

Article

Cropping and Pruning Systems of Primocane Raspberries in the Subtropical Climate

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Abstract: Raspberry production is limited to cold temperate areas of high latitude due to the requirement of low temperatures for flowering and fruiting from most cultivars. However, primocane cultivars, as they are less demanding in cold conditions, represent a possible alternative that suits regions with a subtropical climate. The cultivar Heritage primocane raspberry was investigated in the Cwa climate, in three production systems (PS), during two crop cycles. In PS1, canes were hard pruned at ground level after primocane fruiting. In PS2, canes were tipped to promote subapical bud break for a second harvest. In PS3, canes were tipped again after the second harvest to induce a third harvest. PS1 had the lowest yield, however, after two cycles; in plants of this system it was observed the highest root weight, and starch content. Raspberries subjected to subapical pruning show lower carbohydrate storage in the root system. The production systems had little influence on fruit qualities, in both cycles. The cultivation of cv. Heritage raspberry primocane, in the subtropical Cwa climate can be carried out with sequential pruning, allowing for the production of commercial fruits with harvests distributed over the months, without any reduction in the postharvest quality of the fruits produced.

Keywords: *Rubus idaeus*; cultivation; warm regions; harvest; fruit quality



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1. Introduction

Raspberry (*Rubus idaeus* L.) is traditionally cultivated in regions of temperate climates. Raspberries are cultivated worldwide in an area of 116,393 hectares and yield a production of 947,852 tons [1]. The majority of global production takes place in the Northern Hemisphere, led by Russia, Mexico, Serbia, Poland, and the United States of America, collectively contributing to 72.12% of the total production [1]. In South America, Chile stands out as the largest producer with a production of 11,775 tons. In Brazil, raspberries are cultivated on 40 hectares, producing 240 tons annually, representing just 0.025% of global production [2]. Nevertheless, the increase in the market demand for fresh raspberries has driven the development of new strategies to supply the market for this fruit during the whole year, with productions outside the traditional harvest season and the expansion of cultivation areas for regions of hot climate [3–5].

Raspberry cultivars are classified into primocanes and floricanes based on their fruiting habits, with primocanes producing fruit from the apical nodes on current-year canes. These cultivars do not need low temperatures nor to undergo dormancy period for the induction of flower buds to occur [6]. Floricane cultivars present a biannual cycle. The canes develop vegetatively during spring and summer, and they need to undergo periods of low temperatures to enter dormancy during winter, bloom, and bear fruit in the spring and summer of the second year [3].

The use of primocane raspberry cultivars represents an alternative that is economically feasible for production in regions without chilling weather since the plants have the potential to produce fruit during the whole year under conditions of protected cultivation [5]. Raspberry cultivars, such as Heritage, Autumn Bliss, Autumn Britten, Caroline, Himbo Top, Polka, and Sugana, are some of the primocane cultivars planted in several regions of the world [7].

One of the primary objectives of fruiting pruning in raspberry cultivation is to remove the harvested inflorescences and optimize cane density for the upcoming production cycle. However, pruning strategies vary according to the cultivar group. In primocane cultivars, fruiting first occurs at the apex of newly developed canes. These canes are pruned following the initial harvest, as they retain the potential for additional fruiting. After their second production phase, the canes desiccate and must be replaced by new canes, which will support the subsequent harvest cycle [2,8].

Previous studies indicate that primocane raspberry pruning impacts root carbohydrate reserves, yield, and the duration of the production cycle [9–11]. Therefore, it is essential to conduct investigations that deepen the understanding of the influence of pruning on the physiological aspects of the raspberry plant, aiming to optimize fruit production and quality. In this context, studies on the pruning systems and the resulting performance of primocane raspberries are necessary, aiming at the expansion of the cultivation to areas of warm climate.

Thus, this study aims to assess production systems with various pruning types and their effects on the development, production, and fruit quality of cv. Heritage primocane raspberries cultivated in a subtropical climate (Cwa).

