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Multiplication, Phenological Period and Growth Vigor of Thirty-One Grapevine Rootstocks and the Role of Parentage in Vigor Heredity

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Abstract: Knowledge about the growth vigor of grapevine rootstocks is required for scion-based rootstock selection and rootstock breeding. We performed this trial aiming to evaluate the multiplication and growth vigor of several rootstocks. Thirty-one rootstock genotypes were compared on their multiplication characteristics, phenological periods, and growth indicators across three consecutive seasons. The results suggested that the cuttings of most rootstocks had callus-forming indices (CFIs) over 0.5 except for '188-08' (0.28). The rooting rate of '420A' was 5%, while that of the rest of the rootstocks was greater than 48%. The internode lengths of the one-year-old vines were positively correlated with those (as well as cane lengths and pruning weights) of the adult vines. These rootstocks were grouped into three clusters based on the growth measurements across three seasons. Eight combinations of genetic backgrounds showed various effects on the growth indicators. The high-vigor cluster includes '1103P', '5BB', '225Ru', etc.; the medium-vigor cluster includes 'Dogridge', '101-14M', 'Fercal', etc.; and the low-vigor cluster includes 'Gloire', '3309C', 'Ganzin1', etc. The *Vitis berlandieri* parentage showed a higher vigor heredity, while the *V. riparia* showed a lower vigor heredity. These findings would contribute to rootstock nursery construction and provide references for vigor-based rootstock selection for grafts and parent selection for rootstock breeding.

Keywords: *Vitis*; callus; internode; pruning weight; phenological periods; grapevine; genetic background; meteorology

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1. Introduction

Rootstocks have acted a vital role in grapevine (*Vitis vinifera* L.) cultivation, ever since using them to protect against phylloxera infections in the European vineyards in the nineteenth century [1]. After that, many grapevine rootstock cultivars have been bred and the advantages of rootstocks such as nematode resistance, drought tolerance, salinity tolerance, and lime tolerance have been recognized [2–5]. Furthermore, rootstocks can alter the yield and berry composition of grapes [6,7] by affecting bud fertility, fruit set, berry weight, and nutrition uptake [8–10].

Rootstocks were not taken seriously due to the absence of phylloxera attacks in the viticultural history of China [11], until scientists realized their value in resisting environmental stresses and improving fruit quality. Furthermore, numerous grapevine rootstocks have been successively introduced [12]. In the meantime, several rootstocks have been bred locally since 1984 by using native wild species like *V. amurensis* [11]. Grapevine grafting has become a popular topic in both academic and commercial areas in recent years. Grafted vine materials are also well-sold for their improved fruit quality or yield. And the grafted plants are easy to survive and tend to grow vigorously after grafting tender shoots on a vigorous rootstock. Some sayings in recent years, like the positive effects of a few rootstocks on the popular fresh grape cultivar, 'Shine Muscat' (*V. labruscana* × *V. vinifera*), have driven the price to surge for cultivars '3309C', 'Kober 5BB', and the unverified '3309M'. This should be attributed to the limited planting area of these rootstocks before their value was noted.

The nursery industry in China mainly consists of individual households, cooperatives, or small-scale companies, and very few of them have rootstock nurseries. The promising market for grafts encourages them to construct their own rootstock nurseries, either to meet their own rootstock demand, screen potential rootstocks, or even breed new rootstocks. However, most rootstocks are just conserved as germplasm resources by research institutes after being introduced, especially the lesser-known cultivars and the locally bred ones [13]. To better utilize these rootstocks, their features need to be investigated.

Terroir is critical to vine performance [14]; thus, regional rootstock screening is necessary. Several rootstocks have been tested for nutrition uptake, cold resistance, virus detection, and impact on scion yield and fruit composition in regions such as the Mediterranean, Eastern Canada, and Algeria [15–18]. Recently in China, the primary core collection of grape genetic resources was constructed based on plant phenotypic traits by the national grapevine repository [13]. Responses to stresses like copper and sodium chloride have been tested on many rootstock cultivars [19,20]. The tolerance to cold or waterlogging has also been tested on the major cultivars [21–23]. However, essential knowledge of the multiplication, phenology, and growth vigor of these rootstocks is rarely reported.

The native species *V. amurensis* has been well utilized in northern China for its good cold-hardiness and perfect flowers, but *V. amurensis* is weak and hard to root [11]. Breeders made intraspecific crosses and interspecific hybridizations with species like *V. riparia* to overcome the weaknesses. The improved cultivars include 'Shanhe' lines ('Shanhe 1', 'Shanhe 2', 'Shanhe 3', and 'Shanhe 4') [24], but their planting characteristics are still required to be investigated. Those lesser-known rootstock cultivars can be good candidates for specific viticultural purposes or be used as promising parents just as *V. amurensis* is used to breed new cultivars. Thus, much detail on their growth and multiplication is required as well. Some cultivars such as '5BB', 'SO4' and '1103P' are recognized as easy to grow, even in cold regions. However, their multiplication information, which is vital for a rootstock nursery, has rarely been assessed publicly.

Urged by these questions, we multiplied 31 grapevine rootstocks and then investigated their phenological periods and growth performances for three consecutive seasons. The main objective was to evaluate the multiplication and growth characteristics of these rootstocks. We also aimed to understand the role of genetic background in transmitting vigor. We conducted this trial in Changli, northern China, a major region that produces fresh grapes, wine, and planting materials. This is a first for most of the tested rootstocks. The results would deepen our understanding of these rootstocks. Furthermore, the results could help nursery growers in selecting rootstock cultivars.

2. Materials and Methods

2.1. Multiplication Evaluation of the Plant Materials

Healthy dormant canes of 31 grapevine rootstocks (Table 1) were acquired in the winter of 2010. Canes in bundles were sprayed with lime sulfur solution (2%) and then stored under one meter of moist soil (30–40% moisture content) until the spring, when they were ready to propagate. Canes were cut into cuttings with two fully developed buds (the schematic diagram of the test is shown in Figure 1). The desirable cuttings were approximately 15 cm long and 0.7 cm thick. The basal end of the section was cut at a sharp angle of about 30°, and the upper end was cut flat, and each end was 2 cm below or above the closest bud (Figure 1). Every ten cuttings were tied up to form one bundle. Four bundles of cuttings with tags were soaked in distilled water (20 ± 2 °C) for 5 h, and then their basal ends were dipped into a rooting solution containing 20% naphthylacetic acid (NAA) and 30% heteroauxin (IAA) (Aibidi Biotechnology, Beijing, China) for 3 min right before placing them on the nursery bed. The nursery bed was made of 10 cm of sand with a controllable electric heating system at the bottom. Gaps between cuttings were filled with sand, and the upper buds were exposed to the air. The bottom temperature was set at 26 ± 2 °C, and the air temperature was 15 ± 2 °C. The moisture content of the sand was kept at 50–60% by spraying water on the bed surface two times a day.

