de Clima Temperado, São Joaquim, SC, 2016. p. 161.

Chitarra, M. I. F., & Chitarra, A. B. (2005). Pós-colheita de frutas e hortaliças: fisiologia e manuseio. Lavras, MG: UFLA, FAEPE.

Coelho, E. F., Or, D., & Sousa, V. F. (2011). Aspectos básicos em fertirrigação. In: V. F. Sousa, W. A. Marouelli, E. F. Coelho, J. M. Pinto, & M. A. Coelho Filho (Eds.). Irrigação e fertirrigação em fruteiras e hortaliças. Brasília, DF: Embrapa Informação Tecnológica.

Comissão de Química e Fertilidade do Solo para os Estados do Rio Grande do Sul e Santa Catarina (CQFS-RS/SC). Manual de calagem e adubação para os estados do Rio Grande do Sul e Santa Catarina. Porto Alegre, RS: Sociedade Brasileira de Ciência do Solo, 2016.

Crisosto, C. H., Slaughter, D., Garner, D., & Boyd, J. (2001). Stone fruit critical brusing thresholds. Journal of the American Pomological Society, 55(2), 76.

Dalbó, M. A., Menezes-Netto, A. C., Bruna, E. D., Thomazi-Kleina, H., & May-De-Mio, L. L. (2021). Advances in plum breeding for resistance to *Xylella fastidiosa* in Brazil. Acta Horticulturae, 1322, 19-24. https://doi.org/10.17660/ActaHortic.2021.1322.4

Dechen, A. R., & Nachtigall, G. R. (2007). Elementos requeridos à nutrição de plantas. In R.F. Novais, V. H. Alvarez, N. F. Barros, R. L. Fontes, R. B. Cantarutti, & J. C. L. Neves (Eds.). Fertilidade do Solo. Viçosa, MG: Sociedade Brasileira de Ciência do Solo. p. 91-132.

Demirsoy, H., Demirsoy, L., Uzun, S., & Ersoy, B. (2004), Nondestructive leaf area estimation in peach. European Journal of Horticultural Science, 69(4), 144-146.

Dolinski, M. A., Motta, A. C. V., Serrat, B. M., Mio, L. L. M., & Monteiro, L. B. (2007). Adubação nitrogenada e potássica na produtividade da ameixeira ‚Reubennel', na região de Araucária-PR. Revista Brasileira de Fruticultura, 29(2), 364-370. https://doi.org/10.1590/S0100-29452007000200034

Eidam, T., Pavanello, A. P., & Ayub, R. A. (2012). The plum culture. Revista Brasileira de Fruticultura, 34(1), i-i. https://doi.org/10.1590/S0100-29452012000100001

Feliciano, R. P., Antunes, C., Ramos, A., Serra, A. T., Figueira, M. E., Duarte, C. M. M., Carvalho, A., & Bronze, M. R. (2010). Characterization of traditional and exotic apple varieties from Portugal. Part 1 - Nutritional, phytochemical and sensory Evaluation. Journal of Functional Foods, 2(1), 35-45. https://doi.org/10.1016/j.jff.2009.12.004

Ferreira, L. V., Picolotto, L., Pereira, I. S., Schmitz, J. D., & Antunes, L. E. C. (2018). Nitrogen fertilization in consecutive cycles and its impact on high density peach crops. Pesquisa Agropecuária Brasileira, 53(2), 172-181.https://doi.org/10.1590/s0100-204x2018000200005

Food and Agriculture Organization of the United Nations Agricultural Statistics (FAOSTAT). Retrieved from http://www.fao.org/faostat/en/#data

Franganito, J. P. A. (2014). Resposta da cultura da ameixa em rega deficitária: um caso de estudo com stress pós-colheita [Doctoral dissertation, Instituto Politécnico de Beja].

Giovanaz, M. A., Fachinello, J. C., Goulart, C., Radünz, A. L., Amaral, P. A., & Weber, D. (2014). Produção e qualidade de pêssegos, cv. Jubileu, com uso de fitorreguladores. Revista Ceres, 61(4), 552-557. https://doi.org/10.1590/0034-737X201461040015

Instituto Adolfo Lutz (IAL). (1985). Normas analíticas, métodos químicos e físicos de alimentos. 3.ed. São Paulo, SP: IAL.