2. Materials and Methods

2.1. Plant Material and Description of the Study Area

Primocane raspberry (*Rubus idaeus* L.) rooted cuttings, cv. Heritage, were grown in 30 L pots filled with a substrate composed of coconut fiber (Golden Mix Misto 98, Amafibra, São Paulo, Brazil) and *Sphagnum* peat (Jiffy TPS, Jiffy Group, Zwijndrecht, The Netherlands) at a 2:1 ratio. Weekly nutrient applications were administered through fertigation (N: Ammonium Sulfate 1000 mg L⁻¹; Calcium Nitrate 500 mg L⁻¹; P: Mono Ammonium Phosphate 150 mg L⁻¹; K: Potassium Sulfate 500 mg L⁻¹). The study was conducted in Piracicaba, Brazil (22°42'27.7" S 47°37'47.3" W, altitude of 554 m), within a Cwa climate according to the Köppen and Geiger classification [12]. Raspberry pots were placed in a greenhouse, externally covered with a 150 µm low-density polyethylene (LDPE) diffuser film, and internally equipped with a gray heat-reflective screen (Freshnet®—providing 65% nominal shading). One week post-transplantation, two canes per pot were selected, and any additional emerging buds were removed weekly to control cane growth and evaluate production.

2.2. Treatments and Experimental Design

The treatments under examination comprised distinct production systems (PS) for each cane: PS1 involved harvesting at the apical nodes, followed by hard pruning, after which another cane would be used in the next production cycle (Figure 1A); PS2 entailed harvesting at the apical nodes, followed by tipping to induce subapical bud break, allowing a subsequent harvest on the same cane, and concluded with hard pruning (Figure 1B); PS3 encompassed harvesting at the apical nodes, followed by tipping to promote subapical bud break, a subsequent harvest, further tipping to encourage new sprouting, and a third harvest on the same cane, ultimately concluding with hard pruning (Figure 1C).

The plants underwent evaluation for two complete production cycles, with hard pruning of the canes performed at the end of each cycle. The duration from cane emission to the last harvest of each treatment defined a complete production cycle. Following the first harvest in the apical nodes of the canes during the first cycle, two new canes per plot were selected, initiating the second production cycle (Figure 1A–C).