Table 1. Thirty-one grapevine rootstocks used in the trial and their abbreviations and parentage information.

Rootstock	Abbreviation	Parentage
'Millardet et de Grasset 101-14′	'101-14M′	*V. riparia* × *V. rupestris*
'Paulsen 1103′	'1103P′	*V. berlandieri* × *V. rupestris*
'Richter 110′	'110R′	*V. berlandieri* × *V. rupestris*
'Couderc 1202′	'1202C′	*V. vinifera* × *V. rupestris*
'Ruggeri 140′	'140Ru′	*V. berlandieri* × *V. rupestris*
'Couderc 1613′	'1613C′	(*V. riparia* × *V. longii*) × 'Othello′
'Castel 188-08′	'188-08′	*V. monticola* × *V. riparia*
'Ruggeri 225′	'225Ru′	*V. berlandieri* × *V. riparia*
'Couderc 3309′	'3309C′	*V. riparia* × *V. rupestris*
'Millardet et de Grasse 420A′	'420A′	*V. berlandieri* × *V. riparia*
'Téléki 5 A′	'5A′	*V. berlandieri* × *V. riparia*
'Kober–Téléki 5BB′	'5BB′	*V. berlandieri* × *V. riparia*
'Téléki 5C′	'5C′	*V. berlandieri* × *V. riparia*
'Téléki 8B′	'8B′	*V. berlandieri* × *V. riparia*
'Berlandieri Rességuier No. 2′	'BR2′	*V. berlandieri*
'Riparia Barrett 50′	'Barrett50′	*V. riparia*
'Riparia Beaumont′	'Beaumont′	*V. riparia*
'Beta′	'Beta′	*V. riparia* × [(*V. labrusca* × *V. vinifera*) × *V. labrusca*]
'Dog ridge′	'Dogridge′	*V.* × *champinii* (*V. rupestris* × *V. candicans*)
'Fercal INRA Bordeaux′	'Fercal′	(*V. berlandieri* × *V. vinifera*) × (*V. berlandieri* × *V. longii*)
'Ganzin 1′ ('AxR 1′)	'Ganzin1′	*V. vinifera* × *V. rupestris*
'Riparia Gloire de Montpellier′	'Gloire′	*V. riparia*
'Rupestris du Lot′	'du Lot′	*V. rupestris*
'Saltcreek′ ('Ramsey′)	'Saltcreek′	*V.* × *champinii* (*V. rupestris* × *V. candicans*)
'Rupestris Scheele′	'Shadi′	*V. rupestris*
'Shanhe 1′	'Shanhe1′	*V. amurensis* × *V. riparia*
'Shanhe 2′	'Shanhe2′	*V. amurensis* × *V. riparia*
'Shanhe 3′	'Shanhe3′	*V. amurensis* × *V. riparia*
'Shanhe 4′	'Shanhe4′	*V. amurensis* × *V. riparia*
'Téléki-Fuhr Selektion Oppenheim No.4′	'SO4′	*V. berlandieri* × *V. riparia*
'Wumao′	'Wumao′	*V. berlandieri* × *V. riparia*

After being nursed for 30 days, a total of four bundles (ten cuttings for each bundle as one replicate) for each cultivar were randomly selected for multiplication evaluation. The cutting with visible green tissue or shoot was defined as "budbreak", and the bud length was measured using a vernier caliper. The cutting with visible root(s) was defined as "rooted", and the root(s) number was recorded. We defined the callus-forming grade (i) as the callus covering percentage on the section surface: 0, 0%; 1, 1–20%; 2, 21–40%; 3, 41–60%; 4, 61–80%; 5, 81–100%. One well-trained assistant rated the cuttings visually. For each replicate, the budbreak rate, rooting rate, and callus-forming index [CFI, modified from the salt damage index [19,25]] were calculated. CFI = $(0 \times N_0 + 1 \times N_1 + 2 \times N_2 + 3 \times N_3 + 4 \times N_4 + 5 \times N_5)/(5 \times 10)$, where N_i represents the number of cuttings with the corresponding callus-forming grade (i, i = 0–5), and one bundle of ten cuttings is one replicate.

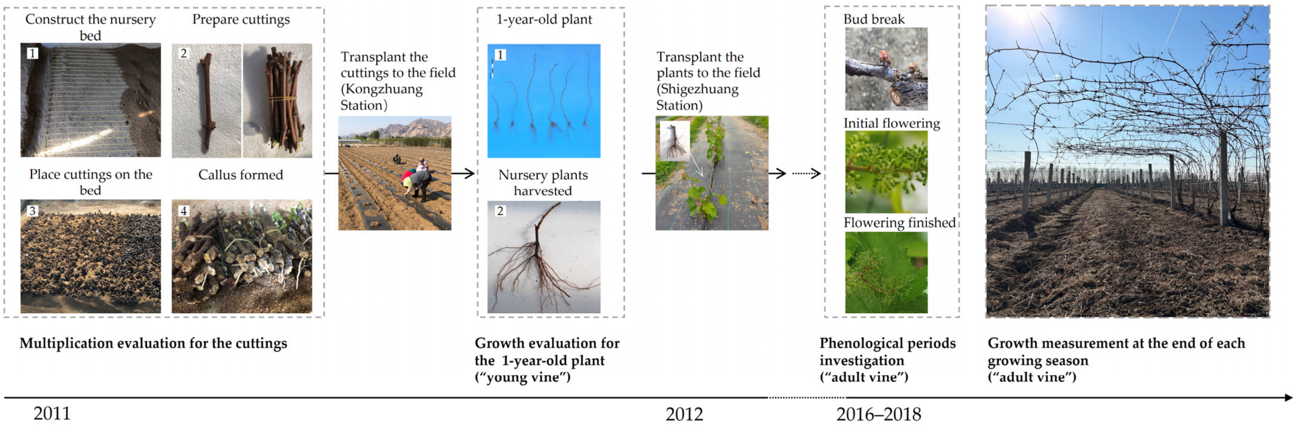

Figure 1. Schematic diagram of the present trial. The multiplication of grapevine rootstocks was evaluated after the cuttings were nursed for 30 days in 2011 and then the cuttings were transplanted into the field at Kongzhuang Station. As the "young vines" grew in the field for 90 days, both above-ground and underground growth were determined. Meanwhile, the nursery plants were harvested. In late March 2012, the plants were transplanted to the germplasm repository at Shigezhuang Station. During the years 2016–2018, the phenological periods including bud-break, initial flowering and the end of flowering of the grapevine rootstocks ("adult vines") were recorded; growth indicators including trunk diameter, cane diameter, cane length, pruning weight, etc., were determined after leaves fell.

