Scientific Papers. Series B, Horticulture. Vol. LXIX, No. 2, 2025
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

INFLUENCE OF CULTIVAR, ROOTSTOCK, AND PLANTING SYSTEM ON PEACH AND NECTARINE YIELD AND FRUIT QUALITY

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Abstract

Productivity in the orchard can be improved by maximizing preharvest factors, including training systems based on compact two-dimensional canopies, high-density trees, and the availability of efficient size-controlling rootstocks. Improved densities have been combined with planar canopies, providing better mechanical and manual pruning and flower thinning, which enhanced yields while optimizing fruit quality and production costs. The study aimed to assess the productive potential of several peach and nectarine cultivars, determining the quantity of produced fruits correlated to flowers. In 2019-2024, two different training systems, Trident (4.0 x 2.0 m - 1,250 trees/ha - 3,750 axis/ha) and Vertical Axis (4.0 x 1.5 m - 1,666 trees/ha - 1,666 axis/ha), have been tested on 14 peach and 16 nectarine cultivars for temperate climate. Three different rootstocks, GF677, Adesoto, and Mirobolan29C, were used for some cultivars.

Key words*: production, training systems, fruit quality, high-density planting, productivity.*

INTRODUCTION

Peaches belong to the Rosaceae family and are highly valued for their nutritional benefits, flavor, and versatility in fresh consumption and processed products. Peach (Prunus persica Batsch L.) and nectarine (Prunus persica var. nucipersica) cultivation plays a significant role in global fruit production, with increasing demand for high-quality fresh fruit driven by consumer preferences and market trends (Abidi, Moreno Sánchez, and Gogorcena Aoiz, 2018). The European Union ranks as the second largest peach grower after China, with an average yearly production of 3,612,000 tons from 2018 to 2020 and a total harvested area of 206,660 hectares in 2019 (Iglesias and Echeverria, 2022). Proper orchard design is crucial for maximizing productivity and fruit quality in peaches (Anthony and Minas, 2021). The success of these crops is strongly influenced by preharvest factors, including cultivar selection, rootstock choice, and orchard management techniques (DeJong et al., 1999). These factors play a crucial role in determining tree vigor, yield efficiency, fruit quality, and overall orchard profitability (Iglesias and Echeverria, 2022; Firde et al., 2019). In modern fruit production, optimizing planting density and training systems is essential for achieving high productivity, resource use efficiency, and maintaining fruit quality standards (Maldera et al., 2021). High-density orchards with two-dimensional canopy structures have gained increasing attention due to their potential to enhance light interception, improve labor efficiency, and facilitate mechanization (Bastías and Corelli-Grappadelli, 2013). Among the most widely studied training systems, Vertical Axis and Trident have been shown to significantly influence tree architecture, fruiting efficiency, and ease of orchard operations (Reig et al., 2018). New training systems were created, mostly by extending the number of axes to two in Bibaum® (Musacchi, 2008), Bi-Axis (Dorigoni et al., 2011), Tatura trellis, Parallel Y, etc. or to three axes in Drilling (Stănică and Platon, 2011; Widmer and Krebs, 2001), Candlestick (Chandelier) (Vercammen, 2011), 3 Leader system (Elkins and DeJong, 2011), Parallel trident, or even four axes in Mikado (Stănică and Platon, 2011; Widmer and Krebs, 2001). The newly developed planting systems were also appropriate for more strong species such as peach (Caruso et al., 1997),

apricot, plum (Meland, 2001). Recently, in Romania several trials were initiated to evaluate new planting systems, canopies designs, cultivars and rootstocks in order to give efficient solutions for new stone fruit orchards (Stănică and Eremia, 2014). The choice of rootstock plays a crucial role in orchard management, influencing both the design and planting density (Anthony and Minas, 2021; Minas, Tanou, and Molassiotis, 2018).Also rootstock selection is another critical determinant of orchard performance, influencing tree vigor, disease resistance, and fruit quality attributes (Pieper et al., 2024). For example, rootstock breeding efforts in Europe have focused on interspecific hybrids as they possess superior traits for tolerance to high pH, drought, salinity, water logging, and fungal diseases (Reig et al., 2020; Reighard, 2000). This study aims to assess the dynamics of several new peach and nectarine cultivars trained under two different canopy systems, focusing on fruit production and quality in relation to crop load, correlated with the total number of flower and the biochemical analysis of fruit composition. The experiment was conducted from 2019 to 2024.