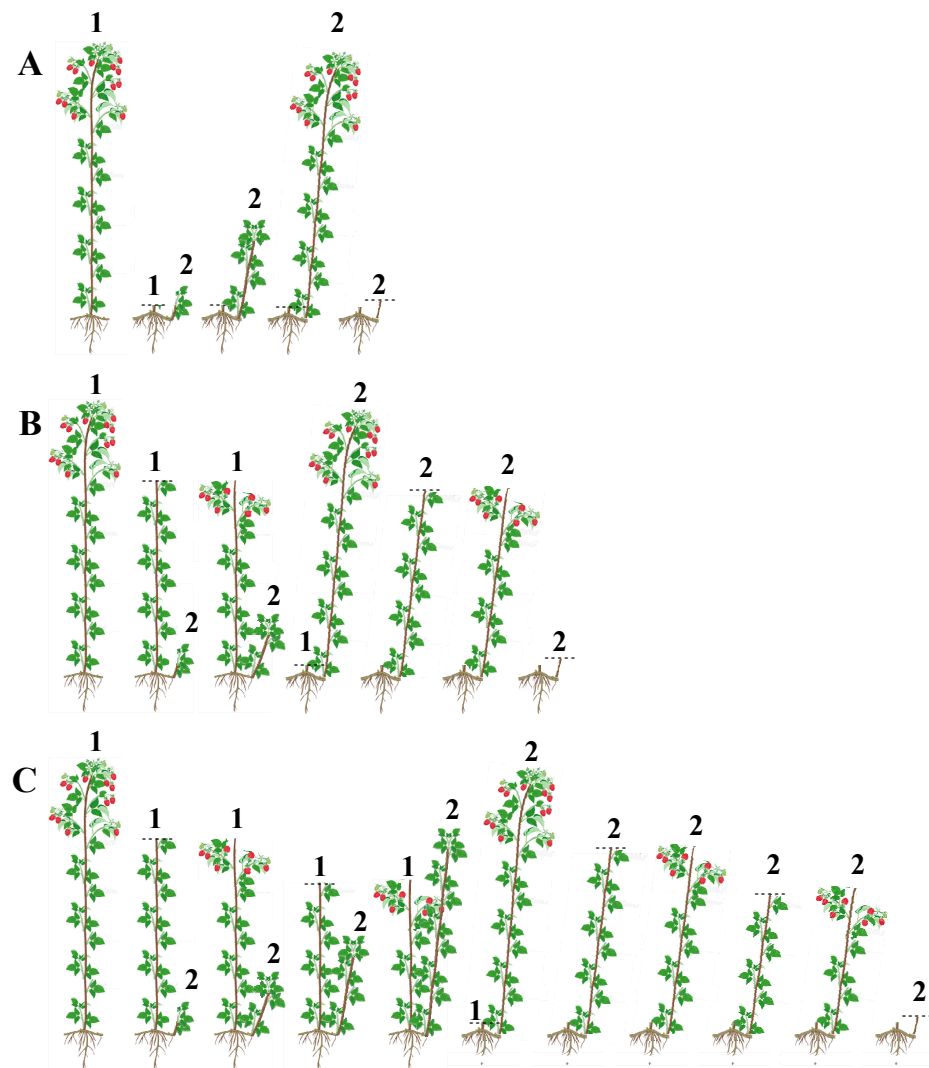


Figure 1. Production systems of cv. Heritage raspberries primocane cultivated in Piracicaba, Brazil, for two cycles (1 and 2). (A): Production system PS1, single harvest in the apical nodes of the canes, followed by hard pruning; (B): Production system PS2, harvest in the apical nodes of the canes, followed by tipping to induce the second harvest, and subsequent hard pruning; (C): Production system PS3, harvest in the apical nodes of the canes, followed by tipping to induce the second harvest, second tipping to induce the third harvest, and finally, hard pruning.

The experimental design employed a randomized block approach in a double factorial scheme (3 treatments $\times$ 2 production cycles) with four blocks. Each block included three pots from each treatment, with two canes in each pot, resulting in a total of 12 pots per treatment and 72 canes evaluated per cycle.

2.3. Vegetative Development, Aspects of Production, and Postharvest Quality

The vegetative development was evaluated by the growth of the canes in each treatment. Over two vegetative cycles, the length of two canes per pot was measured weekly, considering the distance from the base to the apical meristem of each cane. This evaluation continued until the onset of the reproductive period, marked by flowering, at which point the canes ceased their vegetative development.

To determine production per cane, harvests were conducted three times a week, assessing both the number and weight of harvested fruit per cane. The fruits were harvested based on the developmental stages of raspberry fruit, using the color scale for cv. Heritage, specifically at the pink (P) stage, when the drupelets detach easily from the receptacle [13].

Data were recorded in grams per cane per week. Fresh fruit mass was measured using an analytical scale, model AG 200 (Gehaka, São Paulo, Brazil), immediately after each harvest. Soluble solids content was determined using a digital refractometer, model Palette 101 (Atago, Tokyo, Japan), and expressed in °Brix. Titratable acidity (TA) and pH were measured using an automatic titrator (Model 848 Titrino Plus, Metrohm, Herisau, Switzerland) with four replicates of ten fruit for each treatment, and results were expressed as a percentage of citric acid. For anthocyanin content, extracts were obtained from 20 mg of freeze-dried raspberries and 10 mL of extraction solution (85% ethanol P.A. and 15% 1.5 N HCl), following the spectrophotometric method [14]. Absorbance readings were taken with a spectrophotometer (Model Libra S22, Biochrom, Cambridge, UK) at 535 nm. The analyses were performed in periods in which there was fruit in all treatments, encompassing the period from Aug to Dec in the first cycle and from Mar to June in the second cycle, in the Southern Hemisphere.

2.4. Root Biomass and Starch Accumulation

The dry and fresh root masses, along with the starch content, were determined after the completion of the second production cycle for each system used. Root collection took place upon the conclusion of each system's production. Both dry and fresh root masses were measured using an analytical scale (Model AG 200, Gehaka, São Paulo, Brazil). Fresh mass data were collected after the conclusion of the second production cycle, coinciding with the hard pruning of the plants. Subsequently, roots were thoroughly washed in running water until complete substrate removal. After measuring the fresh mass, the roots were placed in identified paper bags and dried in an oven at 55 °C until weight stabilization.