2.2. Evaluation of Cutting Development

Well-developed cuttings were root-dipped in a mixture of water and bioagent (*Agrobacterium vitis* E26, 1/2 in volume) to prevent crown gall infections before being transplanted in the field on April 17, 2011 (Figure 1). The plants grew at the Kongzhuang experimental station (39°42′29′′ N, 119°05′41′′ E; altitude 14 m), Changli Institute of Fruit Research. All the plants were managed uniformly, and only one stronger shoot was kept for each plant. The pest and disease control followed the local standards. Vine materials were harvested, and growth parameters were measured after leaves fell on November 30. Ten plants for each cultivar were carefully dug out, and the soil was carefully washed off the roots. Shoot basal diameter and root diameter were measured using a digital vernier caliper. Roots with a diameter of over 2 mm were defined as thick roots and were counted. The thick root proportion was calculated as the ratio of the number of thick roots to the number of total roots in percentage. The lengths of the shoot and root were determined using a tape measure. The lignified proportion of the shoot was defined as cane length/shoot length in percentage. Total root length and average root length are the sum and mean of the lengths, respectively, of the individual roots for each vine. The soil at the site is sandy loam.

2.3. Growth Measurements for the Vines

The vine materials were harvested with two buds retained (Figure 1). The plant materials were preserved in a ditch, which was then covered with moist soil in the shade. In the spring of 2012, they were planted in the grapevine repository at Shigezhuang experimental station (39°45′01′′ N, 119°12′44′′ E; altitude 20 m), Changli Institute of Fruit Research. Vines were spaced at 0.7 × 4 m and trained on a pergola trellis at a height of 1.8 m. In the planting year, only one vigorous shoot was retained for trunk establishment for each plant. In the first winter, the single cane was pruned at the lower cordon, about one meter high. In the second growing season, the top 5–6 shoots on each plant were allowed to develop until the winter, when each newly formed cane was pruned to two buds. Similarly in the next season, only one shoot was retained on each spur, and around 5–6 new shoots in total were kept. All the vines were generally unearthed several days before the traditional Qingming Festival (4 or 5 April), specifically, 30 March 2016, 1 April 2017 and 1 April 2018. These management changes were repeated in the following years. Investigation and determination were conducted from the fifth to seventh growing seasons (2016–2018). After leaves fell, for each plant, the trunk basal diameter (30 cm above the ground), cane length, cane basal diameter, and shoot length were measured, and the internodes were counted before canes were pruned and weighed. Internode length is defined as cane length/internode number, and lignified proportion is defined as cane length/shoot length. A total of ten plants for each rootstock cultivar were randomly selected and determined. All the vines were managed uniformly and were buried with soil to overcome the cold winter.

2.4. Phenological Periods Investigation for the Vines

During each growing season, the phenological periods for each rootstock cultivar were investigated based on the modified E-L system for grapevine growth stages [26]. The budbreak period is defined as when around 5% of the total buds show green tips (stage E-L 4). Initial flowering is defined as when around 5% of the flower clusters show caps-off (E-L 19). The flowering period ends when the caps fall off (E-L 26). Phenological period recording started on the first day of the year (DOY).

Meteorological data were obtained from the local weather bureau and averaged monthly from April to October (Figure S1 and Table S1). The soil is sandy loam, and its composition was determined (Table S2).

2.5. Statistical Analysis

Data analyses were performed using SPSS 20 (IBM Corp., Armonk, NY, USA). Normality and homogeneity of variance were tested before analysis. A one-way or two-way ANOVA followed by Tukey's post hoc test was employed to compare the means at $p < 0.05$. The nonparametric median test followed by multiple pairwise comparisons was adopted to compare the medians at an adjusted $p < 0.05$ by Bonferroni correction. Principle component analysis (PCA), correlation analysis, hierarchical cluster analysis (HCA), and figure construction were conducted in OriginPro 2018 (OriginLab Corp., Northampton, MA, USA).

3. Results

3.1. Multiplication Characteristics of the Cuttings

The status of cutting development varied largely among these rootstocks after being nursed for 40 days (Table 2). The callus-forming indices (CFIs) ranged from 0.28 ('188-08') to 0.97 (5C). Thirteen rootstocks, or approximately 42% of the total, achieved high CFIs of over 0.9. '188-08' was the only one that attained a CFI less than 0.5, that is, other rootstocks could form calluses in more than half the area of the cutting plane. The average rooting rate of '420A' was 5%, markedly lower than those of other rootstocks, which were greater than 48%. Especially with 'Fercal' and '5A', whose rooting rates reached 100%. The average root number per cutting was found to be positively related to the rooting rate. It ranged from 0.2 to 10.2, with a median of 2.9. Correspondingly, '5A' produced the most roots, while '420A' and 'BR2' produced less than one root on average.

The budbreak rate and bud length lie in ranges of 37.5–100% and 0.42–3.58 cm, respectively. The budbreak rates of two-thirds of the rootstocks reached 80%, especially for 'Beta' which got a rate of 100% and the largest bud length of 3.58 cm. Furthermore, buds of '225Ru' and 'Wumao' germinated less than 50% and were the shortest in length.

3.2. Growth of the One-Year-Old Vine in the Field

Rootstocks performed diversely in both overground and underground growth-related traits after growing in the field for 90 days (Tables 3 and 4). The shoot diameter of '225Ru', which reached 10.1 mm, was significantly larger than that of other rootstocks, which ranged from 5.6 ('Saltcreek') to 8.1 ('Shanhe4') mm. The shoot lengths ranged from 72.7 to 150.3 cm, and 80% of those were longer than one meter (Table 3). Cultivars with longer shoots generally had longer lignified parts, showing a positive correlation between the variables

(Figure S2). Averagely, the lignified shoot length and total shoot length of '110R' were the largest, more than twice those of 'Gloire', '1613C', or 'Shadi'. The variation in lignification rates was relatively small, with a range of 73–100%. Shoots of 'Gloire', 'Beaumont', and '3309C' were less lignified, lower than 75%. The internode lengths ranged from 3.2 to 7.8 cm, being higher on varieties with longer shoots and lower on those with shorter shoots.

Table 2. Multiplication traits of the grapevine rootstock cuttings after being nursed for 40 days.