MATERIALS AND METHODS

The study was conducted in the experimental orchard of the Faculty of Horticulture in Bucharest (44°28′18.14″N and 26°4′13.61″E). In the municipality of Bucharest the climate is moderately continental, with an average annual temperature of 10-11°C. In general, winters are cold, with heavy snow, often accompanied by blizzards, and autumns are long and warm, with early springs. The lowest average monthly temperature is recorded in January, with an average value of -3°C. Summer is very hot, in July the average temperature is 23°C, sometimes reaching 35-40°C. The dominant winds, felt in all seasons, are the east (21.2%), followed by the west (16.3%), the northeast (14.2%) and the southwest (11.2%). Precipitation is low, averaging 585 mm per year, but has a higher flow rate in summer: the highest average monthly amounts of precipitation fall in June (about 85 mm), and the lowest in March (15 mm). On average, precipitation falls on the territory of Bucharest on 117 days/year. The soil type in the Experimental Didactic Field of the Faculty of Horticulture in Bucharest is reddish brown soil. The biological material studied was represented by 14 new peach and 16 nectarine cultivars that are not widely cultivated in Romania's plantation, but also native and foreign varieties found in commercial plantations in Romania. Rootstocks used are GF677, Adesoto, and Mirobolan29C. For some cultivars, two different rootstocks were used for the same cultivar. In this study, the productive performance of several peach and nectarine cultivars was evaluated under two training systems: the Trident and the Vertical Axis. For each cultivar and canopy system, a series of quantitative parameters were determined in order to characterize fruit production. These included the average fruit weight (g/fruit), the number of fruits per tree after manual thinning, the individual tree yield (kg/tree), and the extrapolated yield per hectare (t/ha). In addition, the flower-to-fruit ratio was calculated to assess the efficiency of fruit set. Fruits were manually harvested in two stages, corresponding to the commercial maturity phase for each cultivar and training system combination. The consumption maturity was determined using a DA-Meter device (TR Turoni, Italy), which measures the Index of Absorbance Difference (IAD) - a non-destructive indicator of chlorophyll degradation in the fruit skin, providing an objective estimation of ripening stage and optimal harvest time. These measurements were used to compare the influence of the training system and cultivar on overall yield performance and to identify genotypes with superior productive potential under the given orchard conditions. The total number of flowers was determined for each cultivar at the BBCH 65 stage.

RESULTS AND DISCUSSIONS

The following figure shows the average fruit weight for each peach and nectarine cultivar, grown under the Trident and Vertical Axis training systems. This parameter is a key indicator of fruit quality, influenced by genetic factors, crop load, and canopy light distribution. Previous studies have shown that optimized canopy structures improve light interception and fruit uniformity (Anthony and Minas, 2021; Mazzoni et al., 2022). Consistent with these findings, Trident-canopy generally produced slightly heavier fruits, whereas the Vertical Axis

system favored a more uniform fruit size across the canopy.

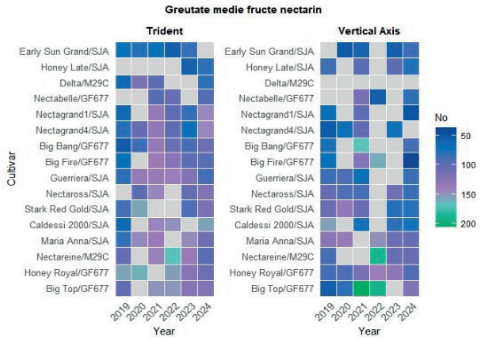

Figure 1. The average fruit weight for nectarine cultivars, grown under the Trident and Vertical Axis training systems (2019-2024)

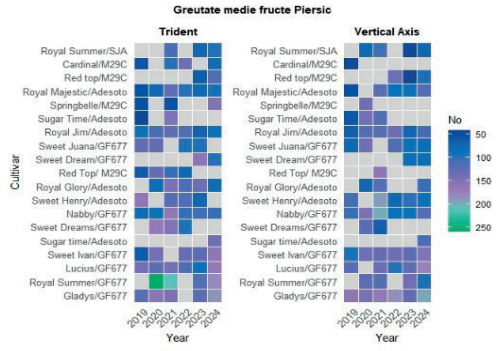

Figure 2. The average fruit weight for peach cultivars, grown under the Trident and Vertical Axis training systems (2019-2024)