The determination of starch in root samples was conducted following a previously established protocol, with modifications [15]. Soluble sugars were extracted using 200 mg of root samples subjected to three consecutive extractions in 70% ethanol at 60 °C and two extractions with 37% perchloric acid. The extract comprised the recovery of supernatants post-centrifugation at 500 rpm. Glucose measurement employed the phenol sulfuric acid method with a reaction mixture of 50 µL of extract, 450 µL of H₂O, and 500 µL of phenol reagent (5% in water). After vortexing, 2 mL of concentrated sulfuric acid were added, followed by further agitation. Readings were taken with a spectrophotometer at 490 nm. A glucose standard curve (2 to 80 µg) facilitated the calculation of the glucose amount released from perchloric acid digestion. The data were expressed in mg of starch per g dry mass of root.

2.5. Statistical Analysis

The obtained data were subjected to Analysis of Variance (ANOVA) using R Studio software (R Core Team, 2018—Version 1.2.5033), and mean comparisons were performed with the Scott-Knott test ($p \leq 0.05$).

3. Results

3.1. Vegetative Development, Aspects of Production, and Postharvest Quality

The final cane growth was not influenced by the production system. The mean cane length at the end of the first cycle was 130.9 ± 3.4 cm and 153.5 ± 5.0 cm in the second cycle. During the first cycle, the vegetative period of the plants extended for 104 days. In contrast, the second cycle experienced a reduced vegetative development period of 90 days, from the beginning of cane development until the first harvest.

Harvest timing was similar for treatment PS1, as well as for PS2 and PS3, initiating in early Aug and extending until early Dec (Figure 2). In PS1, the first harvest was followed by hard pruning. Subsequent harvests started only from Mar of the subsequent year, extending until early June in the new canes that developed from Dec to Apr (Figure 2A). The first production cycle for PS2 occurred from Aug to Feb, when the plants ceased production in the subapical buds, and a hard pruning of the canes was conducted. The second production cycle of PS2 began in late Mar with canes that developed from Dec to Apr, producing fruit

in the apical nodes until June, which was followed by cane tipping that promoted subapical bud break and resulted in a second harvest from June to Sept (Figure 2B). In PS3, a third harvest was subsequently obtained from mid-Feb to late Mar (Figure 2C).