Rootstock	CFI	Rooting Rate (%)	Root Number	Budbreak Rate (%)	Bud Length (cm)
'101-14M'	0.94 ± 0.06 a–d	62.5 ± 15.0 d–g	1.3 ± 0.1 no	85.0 ± 10.0 b–f	1.05 ± 0.07 k–o
'1103P'	0.54 ± 0.01 m	83.0 ± 17.0 abc	4.2 ± 0.3 de	92.8 ± 4.9 a–d	1.17 ± 0.08 jkl
'110R'	0.72 ± 0.07 i–l	87.5 ± 12.6 ab	3.7 ± 0.4 ef	82.5 ± 9.6 c–g	1.08 ± 0.05 klm
'1202C'	0.92 ± 0.04 a–d	90.0 ± 8.2 ab	5.8 ± 0.4 b	72.5 ± 9.6 ghi	0.95 ± 0.03 mno
'140Ru'	0.87 ± 0.05 b–g	87.5 ± 5.0 ab	3.5 ± 0.3 fg	92.5 ± 9.6 a–d	1.35 ± 0.05 j
'1613C'	0.76 ± 0.04 h–k	83.3 ± 6.1 abc	2.6 ± 0.1 h–k	71.8 ± 5.6 ghi	1.86 ± 0.16 d–g
'188-08'	0.28 ± 0.07 n	61.3 ± 13.7 d–g	1.6 ± 0.2 l–o	97.3 ± 5.5 ab	1.84 ± 0.15 e–h
'225Ru'	0.88 ± 0.05 a–e	90.0 ± 8.2 ab	4.5 ± 0.4 d	37.5 ± 9.6 l	0.45 ± 0.03 r
'3309C'	0.94 ± 0.03 a–d	62.5 ± 9.6 d–g	2.3 ± 0.2 i–l	92.5 ± 5.0 a–d	1.68 ± 0.09 ghi
'420A'	0.78 ± 0.08 f–j	5.0 ± 5.8 h	0.2 ± 0.3 q	67.5 ± 5.0 ij	0.74 ± 0.06 pq
'5A'	0.70 ± 0.04 jkl	100 ± 0 a	10.2 ± 0.7 a	95.0 ± 5.8 abc	1.94 ± 0.14 def
'5BB'	0.92 ± 0.04 a–d	67.5 ± 5.6 c–f	2.9 ± 0.2 ghi	85.3 ± 5.0 b–f	1.24 ± 0.12 jk
'5C'	0.97 ± 0.03 a	67.5 ± 5.0 c–f	2.2 ± 0.1 i–l	90.0 ± 8.2 a–e	1.22 ± 0.11 jk
'8B'	0.93 ± 0.02 a–d	80.0 ± 14.1 bcd	5.7 ± 1.9 b	60.0 ± 0 jk	0.63 ± 0.03 q
'BR2'	0.77 ± 0.11 g–j	48.0 ± 22.2 g	0.5 ± 0.2 pq	85.5 ± 17.1 b–f	0.87 ± 0.09 nop
'Barrett50'	0.86 ± 0.06 c–g	91.8 ± 8.4 ab	5.3 ± 0.7 bc	92.8 ± 5.3 a–d	2.05 ± 0.25 cd
'Beaumont'	0.85 ± 0.05 d–h	55.0 ± 10.0 fg	2.6 ± 0.2 h–k	85.0 ± 5.8 b–f	1.05 ± 0.09 k–o
'Beta'	0.68 ± 0.06 kl	77.5 ± 9.6 bcd	3.7 ± 0.5 ef	100 ± 0 a	3.58 ± 0.26 a
'Dogridge'	0.76 ± 0.02 h–k	75.0 ± 12.9 b–e	1.9 ± 0.1 k–n	90.0 ± 8.2 a–e	1.10 ± 0.03 klm
'Fercal'	0.66 ± 0.03 l	100 ± 0 a	5.9 ± 0.3 b	75.0 ± 5.8 f–i	2.28 ± 0.29 b
'Ganzin1'	0.80 ± 0.08 e–i	77.5 ± 12.6 bcd	3.3 ± 0.4 fgh	95.0 ± 5.8 abc	1.64 ± 0.12 hi
'Gloire'	0.96 ± 0.03 ab	80.0 ± 8.2 bcd	3.7 ± 0.3 ef	92.5 ± 5.0 a–d	1.79 ± 0.09 f–i
'du Lot'	0.87 ± 0.09 a–f	85.0 ± 12.9 abc	4.9 ± 0.4 cd	70.0 ± 8.2 hij	0.87 ± 0.11 nop
'Saltcreek'	0.94 ± 0.05 a–d	85.0 ± 5.8 abc	4.9 ± 0.5 cd	52.5 ± 5.0 k	0.85 ± 0.11 op
'Shadi'	0.93 ± 0.09 a–d	57.5 ± 15.0 efg	1.4 ± 0.1 mno	80.0 ± 14.1 d–h	1.07 ± 0.10 k–n
'Shanhe1'	0.91 ± 0.06 a–d	77.5 ± 9.6 bcd	2.6 ± 0.3 h–k	87.5 ± 5.0 a–e	1.63 ± 0.11 i
'Shanhe2'	0.85 ± 0.07 d–h	75.0 ± 10.0 b–e	1.9 ± 0.2 k–n	95.0 ± 5.8 abc	1.90 ± 0.17 def
'Shanhe3'	0.78 ± 0.08 f–j	90.0 ± 0 ab	2.8 ± 0.3 g–j	92.5 ± 5.0 a–d	2.02 ± 0.18 cde
'Shanhe4'	0.95 ± 0.05 abc	55.0 ± 12.9 fg	1.0 ± 0.1 op	90.0 ± 11.5 a–e	2.16 ± 0.18 bc
'SO4'	0.94 ± 0.05 a–d	62.5 ± 22.2 d–g	2.1 ± 0.1 j–m	77.5 ± 5.0 e–i	0.98 ± 0.08 l–o
'Wumao'	0.90 ± 0.05 a–e	72.5 ± 15.4 b–f	4.9 ± 0.4 cd	40.0 ± 3.3 l	0.42 ± 0.03 r

Note: Data shown are means ± standard error, n = 4. Different lowercase letters within each column represent significant differences at $p < 0.05$ by Tukey's test. CFI, callus-forming index.

Table 3. Growth indicators of the shoot 90 days after planting the grapevine rootstock cuttings in the field (the young vine).

Rootstock	Shoot Basal Diameter (mm)	Cane Length (cm)	Internode Length (cm)	Shoot Length (cm)	Lignified Proportion (%)
'101-14M'	6.9 ± 0.9 b–f	125.8 ± 25.8 abc	6.5 ± 1.4 bcd	126.2 ± 25.5 a–f	99.6 ± 1.1 a
'1103P'	6.4 ± 0.8 c–f	112.6 ± 29.9 b–g	6.6 ± 1.5 bc	112.6 ± 29.9 c–g	100 ± 0 a
'110R'	7.1 ± 1.4 b–e	148.6 ± 18.7 a	7.8 ± 1.0 a	150.3 ± 18.2 a	98.9 ± 2.6 a
'1202C'	7.4 ± 1.3 bcd	124.8 ± 22.8 a–d	5.2 ± 0.7 efg	143.0 ± 27.2 ab	89.0 ± 16.5 abc
'140Ru'	6.5 ± 0.8 c–f	120.3 ± 31.7 a–e	5.4 ± 0.8 efg	126.1 ± 29.0 a–f	95.3 ± 10.0 ab
'1613C'	5.9 ± 1.2 ef	72.7 ± 25.4 jkl	3.7 ± 0.9 ij	72.7 ± 25.4 i	100 ± 0 a
'188-08'	6.7 ± 0.6 c–f	91.8 ± 24.4 e–k	4.8 ± 0.6 fgh	100.2 ± 25.0 fgh	91.6 ± 13.1 abc
'225Ru'	10.1 ± 2.6 a	96.0 ± 23.9 d–j	6.1 ± 1.3 b–e	111.0 ± 31.1 c–g	87.9 ± 11.8 abc
'3309C'	6.9 ± 1.7 b–f	85.1 ± 26.7 g–l	3.8 ± 0.9 ij	113.2 ± 24.3 c–g	74.7 ± 12.8 d
'420A'	6.7 ± 1.2 c–f	135.8 ± 30.6 ab	5.2 ± 0.7 efg	137.3 ± 31.5 abc	99.1 ± 3.0 a
'5A'	7.4 ± 1.2 bcd	119.8 ± 24.3 a–e	6.0 ± 0.8 b–e	125.8 ± 24.7 a–f	95.5 ± 6.7 ab
'5BB'	7.3 ± 1.3 bcd	101.9 ± 30.4 c–i	6.3 ± 1.0 b–e	106.8 ± 33.2 d–g	96.4 ± 8.4 ab
'5C'	6.4 ± 1.1 c–f	80.7 ± 23.2 h–l	4.7 ± 1.2 f–i	100.5 ± 24.6 fgh	81.9 ± 21.4 cd