Nectarine cultivars

The highest average fruit weight on the Trident system was recorded for Nectareine/M29C (164 g-2022) and Honey Royal/GF677' (160.45 g - 2020) cultivars, exceeding over 150 g per fruit. The lowest value was observed for Big Bang/GF677 (85.40 g - 2020) cultivar, below 100 g. On the Vertical Axis, the cultivars Big Top/GF677 (205.05 g - 2021; 191.60 g - 2022), Nectareine/M29C (187.50 g - 2022) showed the largest fruits around 200 g, while Big Fire/GF677(36.5 g - 2024) and Nectagrand 1/SJA (47.05 g - 2024) cultivars, registered the smallest ones, below 50 g.

Peach Cultivars

For the Trident training system, the highest average fruit weight was recorded for the Royal Summer/GF677 (258.67 g - 2020) cultivar, reaching nearly 250 g per fruit, while the lowest value was observed for Royal Jim/Adesoto(87 g - 2024) and Springbelle/M29C (51.88 g - 2019) cultivars, both below 50 g per fruit. Under the Vertical Axis system, the highest fruit weight was obtained for Nabyy/GF677 (164 g - 2021) cultivar, close to 200 g per fuit, whereas the lowest was recorded for Royal Summer/SJA (42.05 g - 2023) cultivar, below 50 g.

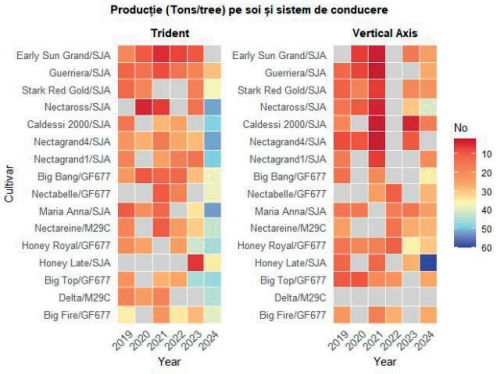

Figure 3. Production (kg/tree) for nectarin cultivars, grown under the Trident and Vertical Axis training systems (2019-2024)

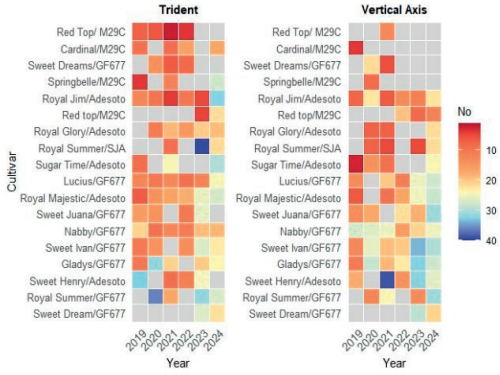

Figure 4. Production (kg/tree) for peach cultivars, grown under the Trident and Vertical Axis training systems (2019-2024)

Nectarine cultivars

For the Trident training system, the highest yield per tree was recorded for the Nectaross/SJA, Nectagrand 4/SJA (51.6 kg - 2024) and Maria Anna/SJA (52.3 kg - 2024) cultivars, reaching nearly 50kg/tree, while the lowest value was observed for Honey Late/SJA (5.8 kg - 2023), Nectaross/SJA (4.6 kg - 2020) cultivars, both below 10 kg/tree. Under the Vertical Axis system, the highest highest yield per tree was obtained for Nectaross/SJA (40.4 kg - 2024)

cultivar over 40kg/tree, whereas the lowest was recorded for Caldessi 2000/SJA (2.1 kg - 2021), Guerriera/SJA (2.1 kg - 2021) cultivars, both below 5kg/tree.