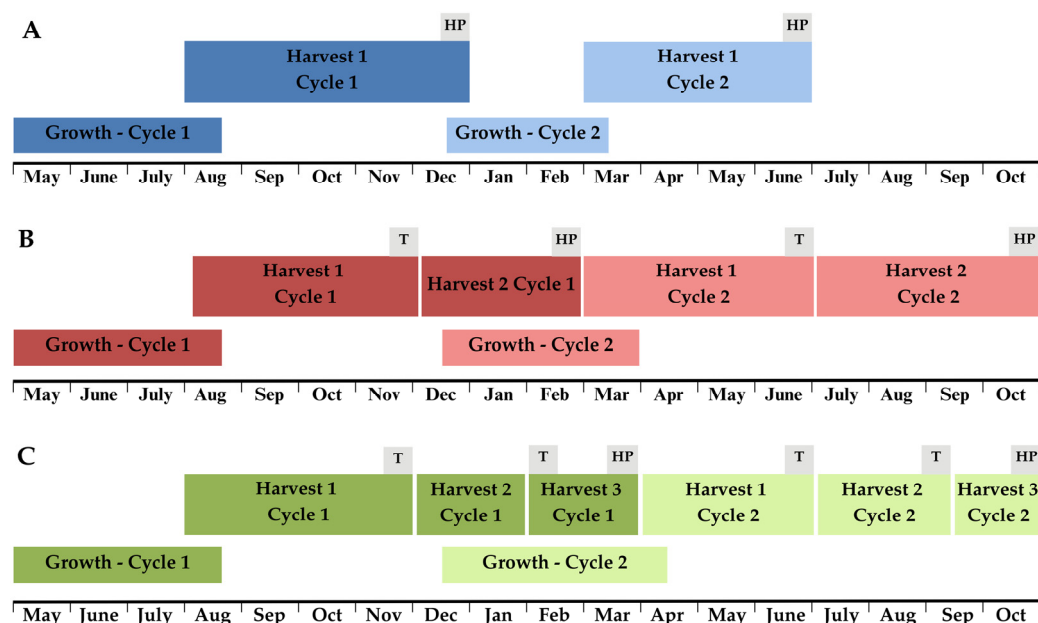


Figure 2. Three production systems in two production cycles for a single cane, showing different harvest strategies. Each system includes two cycles, with additional harvests in systems PS2 and PS3. (A): Production system PS1, with a single harvest at the apical nodes of the canes, followed by hard pruning (HP); (B): Production system PS2, with an initial harvest at the apical nodes, followed by tipping (T) to induce a second harvest, and subsequent hard pruning; (C): Production system PS3, featuring an initial harvest at the apical nodes, followed by tipping to induce a second harvest, a second tipping to promote a third harvest, and ending with hard pruning.

During the first cycle, the total production per cane in PS1 was 168 g, 252 g in PS2, and 313 g in PS3 (Table 1). Differences were also observed in the second cycle, where PS1 continued to produce less per cane (164 g), PS3 more (204 g) and PS2 was an intermediary between them (189 g). In the second production cycle in all treatments, the production was lower (Table 1). There were declines in production between the first and second cycles for all three treatments, with the smallest decrease of 2.7% for PS1, followed by 24.8% for PS2 and 34.6% for PS3 (Table 1). According to the results for the area under the progress curve, there was no interaction between the factors' production system and cultivation cycles (Table 1). Production systems PS2 and PS3 were equivalent to each other, and superior to PS1. The distribution of yields from Mar to Oct in the second cycle exhibited a comparable pattern between PS2 and PS3, but significantly differed from PS1. PS1 concluded its entire harvest distribution by July, while PS2 and PS3 extended their harvest until Oct in the second cycle.

The physicochemical parameters of the raspberries were minimally affected by the variations in production systems. The soluble solids contents, titrable acidity, and anthocyanins varied throughout the months of harvest but did not show significant variations as a function of the treatments (Tables 2–4). For the soluble solids contents, in the first cycle, a clear trend for higher values occurring in Aug and Sept is observed, with a noticeable decrease from Oct in the first cycle to Mar in the second cycle (Table 2). In the second cycle, the differences were less pronounced from Mar to Aug, with a reduction observed in Sept and Oct of that year (Table 2).

Table 1. Production per cane of cv. Heritage primocane raspberry, in three production systems (PS1, PS2, and PS3) across two production cycles, in Piracicaba, Brazil. The first cycle began in August and ended in March, while the second cycle started in March and concluded in October. PS1: single harvest at apical nodes followed by hard pruning; PS2: initial harvest at apical nodes, followed by tipping to induce a second harvest and subsequent hard pruning; PS3: initial harvest at apical nodes, followed by tipping to induce a second harvest, a second tipping to promote a third harvest, and final hard pruning.

Systems	Production per Cane (g)	
	1st Cycle	2nd Cycle
PS 1	168.5 bA	163.9 bB
PS 2	252.3 aA	189.7 aB
PS 3	313.2 aA	204.7 aB

Different lowercase letters in the columns and capital letters in the lines indicate significant differences ($p \leq 0.05$) according to the Scott-Knott test.

Table 2. Soluble solids content (°Brix) in fruits of cv. Heritage primocane raspberries from monthly harvests over two production cycles across three production systems (PS1, PS2, and PS3), in Piracicaba, Brazil. PS1: single harvest at apical nodes followed by hard pruning; PS2: initial harvest at apical nodes, followed by tipping to induce a second harvest and subsequent hard pruning; PS3: initial harvest at apical nodes, followed by tipping to induce a second harvest, a second tipping to promote a third harvest, and final hard pruning.