Table 3. *Cont.*

Rootstock	Shoot Basal Diameter (mm)	Cane Length (cm)	Internode Length (cm)	Shoot Length (cm)	Lignified Proportion (%)
'8B'	6.9 ± 1.1 b–f	97.9 ± 16.8 c–j	5.4 ± 0.8 efg	121.0 ± 15.5 b–f	82.1 ± 17.0 cd
'BR2'	6.5 ± 1.7 c–f	110.3 ± 42.6 b–g	6.0 ± 1.3 b–e	115.5 ± 32.7 b–g	92.5 ± 15.0 abc
'Barrett50'	6.8 ± 1.1 b–f	127.4 ± 21.9 abc	5.4 ± 1.1 d–g	135.5 ± 14.2 a–d	93.6 ± 8.7 abc
'Beaumont'	6.2 ± 1.1 def	78.7 ± 32.4 i–l	3.8 ± 0.7 ij	105.5 ± 28.7 e–h	73.5 ± 15.7 d
'Beta'	7.0 ± 0.6 b–e	134.4 ± 14.9 ab	6.1 ± 0.4 b–e	136.3 ± 15.8 abc	98.7 ± 2.7 a
'Dogridge'	7.8 ± 1.5 bc	116.3 ± 28.4 b–f	4.6 ± 0.8 ghi	116.3 ± 28.4 b–g	100 ± 0 a
'Fercal'	6.1 ± 1.6 def	87.2 ± 30.2 g–k	4.1 ± 1.2 hij	98.1 ± 32.1 f–i	90.7 ± 16.9 abc
'Ganzin1'	6.5 ± 1.1 c–f	107.8 ± 37.5 b–h	5.5 ± 1.5 d–g	116.9 ± 28.7 b–g	89.7 ± 15.8 abc
'Gloire'	7.2 ± 2.0 b–e	57.8 ± 27.0 l	3.7 ± 1.2 ij	78.6 ± 29.2 hi	73.0 ± 16.0 d
'du Lot'	6.3 ± 0.5 def	86.7 ± 21.0 g–k	6.1 ± 1.6 b–e	88.4 ± 22.5 ghi	98.5 ± 4.1 a
'Saltcreek'	5.6 ± 0.5 f	88.8 ± 31.5 f–k	6.2 ± 0.7 b–e	88.8 ± 31.5 ghi	100 ± 0 a
'Shadi'	6.8 ± 0.9 b–f	63.7 ± 31.9 kl	3.2 ± 0.7 j	78.7 ± 28.4 hi	83.9 ± 26.6 bcd
'Shanhe1'	7.0 ± 1.2 b–e	116.2 ± 19.6 b–f	7.0 ± 0.9 ab	122.2 ± 17.4 a–f	95.4 ± 10.3 ab
'Shanhe2'	6.1 ± 1.1 def	132.6 ± 18.1 ab	6.9 ± 0.7 ab	132.6 ± 18.1 a–e	100 ± 0 a
'Shanhe3'	7.2 ± 0.6 b–e	116.7 ± 18.0 b–f	5.7 ± 0.8 c–f	118.1 ± 18.1 b–f	98.9 ± 2.7 a
'Shanhe4'	8.1 ± 1.0 b	121.3 ± 40.0 a–e	5.2 ± 1.1 efg	125.9 ± 39.0 a–f	95.8 ± 4.9 ab
'SO4'	6.5 ± 0.6 c–f	118.3 ± 11.4 b–e	5.5 ± 0.6 d–g	124.6 ± 11.9 a–f	95.2 ± 6.8 ab
'Wumao'	6.2 ± 1.0 def	137.2 ± 13.7 ab	6.9 ± 0.9 ab	142.7 ± 12.6 ab	96.2 ± 5.4 ab

Note: Data shown are means ± standard error, n = 10. Different lowercase letters within each column represent significant differences at $p < 0.05$ by Tukey's test.

Table 4. Growth indicators of the roots 90 days after planting the grapevine rootstock cuttings in the field (the young vine).