Peach Cultivars

For the Trident training system, the highest yield per tree was recorded for the Royal Summer/SJA (39.42 kg - 2023), Royal Summer/GF677 (36.08 kg - 2020), and Royal Jim/Adesoto (32.15 kg - 2024) cultivars, reaching between 30-40 kg/tree, while the lowest value was observed for Red Top/M29C (1.54 kg - 2021), and Springbelle/M29C (3.63 kg - 2019) cultivars, both below 5kg/tree. Under the Vertical Axis system, the highest highest yield per tree was obtained for Sweet Henry/Adesoto (38.95 kg - 2021) cultivars, close 40 kg/tree, whereas the lowest was recorded for Sugar Time/Adesoto (2.36 kg - 2019) and Cardinal/M29C (3.64 kg - 2019) cultivars, both below 10 kg/tree.

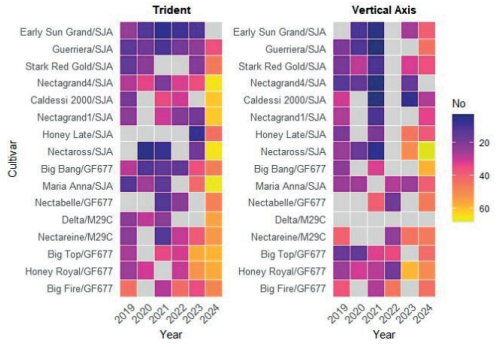

Figure 5. Production (tons/ha) for nectarin cultivars, grown under the Trident and Vertical Axis training systems (2019-2024)

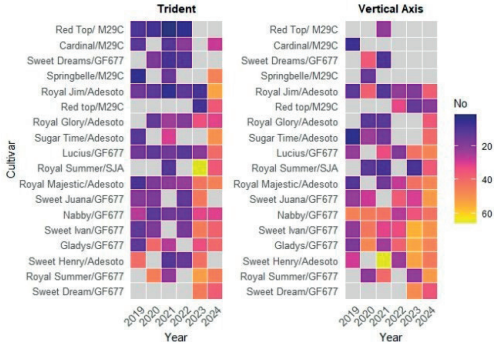

Figure 6. Production (tons/ha) for peach cultivars, grown under the Trident and Vertical Axis training systems (2019-2024)

Nectarine cultivars

For the Trident training system, the highest yield per hectare was recorded for the Nectagrand 1/SJA(61 tons/ha - 2024), Nectaross/SJA (64.47 tons/ha - 2024), and Maria Anna/SJA (65.38 tons/ha - 2024) cultivars, reaching over 60 t/ha, while the lowest value was observed for Nectaross/SJA (5.37 tons/ha - 2020; 7.68 tons/ha - 2021), and Honey Late/SJA (7.24 tons/ha - 2023) cultivars, both below 10 tons/ha. Under the Vertical Axis system, the highest highest yield per hectare was obtained for Nectaross/SJA(67.30-2024), Big Bang/GF677 (58 tons/ha - 2024), Honey Royal/GF677 (58.76 tons/ha - 2023) cultivars, between over 50 tons/ha, whereas the lowest was recorded for Guerriera/SJA (3.51 tons/ha - 2021) and Big Top/GF677 (15.88 tons/ha - 2019) cultivars, both below 15 t/ha.

Peach Cultivars

For the Trident training system, the highest yield per hectare was recorded for the Royal Summer/SJA (65.67 tons/ha - 2023), Royal Summer/GF677 (52.48 tons/ha - 2023), and Sugar Time/Adesoto (49.71 tons/ha - 2024) cultivars, reaching over 50 t/ha, while the lowest value was observed for Springbelle/M29C (4.54 tons/ha - 2019) and Red TopM29C (1.93tons/ha-2022) cultivars, both below 15 t/ha. Under the Vertical Axis system, the highest highest yield per hectare was obtained for Sweet Henry/ Adesoto (64.89 tons/ha - 2021), Sweet/ IvanGF677 (55.88 tons/ha - 2023), Sweet JuanaGF677 (51.40 tons/ha - 2024) cultivars, between over 50 t/ha, whereas the lowest was recorded for Sugar Time/Adesoto (3.93 tons/ha - 2019) and Royal Summer/SJA (8.12 tons/ha - 2023) cultivars, both below 10 t/ha.