Soluble Solids Content (°Brix)								
System	Aug	Sept	Oct	1st Cycle Nov	Dec	Jan	Feb	Mar
	PS 1	10.6 aA	10.2 aA	8.4 aB	8.6 aB	8.1 bB	-	-
PS 2	10.4 aA	10.3 aA	8.6 aB	8.7 aB	9.9 aA	9.1 aB	7.8 aC	7.6 bC
PS 3	10.8 aA	10.1 aB	8.2 aE	8.5 aD	9.5 aC	8.9 aD	7.8 aE	8.4 aD
System	Mar	Apr	May	2nd Cycle June	July	Aug	Sept	Oct
	PS 1	9.1 aA	9.7 aA	9.3 aA	8.6 bB	-	-	-
PS 2	9.0 aC	9.8 aB	9.1 aC	9.4 aC	10.5 aA	8.7 bC	7.6 bD	7.7 aD
PS 3	8.0 bC	9.7 aA	9.0 aB	8.8 bB	9.4 bA	9.5 aA	8.7 aB	7.9 aC

Different lowercase letters in the columns and capital letters in the lines indicate significant differences ($p \leq 0.05$) according to the Scott-Knott test.

Table 3. Titrable acidity in fruits of cv. Heritage primocane raspberries from monthly harvests over two production cycles across three production systems (PS1, PS2, and PS3), in Piracicaba, Brazil. A: Production system PS1: single harvest in the apical nodes of the canes, followed by hard pruning; B: Production system PS2, harvest in the apical nodes of the canes, followed by tipping to induce the second harvest, and subsequent hard pruning; C: Production system PS3, harvest in the apical nodes of the canes, followed by tipping to induce the second harvest, second tipping to induce the third harvest, and finally, hard pruning.

Titrable Acidity (% of Citric Acid)								
System	Aug	Sept	Oct	1st Cycle Nov	Dec	Jan	Feb	Mar
	PS 1	1.87 aA	1.79 aA	1.47 aC	1.59 aB	1.81 aA	-	-
PS 2	1.78 aB	1.63 bC	1.49 aC	1.56 aC	1.69 bB	1.54 aC	1.77 aB	1.92 bA
PS 3	1.85 aB	1.71 aC	1.47 aD	1.53 aD	1.81 aB	1.55 aD	1.86 aB	2.18 aA
System	Mar	Apr	May	2nd Cycle June	July	Aug	Sept	Oct
	PS 1	1.76 aB	1.84 aB	1.95 aA	2.02 aA	-	-	-
PS 2	1.59 bC	1.80 aB	1.88 aA	1.88 bA	1.79 bB	1.94 aA	1.62 aC	1.41 aD
PS 3	1.60 bC	1.79 aB	1.92 aA	1.91 bA	1.95 aA	1.88 aA	1.65 aC	1.26 bD

Different lowercase letters in the columns and capital letters in the lines indicate significant differences ($p \leq 0.05$) according to the Scott-Knott test.

Table 4. Anthocyanin content in fruits of cv. Heritage primocane raspberries from monthly harvests across two production cycles (cycle 1: Aug to Dec; cycle 2: Mar to June) in three production systems (PS1, PS2, and PS3) in Piracicaba, Brazil. PS1: single harvest at the apical nodes of the canes, followed by hard pruning; PS2: harvest at the apical nodes, followed by tipping to stimulate a second harvest, and then hard pruning; PS3: harvest at the apical nodes, followed by a first tipping to induce a second harvest, a second tipping for a third harvest, and finally, hard pruning.

Anthocyanins (mg g ⁻¹ of Freeze-Dried Fruit)					
System	1st Cycle				
	Aug	Sept	Oct	Nov	Dec
PS 1	28.9 aB	22.1 aB	39.3 aA	35.8 aA	38.0 aA
PS 2	28.4 aB	21.2 aB	36.1 aA	33.9 aA	36.6 aA
PS 3	24.2 aB	26.4 aB	36.4 aA	33.5 aA	39.7 aA
System	2nd Cycle				
	Mar	Apr	May	June	
PS 1	37.0 aA	33.5 aB	33.9 aB	32.6 aB	
PS 2	39.8 aA	34.6 aB	34.3 aB	35.6 aB	
PS 3	39.5 aA	34.3 aB	33.2 aB	34.7 aB	

Different lowercase letters in the columns and capital letters in the lines indicate significant differences ($p \leq 0.05$) according to the Scott-Knott test.