Rootstock	Number of Roots per Cutting	Thick Root Number	Thick Roots Proportion (%)	Average Root Length (cm)	Total Root Length (cm)
'101-14M'	8.2 ± 2.66 k	3.4 ± 1.8 c–g	41.9 ± 16.3 bc	12.6 ± 3.8 m	99.3 ± 34.1 k
'1103P'	13.3 ± 3.84 e–j	3.0 ± 1.8 e–h	24.9 ± 19.1 d–j	28.1 ± 6.8 b–h	381.4 ± 156.1 d–h
'110R'	13.9 ± 4.38 d–j	5.3 ± 1.7 ab	39.9 ± 12.5 bcd	12.8 ± 2.1 m	178.5 ± 65.1 jk
'1202C'	10.0 ± 2.49 ijk	3.3 ± 1.6 d–g	33.6 ± 13.3 b–g	23.9 ± 4.5 f–j	241.8 ± 84.6 hij
'140Ru'	14.7 ± 5.38 c–i	3.3 ± 0.8 d–g	26.5 ± 13.2 d–j	35.1 ± 7.3 ab	492.6 ± 142.4 a–d
'1613C'	15.6 ± 7.37 a–h	1.6 ± 1.3 gh	15.6 ± 17.0 ijk	21.8 ± 9.8 h–l	297.3 ± 160.1 f–j
'188-08'	20.3 ± 4.52 ab	2.8 ± 1.4 e–h	14.6 ± 8.9 jk	19.0 ± 2.8 j–m	381.7 ± 87.8 d–h
'225Ru'	19.6 ± 5.13 abc	3.7 ± 1.4 b–f	21.1 ± 11.3 g–k	30.8 ± 7.0 a–f	585.3 ± 148.6 a
'3309C'	17.6 ± 3.44 a–e	1.4 ± 1.3 h	8.2 ± 6.8 k	31.8 ± 7.4 a–e	558.9 ± 181.5 abc
'420A'	13.3 ± 3.13 e–j	4.1 ± 1.4 b–f	30.5 ± 5.6 b–i	24.4 ± 10.1 f–j	334.1 ± 208.4 e–i
'5A'	16.3 ± 4.27 a–g	5.2 ± 1.5 a–d	34.2 ± 15.0 b–g	34.9 ± 10.2 ab	547.8 ± 125.4 abc
'5BB'	20.7 ± 7.92 a	4.0 ± 2.8 b–f	20.8 ± 12.5 g–k	24.8 ± 4.8 e–j	509.6 ± 206.4 a–d
'5C'	18.7 ± 1.63 a–d	4.2 ± 1.2 b–f	22.7 ± 7.9 f–k	26.9 ± 4.2 c–i	500.8 ± 76.7 a–d
'8B'	16.4 ± 3.95 a–f	4.0 ± 1.8 b–f	24.7 ± 12.5 e–j	12.2 ± 2.2 m	198.8 ± 58.0 ijk
'BR2'	8.3 ± 2.63 k	5.3 ± 2.6 abc	61.3 ± 10.6 a	31.6 ± 16.5 a–e	271.8 ± 173.4 g–j
'Barrett50'	17.8 ± 4.49 a–e	4.3 ± 1.6 b–f	25.8 ± 11.8 d–j	25.6 ± 4.2 e–j	444.3 ± 87.6 a–f
'Beaumont'	16.1 ± 4.26 a–g	2.7 ± 1.0 e–h	18.0 ± 7.8 h–k	16.1 ± 3.1 lm	258.7 ± 74.6 g–j
'Beta'	11.5 ± 3.34 f–k	3.6 ± 1.3 b–f	32.3 ± 11.0 b–h	33.8 ± 6.8 abc	386.9 ± 128.8 d–h
'Dogridge'	14.4 ± 4.38 d–j	4.0 ± 1.9 b–f	28.6 ± 13.5 b–j	17.1 ± 4.6 klm	257.9 ± 136.0 g–j
'Fercal'	11.9 ± 6.17 f–k	4.3 ± 2.4 b–f	39.6 ± 23.4 b–e	28.6 ± 4.4 b–h	338.3 ± 168.0 e–i
'Ganzin1'	11.2 ± 5.51 g–k	2.9 ± 1.9 e–h	30.4 ± 17.1 b–i	29.9 ± 10.0 b–g	331.7 ± 185.2 e–j
'Gloire'	15.2 ± 2.39 b–h	3.3 ± 1.7 d–g	22.0 ± 11.3 g–k	20.3 ± 3.0 i–l	306.9 ± 59.0 f–j
'du Lot'	17.9 ± 5.14 a–e	3.6 ± 2.1 b–f	22.0 ± 16.7 g–k	22.6 ± 6.3 h–l	424.3 ± 215.0 b–f
'Saltcreek'	9.6 ± 2.72 jk	2.4 ± 1.0 fgh	27.9 ± 14.8 c–j	28.2 ± 7.0 b–h	262.8 ± 74.1 g–j
'Shadi'	15.1 ± 3.81 c–h	3.7 ± 1.4 b–f	26.1 ± 11.4 d–j	15.8 ± 2.0 lm	239.4 ± 67.5 hij
'Shanhe1'	17.3 ± 4.24 a–e	4.4 ± 2.1 b–e	26.3 ± 11.4 d–j	25.0 ± 6.7 e–j	431.9 ± 153.3 b–f
'Shanhe2'	15.3 ± 4.64 b–h	6.2 ± 2.3 a	43.0 ± 14.5 b	37.6 ± 6.0 a	570.0 ± 192.4 ab
'Shanhe3'	15.7 ± 3.43 a–g	3.6 ± 0.7 b–f	23.6 ± 4.9 f–j	25.9 ± 6.3 d–j	408.7 ± 136.0 c–g
'Shanhe4'	18.4 ± 5.99 a–e	3.3 ± 1.7 d–g	19.7 ± 13.5 g–k	26.8 ± 4.3 d–i	479.9 ± 133.0 a–e
'SO4'	16.1 ± 4.72 a–g	3.9 ± 1.2 b–f	26.1 ± 10.1 d–j	32.7 ± 6.6 a–d	525.6 ± 200.4 a–d
'Wumao'	10.6 ± 3.41 h–k	3.7 ± 1.2 b–f	37.8 ± 16.3 b–f	23.5 ± 4.8 g–k	248.2 ± 85.7 hij

Note: Data shown are means ± standard error, n = 10. Different lowercase letters within each column represent significant differences at $p < 0.05$ by Tukey's test.

The total number of roots per plant averaged 14.9 and varied largely among rootstocks (Table 4). '5BB', '188-08', and '225Ru' grew sufficient roots for approximately 20 per plant, while '101-14M' and 'BR2' generated about eight roots for each plant. Root-rich cultivars tended to have fewer thick roots than root-poor varieties, which resulted in a negative correlation between total root number and thick root proportion (Figure S2). The total root length ranged from 99.3 to 585.3 cm, to which the root number and/or average root length contributed (Figure S2). The total root length of '101-14M' (99.3 cm) was far below the average length of 370.8 cm, while those of '225Ru', 'Shanhe2', '3309C', '5A', etc., were far over 500 cm.

3.3. Phenological Periods of the Rootstocks

Phenological periods are essential for grapevine breeding, and they varied among 31 rootstock genotypes (Figure 2). Budbreak occurred mostly between 98–110 days of the year (DOY). Budbreak of the Shanhe series (Shanhe1–4) occurred the earliest, 11 days before that of '1613C'. The range of the budbreak period was smaller than that of the florescence period which started at 127–145 DOY, indicating a maximum gap of three weeks between the earliest varieties (Shanhe series, 'BR2', and '3309C') and the latest ones ('Saltcreek' and '1613C'). Flowering lasted mostly for 7–8 days, but it lasted for only 4 days on '420A', 'Shadi', and 'Beaumont', and over 10 days on '1202C', 'Shanhe4', '110R', etc. Furthermore, the advanced flowering period in 2017 is evident in Figure 2.