Instituto Brasileiro de Geografia e Estatística (IBGE). (2017). Censo Agropecuário 2017. Retrieved from https://censoagro2017.ibge.gov.br/templates/censo_agro/resultadosagro/index.html

Jawandha, S. K., Gill, P. P. S., Singh, H., & Thakur, A. (2017). Effect of potassium nitrate on fruit yield, quality and leaf nutrients content of plum. Vegetos - An International Journal of Plant Research, 30, 325-328. http://dx.doi.org/10.5958/2229-4473.2017.00090.8 https://doi.org/10.5958/2229-4473.2017.00090.8

Junges, A. H., Santos, H. P., Garrido, L. R., & Anzanello, R. (2020). Boletim Agrometeorológico da Serra Gaúcha-Edição Outubro 2020: condições meteorológicas de agosto e setembro de 2020, prognóstico climático para outubro-novembro-dezembro e recomendações fitotécnicas para vinhedos e pomares. Bento Gonçalves, RS: Embrapa Uva e Vinho.

Mayer, N. A., Franzon, R. C., & Raseira, M. (2019). Pêssego, nectarina e ameixa: o produtor pergunta, a Embrapa responde. Brasília, DF : Embrapa.

Nachtigall, G. R., & Hawerroth, F. J. (2023). Persistência do fenômeno 'La Niña' provoca redução no volume de precipitação pulviométrica nos meses de outubro a dezembro 2022. Bento Gonçalves, RS: Embrapa Uva e Vinho.

Nachtigall, G. R. (2016). Irrigação/fertirrigação em fruticultura de clima temperado no Brasil. Proceedings of the 45th Congresso Brasileiro de Engenharia Agrícola, Florianópolis, SC, 2016.

Nachtigall, G. R., Cargnino, C., & Nava, G. (2012). Efeito da irrigação e fertirrigação na produtividade e qualidade de macieiras Royal Gala. Proceedings of the Reunião Brasileira de Fertilidade do Solo e Nutrição de Plantas, Maceió, v. 30, p. 2012, 2012.

Pessoa, C. O. (2016). Ponto de colheita, efeito do 1-metilciclopropeno, etileno e armazenamento refrigerado em ameixeira 'Gulfblaze' [Doctoral dissertation, Escola Superior de Agricultura "Luiz de Queiroz"].

Petri, J. L., Hawerroth, F. J., Leite, G. B., Sezerino, A. A., & Couto, M. (2016). Reguladores de crescimento para frutíferas de clima temperado. Florianópolis, SC: Epagri.

Pramanick, K. K., Kashyap, P., Shukla, A. K., Watpade, S., & Kumar, J. (2022). Water and nutrient management in stone fruits. In S. S. Roy, P. Kashyap, & T. Adak (Eds.). Natural Resource Management in Horticultural Crops. New Delhi: Today & Tomorrow's Printers and Publishers. p. 93-121.

Queiroz, H. T. (2014). Caracterização de genótipos de pessegueiros e ameixeiras na Depressão Central do Estado do Rio Grande do Sul [Master's thesis, Federal University of Rio Grande do Sul].

Saenz, J. L., Dejong, T. M., & Weinbaum, S. A. (1997). Nitrogen stimulated increases in peach yields are associated with extended fruit development period and increased fruit sink capacity. Journal of the American Society for Horticultural Science, 122(6), 772-777. https://doi.org/10.21273/JASHS.122.6.772

Simonetto, P. R., Fioravanço, J. C., Raseira, M. C. B., & Grellmann, E. O. (2007). Fenologia e características agronômicas de cultivares de ameixeira (Prunus salicina Lindl.) recomendadas para a Região serrana do RS. Porto Alegre, RS: Fepagro, Pelotas, RS: Embrapa Clima Temperado.

Soto Parra, J. M., Ramírez, F. J. P., Chávez, E. S., Leal, R. P., & Sotelo, M. B. (2016). Fertirrigação com macronutrientes em macieira ‚Golden Delicious': impacto na produtividade e na qualidade dos frutos. Nova Scientia, 8(16), 162-180. https://doi.org/10.21640/ns.v8i16.414

Testezlaf, R. (2017). Irrigação: Métodos, sistemas e aplicações. Campinas, SP: Unicamp/FEAGR.

Vargas, D. P., Nachtigall, G. R., & Simões, F. (2017). Efeito da irrigação e fertirrigação na coloração da película, firmeza e sólidos solúveis totais de maçãs 'Galaxy', na região dos Campos de Cima da Serra, RS. Proceedings of the 15th Encontro Nacional de Fruticultura de Clima Temperado, Fraiburgo, SC.

Vélez, J. E., Álvarez-Herrera, J. G., & Alvarado-Sanabria, O. H. (2012). El estrés hídrico em cítricos (Citrus spp.): Uma revisión. Orinoquia, 16(2), 32-39. https://doi.org/10.22579/20112629.245

Wrege, M. S., Steinmetz, S., Reisser Junior, C., & Almeida, I. R. (2012). Atlas climático da região Sul do Brasil: Estados do Paraná, Santa Catarina e Rio Grande do Sul. Pelotas, RS: Embrapa Clima Temperado, Colombo, PR: Embrapa Florestas.