The titrable acidity of the cv. Heritage raspberries, in both the first and second cycles, ranged from 1.47% to 2.18% of citric acid in the first cycle and 1.26% to 2.02% in the second cycle (Table 3). During the first cycle, there was a tendency for the highest values to occur in Aug and Sept, and in the second cycle, in Feb and Mar, with the lowest values recorded from Oct in the first cycle to Jan in the second cycle. In the second cycle, the highest values were observed between Apr and Aug, while the lowest values occurred in Mar, Sept, and Oct of the same year (Table 3).

In both cycles, seasonal differences in anthocyanin concentrations were observed. During the first cycle, the highest anthocyanin levels were recorded in Oct, Nov, and Dec, while the lowest levels occurred in Aug and Sept. In the second cycle, the peak was in Mar, whereas the lowest contents were noted in Apr, May, and June (Table 4).

3.2. Root Biomass and Starch Accumulation

After the termination of the harvests of the second cycle, the fresh and dry masses were evaluated, as well as the starch content in the roots of the plants. The values for PS2 and PS3 are very close, not differing from each other for these three parameters (Table 5). Nevertheless, they were around 30% inferior to PS1 (Table 5).

Table 5. Fresh mass, dry mass, and starch content in the roots of cv. Heritage raspberries subjected to different production systems for two complete cycles, in Piracicaba, Brazil. Values represent the average of all harvests throughout each cycle. A: Production system PS1: single harvest in the apical nodes of the canes, followed by hard pruning; B: Production system PS2, harvest in the apical nodes of the canes, followed by tipping to induce the second harvest, and subsequent hard pruning; C: Production system PS3, harvest in the apical nodes of the canes, followed by tipping to induce the second harvest, second tipping to induce the third harvest, and finally, hard pruning.

Systems	Fresh Mass (g)	Dry Mass (g)	Starch (mg g ⁻¹)
PS 1	117.8 a	28.9 a	4.65 a
PS 2	81.7 b	19.0 b	3.14 b
PS 3	82.7 b	19.5 b	3.23 b

Different lowercase letters in the columns indicate significant differences ($p \leq 0.05$) according to the Scott-Knott test.

4. Discussion

The raspberry plants were subjected to different pruning systems over two production cycles. Due to the different periods of the year in which these cycles started, differences were observed in both the time required to start production and the size of the canes. In the first cycle, the reproductive period began, on average, 104 days after transplanting, in canes measuring 130 cm. In the second cycle, the start of the reproductive period was shorter, averaging 90 days, with taller canes reaching 153 cm. This difference likely occurred because, in the first cycle, vegetative development took place from May to September, with milder temperatures and lower global solar radiation in the Southern Hemisphere. In the second cycle, the canes developed from December to April, experiencing higher temperatures and greater radiation, resulting in canes that grew, on average, taller than those of the previous cycle. Similar seasonal characteristics influencing cane growth have been observed in the primocane raspberry cv. Autumn Bliss, where higher cultivation temperatures resulted in an increased growth rate of the canes [16].

The pruning systems used influenced fruit production per cane (g), regardless of the production cycle. The systems involving one subapical pruning (PS2) or two subapical prunings (PS3) yielded similar production levels within each cycle, both of which were higher compared to the hard pruning without subapical prunings (PS1). However, systems with subapical prunings on the same cane may present additional challenges for the labor responsible for this cultural practice in raspberry cultivation. These findings are consistent with a study in which the primocane raspberry production over three consecutive years was higher when subjected to a double-cropping system that included harvesting from the apical nodes of the canes, followed by a second harvest from the subapical buds, as compared to production only from the apical nodes of the canes [17]. It should be noted that the present experiment compared production across two complete cycles of different durations. The tipplings and subsequent harvests in PS2 and PS3 increased fruit production but prolonged the production cycle, whereas PS1 completed both production cycles three and a half months before PS2 and five months before PS3. During this period, it would have been possible to initiate a third cycle and the beginning of a new harvest, based on the time elapsed until a new harvest began for PS1 in the first and second cycles.