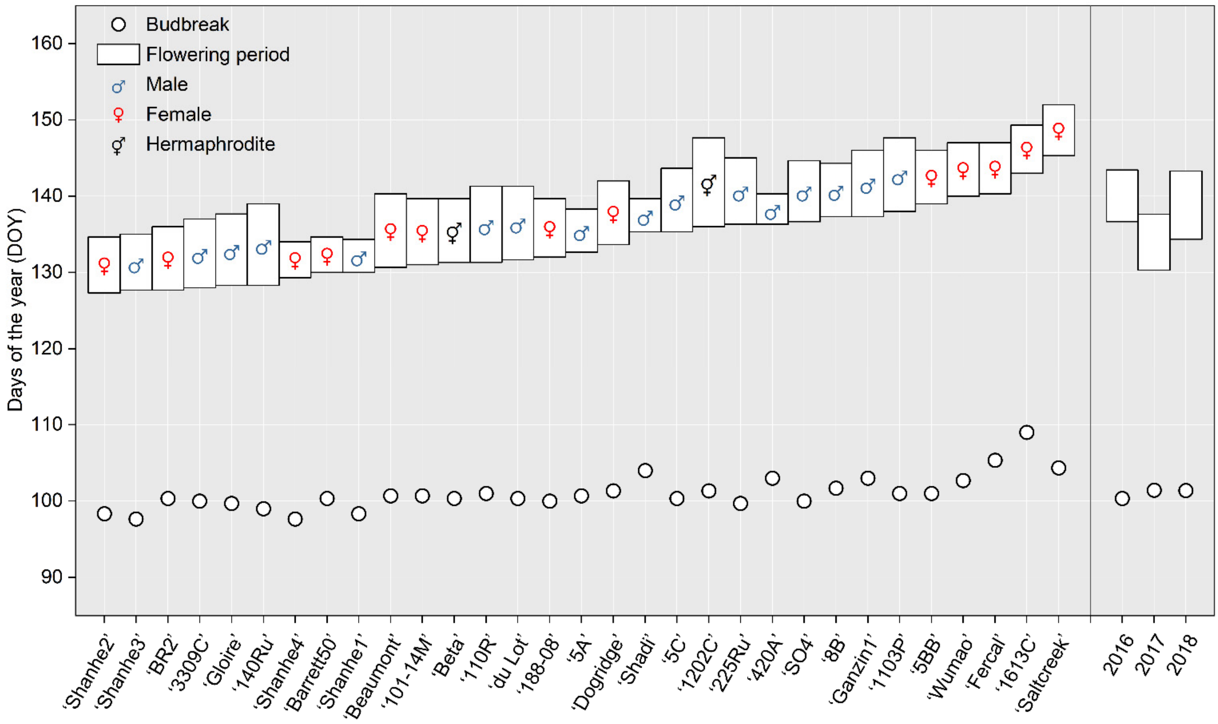

Figure 2. Phenological periods of 31 grapevine rootstocks in North China in 2016–2018. DOY, day of the year. Male, female and hermafrotide indicate the sex of the flower of the rootstocks.

3.4. Growth of the Adult Vine

Growth-related indices varied significantly among rootstocks and seasons (Table 5). Rootstock exerted a larger effect on lignified proportion and internode length, while the season effect was larger on other traits. The interaction effect of rootstock by season was also significant (Table S3).

Table 5. Comparison of growth indicators among 31 grapevine rootstocks in three growing seasons (2016–2018) (the adult vine).