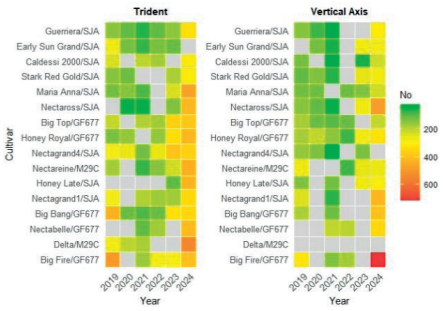

Figure 7. Number of fruits after tinning of nectarin cultivars grown under the Trident and Vertical Axis training systems (2019-2024)

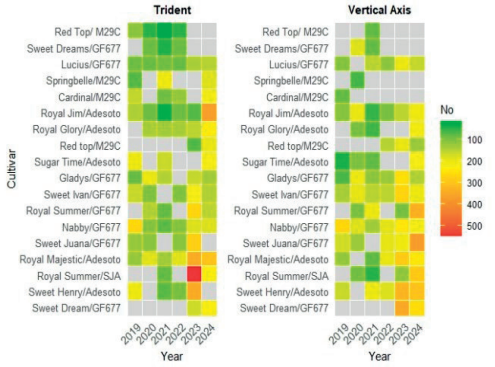

Figure 8. Number of fruits after tinning of peach cultivars grown under the Trident and Vertical Axis training systems (2019-2024)

Nectarine cultivars

For the Trident training system, the highest number of fruits after tinning was recorded for the Delta/M29C (546No. - 2024), Big Bang/GF677 (430No. - 2019), Big Fire/GF677 (500No. - 2019), and Maria Anna/SJA (476No. - 2024) cultivars, reaching over 400 fruits/tree, while the lowest value was observed for Guerriera/SJA(59No. - 2021), and Nectaross/SJA (43No.-2021) cultivars, both below 60 fruits/tree. Under the Vertical Axis system, the highest highest number of fruits after tinning was obtained for Big Fire/GF677 (4714No. - 2024), and Nectagrand4/M29C (447No. - 2024) cultivars, between 400-600 fruits/tree, whereas the lowest was recorded for Nectagrand 4/SJA (21No. - 2021) and Caldessi 200/SJA (29No. - 2021) cultivars, both below 50 fruits/tree.

Peach Cultivars

For the Trident training system, the highest number of fruits after tinning was recorded for the Royal Jim/Adesoto (548No. - 2023) and Royal Majestic/Adesoto (307No. - 2024) cultivars, reaching between 300-500 fruits/tree, while the lowest value was observed for Royal Summer/SJA (45No. - 2021), and Royal Jim/Adesoto (52No. - 2021) cultivars, both below 100 fruits/tree. Under the Vertical Axis system, the highest highest number of fruits after tinning was obtained for Royal Summer/GF677 (336No. - 2024), Sweet Juana/GF677 (374No. - 2024) and Sweet Henry/GF677 (304No. - 2024) cultivars, over 300 fruits/tree, whereas the lowest was recorded for Sugar Time/Adesoto (40No. - 2019) and Royal Majestic/Adesoto (53.02No. - 2019) cultivars, both below 100 fruits/tree.

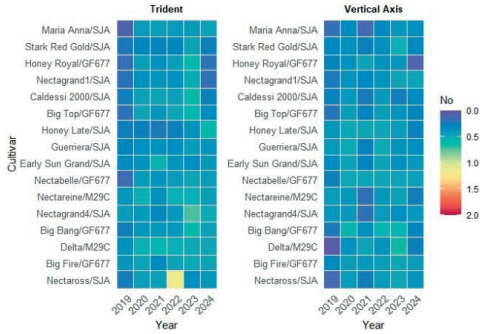

Figure 9. Fruits-flowers rate for nectarin cultivars under the Trident and Vertical Axis training systems (2019-2024)

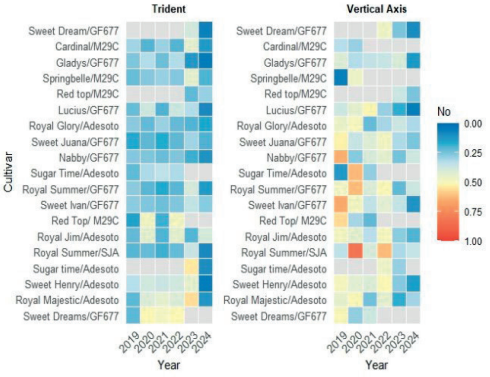

Figure 10. Fruits-flowers rate for peach cultivars under the Trident and Vertical Axis training systems (2019-2024)