High levels of soluble solids and acidity are important parameters in fruit farming, often associated with a better flavor profile and organoleptic quality of the fruit [18], while polyphenols and anthocyanins are more closely related to health benefits [19]. The various production systems had minimal impact on fluctuations in the soluble solids content of the raspberries. This parameter, along with the fruit's titratable acidity, is significantly influenced by factors such as the cultivation region, specific cultivar, and production period [20,21]. The reduction in soluble solids content throughout the production cycle may be associated with climatic factors, as this decrease is more evident in months typically characterized by high temperatures. Previous studies suggest that elevated temperatures impact soluble solids content in raspberry fruits, likely due to an increase in plant respiration rate, which heightens carbohydrate consumption and modifies the source–sink relationship, ultimately resulting in lower soluble solids content levels [22]. Despite this reduction during the production cycle, fruit quality for commercialization is not adversely affected, as the minimum values observed in the present study remain acceptable and comparable to those reported for the cv. Heritage in Brazil, which show approximately 6.0 °Brix in fruits of this cultivar [22,23].

Notably, the fruit exhibited higher soluble solids content at the onset of the cycles, followed by a reduction in sugar accumulation during the harvest period. The production systems also did not significantly affect the titratable acidity of the fruit. The highest acidity levels occurred in the colder months of the cycles, while in the second production cycle, the lowest acidity levels were observed in the warmer months. Lower acidity might be related to metabolic changes and the consumption of organic acids during warmer periods [24].

The anthocyanin content of the raspberries was not affected by the different production systems. However, environmental factors are key determinants of antioxidant compound

accumulation in raspberries [19,25,26]. In this study, the time of year (months) during which production occurred significantly influenced the anthocyanin content. Higher anthocyanin levels were recorded in October, November, and December in the first cycle, and in March in the second cycle, coinciding with the months of higher global solar radiation during each evaluated period. Anthocyanins play an important role in protecting plants from the damage of high solar radiation and are more abundant under high light intensity [27].

The pruning systems with subapical prunings (PS2 and PS3), which included sequential harvests that promoted higher production per cane, led to lower root system masses and reduced carbohydrate reserves in the roots compared to the hard pruning system (PS1). System PS1, which had the lowest mean fruit production per cane at the end of the two cycles, showed the highest root mass and greatest starch content, indicating greater reserve accumulation and lower depletion in plants subjected to this system. Sequential prunings (subapical prunings) may result in greater reserve use, consequently leading to greater depletion of the plants for future production [28]. In this experiment, the severe pruning system (PS1) experienced a minimal decline in production of approximately 2.73% from the first cycle to the second cycle, likely due to the carbohydrate reserves available to the plant. In treatments with two harvests (PS2) and three harvests (PS3), the production reduction from one harvest to the next was 24.8% and 34.6%, respectively, likely due to the depletion of reserves from the sequential prunings.

Starch is the most abundant storage carbohydrate in woody tissues, accumulating in plants during periods of high photosynthetic activity and depleting when carbohydrate usage exceeds production [29,30]. Studies on the raspberry cv. Titan have shown that raspberry roots serve as major carbon sinks, utilized during fruit maturation when carbohydrate synthesis sources are limited [31]. In the present study, during and after apical production, the canes were undergoing lignification, and leaf senescence occurred. In systems PS2 and PS3, where lignified canes were retained for subsequent harvests, the carbohydrate source for fruit maturation may have come from root system reserves, potentially explaining the lower starch content and root mass in these systems compared to PS1.

5. Conclusions

This study provides evidence that under subtropical climate conditions (Cwa), the cv. Heritage primocane raspberry, cultivated with subapical prunings and subjected to two or three harvests on the same cane, exhibits higher production over the corresponding period than the system with only one harvest. This approach prolongs the uninterrupted harvest season for two complete production cycles, spanning 14 months. Furthermore, it does not adversely affect the postharvest quality of the fruit, as observed in anthocyanin content, soluble solids, and titratable acidity. However, raspberries subjected to subapical pruning show lower carbohydrate storage in the root system compared to hard pruning, which may impact the longevity of these plants. For future studies, it is recommended to conduct a socioeconomic analysis of labor costs across different production systems to assess the economic feasibility of management practices in primocane raspberry cultivation under a subtropical climate.

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