Nectarine cultivars

Overral, for the Trident planting system, the fruit-to-flower ratio was optimal for the majority of cultivars, reflecting a high fruit set efficiency under the tested conditions, between 0.7-0.9, while the lowest value was observed for Maria Anna/SJA (8% No - 2019), and Nectabelle/GF677 (15% No - 2019) cultivars,both below 0.5. Under the Vertical Axis system, the fruit-to-flower ratio was optimal for the majority of cultivars, reflecting a high fruit set efficiency under the tested conditions, between 0.7-0.8, while the lowest value was observed for Nectaross/SJA (13% No - 2019), and Delta/M29C (4% No - 2019) cultivars, both below 0.5.

Peach Cultivars

For the Trident planting system, the optimal fruit-to-flower ratio was for Red Top/M29C,(48% No - 2020 - 48% No -2022), Royal Jim/Adesoto(43% No – 2020 -43% No - 2022), Sugar Time/Adesoto(54% No - 2023), and Royal Majestic/Adesoto (54% No - 2023) cultivars, reflecting a fruit set efficiency under the tested conditions, over 0.5, while the lowest value was observed for Sweet Dream/GF677 (6% No -2024), and Sweet Henfry/Adesoto(5% No -2024), Gladys/GF677 (5% No - 2024) both below 0.25. Under the Vertical Axis system, the fruit-to-flower ratio was even better for the majority of cultivars, reflecting a high fruit set efficiency

Royal Summer/SJA (47% No - 2019) and Nabby GF677 (64% No - 2019) rich over 0.9, while the lowest value was observed for Lucius/GF677 (5% No - 2024), and Springbelle/ M29C (6% No - 2019) both below 0.25.

DISSCUSIONS

The results obtained in this study highlight the combined influence of training system, rootstock, and crop management on the productive performance of peach and nectarine cultivars. In general, trees trained under the Vertical Axis system showed a lower average fruit weight compared to those trained under the Trident canopy. This trend was mainly associated with the higher crop load per tree, since fruit thinning was performed less than in normal parameters. Within the Trident system, the cultivar Big Bang/GF677 recorded the lowest fruit weight despite its high genetic potential (over 150 g per fruit), whereas the same cultivar reached higher values under the Vertical(Avilán et al. 1997).

Yield Performance

Regarding yield performance, Royal Summer/GF677 (2020) achieved the highest production per tree and per hectare under the Trident system, confirming its excellent adaptation to vigorous rootstocks and balanced canopy structure. Conversely, Sugar Time/Adesoto and Springbelle (2019) registered the lowest yields, likely due to weaker vegetative growth and reduced fruit set. On the Vertical Axis, Nabyy/GF677 (2021) reached the highest yield, while Royal Summer/GF677 (2023) showed the lowest. Despite the low vigor of the Saint Julien A (SJA) rootstock, which can limit fruit size in some cultivars, results indicate that it can still sustain high yields, demonstrating good adaptability to intensive orchard systems when properly managed(Anthony and Minas, 2021).

Fruit Thinning and Crop Load

The differences between years also underline the importance of fruit thinning practices. In 2021, the number of fruits after thinning reached the lowest levels across all cultivars, a direct consequence of the insufficient thinning performed in 2020, which resulted in tree exhaustion and reduced flower bud formation. This observation reinforces the essential role of adequate crop load management in maintaining fruit size and yield stability over time(Widmer and Krebs, 2001).

Flower-Fruit Ratio

The fruit-to-flower ratio further illustrated the physiological efficiency of the trees. The lowest values were recorded in 2019, when the trees were in their third year after planting, still in the establishment phase with limited fruiting wood(Lauri and Corelli Grappadelli 2014). In contrast, during the following seasons, most cultivars exhibited higher fruit-to-flower ratios, particularly under the Trident system, indicating improved reproductive balance and fruit set efficiency as the orchard matured.

CONCLUSIONS

Overall, these findings demonstrate that the interaction between canopy structure, rootstock vigor, and fruit thinning plays a decisive role in determining both yield potential and fruit quality in modern peach and nectarine orchards. Proper coordination of these factors ensures stable production, optimized fruit size, and long-term orchard sustainability.

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