Season	Rootstock	Trunk Diameter (mm)	Cane Diameter (mm)	Total Cane Length (cm)	Total Shoot Length (cm)	Lignified Proportion (%)	Internode Length (cm)	Pruning Weight (g)
2016	'101-14M'	24.98 ± 4.55 a–d	11.42 ± 1.72 ab	1901.8 ± 863.0 a–e	2169.2 ± 940.1 abc	86.3 ± 6.6 b–e	8.62 ± 0.85 g–l	1051.0 ± 427.5 a–f
	'1103P'	21.76 ± 2.17 bcd	8.79 ± 1.05 e–i	2768.3 ± 696.0 a	2836.0 ± 761.7 a	98.4 ± 2.1 a	10.84 ± 0.90 b–f	1033.1 ± 203.8 a–f
	'110R'	21.76 ± 4.50 bcd	9.87 ± 1.20 b–i	1881.1 ± 784.2 a–e	2087.6 ± 861.8 abc	89.3 ± 4.1 a–e	10.18 ± 1.10 b–h	1189.0 ± 471.6 a–d
	'1202C'	21.11 ± 2.98 bcd	9.54 ± 0.72 b–i	1202.0 ± 327.0 b–g	1416.4 ± 332.3 bcd	84.0 ± 8.1 cde	5.49 ± 0.87 m	711.0 ± 172.5 b–i
	'140Ru'	25.69 ± 2.10 abc	10.89 ± 0.63 a–f	2102.3 ± 534.3 abc	2262.9 ± 563.7 ab	92.4 ± 3.4 a–d	10.32 ± 0.47 b–h	1116.0 ± 291.0 a–e
	'1613C'	19.76 ± 0.98 cd	10.29 ± 1.00 a–i	496.0 ± 41.6 g	953.0 ± 75.6 d	51.3 ± 1.5 g	7.57 ± 0.11 j–m	433.3 ± 20.2 ghi
	'188-08'	19.18 ± 2.06 cd	9.09 ± 0.90 c–i	1416.1 ± 361.2 b–g	1511.7 ± 400.7 bcd	93.9 ± 4.1 abc	8.80 ± 0.77 f–l	634.4 ± 170.9 d–i
	'225Ru'	23.62 ± 2.16 bcd	10.41 ± 0.93 a–i	1584.2 ± 397.2 b–f	1828.9 ± 342.5 a–d	86.6 ± 7.3 b–e	10.16 ± 0.96 b–h	1228.0 ± 320.9 abc
	'3309C'	20.86 ± 4.02 bcd	8.53 ± 0.80 ghi	1694.9 ± 369.6 b–f	1953.1 ± 370.9 a–d	86.1 ± 8.4 b–e	7.02 ± 0.69 lm	670.0 ± 126.0 c–i
	'420A'	23.96 ± 6.35 bcd	10.53 ± 0.71 a–g	1659.2 ± 694.8 b–f	1859.4 ± 711.6 a–d	88.9 ± 9.4 a–e	9.81 ± 1.22 c–i	977.0 ± 403.0 a–h
	'5A'	22.14 ± 3.09 bcd	10.74 ± 1.82 a–g	1533.3 ± 730.9 b–f	1644.7 ± 736.2 bcd	90.5 ± 8.3 a–d	10.76 ± 1.48 b–g	1000.0 ± 461.4 a–g
	'5BB'	25.74 ± 4.56 abc	11.25 ± 1.32 abc	1502.6 ± 477.8 b–f	1734.7 ± 511.9 bcd	86.5 ± 4.3 b–e	12.17 ± 1.07 ab	1027.0 ± 303.8 a–f
	'5C'	21.27 ± 3.38 bcd	9.68 ± 0.70 b–i	1724.8 ± 185.3 b–f	1798.2 ± 214.4 a–d	95.8 ± 2.9 ab	10.28 ± 0.81 b–h	961.0 ± 261.5 a–h
	'8B'	21.44 ± 3.72 bcd	9.33 ± 1.01 b–i	1567.7 ± 540.5 b–f	1698.9 ± 553.2 bcd	92.0 ± 4.6 a–d	11.09 ± 0.80 b–e	859.0 ± 280.2 a–i
	'BR2'	21.97 ± 2.03 bcd	9.52 ± 0.61 b–i	2184.5 ± 497.4 ab	2265.2 ± 534.0 ab	96.6 ± 2.0 ab	11.79 ± 0.66 abc	1364.0 ± 279.1 a
	'Barrett50'	21.53 ± 0.59 bcd	10.93 ± 0.75 a–e	1331.4 ± 527.4 b–g	1559.4 ± 681.6 bcd	87.2 ± 4.0 a–e	11.28 ± 0.71 a–e	906.0 ± 398.4 a–i
	'Beaumont'	25.00 ± 5.02 a–d	10.75 ± 2.07 a–g	1774.3 ± 728.0 a–f	2154.2 ± 738.0 abc	78.0 ± 15.2 ef	9.29 ± 1.82 e–k	1238.0 ± 482.0 abc
	'Beta'	25.75 ± 2.62 abc	11.16 ± 1.84 a–d	1552.7 ± 533.3 b–f	1695.2 ± 554.3 bcd	91.5 ± 5.6 a–d	9.71 ± 2.61 c–j	1018.0 ± 424.7 a–f
	'Dogridge'	27.32 ± 2.67 ab	10.39 ± 1.44 a–i	1419.2 ± 284.1 b–g	1715.8 ± 362.1 bcd	83.2 ± 3.6 cde	7.12 ± 0.52 klm	1028.0 ± 186.0 a–f
	'Fercal'	23.31 ± 5.36 bcd	10.53 ± 2.92 a–g	1183.1 ± 709.9 c–g	1359.0 ± 806.6 bcd	88.3 ± 6.3 a–e	9.48 ± 1.63 d–j	514.0 ± 381.1 f–i
	'Ganzin1'	19.20 ± 4.74 cd	9.01 ± 1.22 c–i	1293.7 ± 159.9 b–g	1635.9 ± 192.8 bcd	78.3 ± 3.0 ef	6.85 ± 0.53 lm	553.0 ± 69.8 e–i
	'Gloire'	19.43 ± 4.06 cd	8.21 ± 0.82 hi	982.4 ± 436.2 d–g	1183.6 ± 493.2 cd	81.8 ± 5.8 def	7.84 ± 0.71 i–l	368.0 ± 153.3 i
	'du Lot'	18.23 ± 2.96 d	8.94 ± 1.13 d–i	1570.3 ± 659.8 b–f	1697.1 ± 709.7 bcd	92.3 ± 4.4 a–d	11.03 ± 1.66 b–e	814.0 ± 363.4 a–i
	'Saltcreek'	18.05 ± 3.23 d	10.49 ± 0.73 a–h	811.2 ± 606.0 fg	910.6 ± 686.2 d	89.4 ± 4.8 a–e	8.41 ± 0.87 h–l	404.0 ± 342.5 hi
	'Shadi'	31.46 ± 5.90 a	12.47 ± 1.25 a	1172.0 ± 339.7 c–g	1561.4 ± 354.4 bcd	72.8 ± 8.4 f	7.09 ± 0.74 lm	920.0 ± 202.5 a–i
	'Shanhe1'	22.50 ± 2.67 bcd	8.16 ± 0.46 i	1977.2 ± 703.2 a–d	2099.3 ± 774.5 abc	93.8 ± 4.3 abc	11.61 ± 0.37 a–d	867.0 ± 322.8 a–i
	'Shanhe2'	24.42 ± 4.18 a–d	10.26 ± 0.59 a–i	1620.8 ± 285.6 b–f	1715.4 ± 305.7 bcd	94.6 ± 3.1 abc	9.96 ± 0.96 c–i	779.0 ± 133.0 b–i
	'Shanhe3'	23.90 ± 2.69 bcd	8.62 ± 0.86 f–i	1762.5 ± 376.1 b–f	1881.4 ± 383.2 a–d	92.7 ± 4.8 a–d	11.15 ± 1.37 b–e	779.0 ± 172.3 b–i
	'Shanhe4'	24.47 ± 7.31 a–d	9.88 ± 0.69 b–i	956.9 ± 353.5 efg	1137.1 ± 365.6 cd	83.2 ± 6.5 cde	8.73 ± 2.14 f–l	433.3 ± 155.3 ghi
	'SO4'	22.27 ± 2.90 bcd	10.31 ± 1.04 a–i	1903.7 ± 500.7 a–e	2151.4 ± 567.7 abc	87.9 ± 3.8 a–e	9.97 ± 0.91 b–i	1267.0 ± 319.1 ab
	'Wumao'	23.65 ± 2.48 bcd	11.52 ± 1.15 ab	1722.0 ± 470.3 b–f	1874.4 ± 563.3 a–d	93.0 ± 6.9 a–d	13.39 ± 1.35 a	1091.0 ± 363.4 a–e
2017	'101-14M'	23.00 ± 5.29 ab	10.10 ± 1.91 a–g	610.0 ± 417.5 cd	799.0 ± 493.3 cd	72.2 ± 14.2 e	7.78 ± 1.38 f–k	374.5 ± 274.1 cd
	'1103P'	21.75 ± 3.22 ab	7.81 ± 1.72 ghi	1523.8 ± 730.3 ab	1673.8 ± 785.3 abc	91.9 ± 4.9 abc	10.21 ± 1.39 a–f	775.6 ± 480.4 a–d
	'110R'	24.94 ± 4.48 ab	10.73 ± 1.34 a–f	1079.7 ± 340.7 a–d	1373.9 ± 483.9 a–d	81.5 ± 8.8 b–e	9.88 ± 1.03 a–g	683.0 ± 244.7 a–d
	'1202C'	25.51 ± 3.21 ab	10.85 ± 1.08 a–e	1077.0 ± 312.1 a–d	1283.0 ± 399.6 a–d	85.0 ± 5.5 b–e	7.03 ± 0.34 h–k	655.0 ± 187.0 a–d
	'140Ru'	26.94 ± 6.26 ab	9.02 ± 0.80 c–i	1254.0 ± 397.8 a–d	1517.0 ± 474.7 a–d	79.9 ± 9.0 cde	8.89 ± 1.08 a–j	595.0 ± 183.3 a–d
	'1613C'	25.23 ± 4.50 ab	10.54 ± 0.06 a–f	1115.0 ± 233.3 a–d	1275.0 ± 176.8 a–d	90.5 ± 10.6 abc	7.29 ± 0.74 g–k	620.0 ± 141.4 a–d
	'188-08'	29.18 ± 5.99 a	10.83 ± 1.17 a–e	1338.2 ± 511.5 abc	1486.0 ± 575.0 a–d	91.4 ± 3.2 abc	8.47 ± 0.56 b–k	612.8 ± 244.6 a–d
	'225Ru'	26.11 ± 3.80 ab	9.34 ± 0.90 a–h	1568.0 ± 524.3 ab	1862.2 ± 593.7 ab	85.1 ± 3.7 b–e	10.77 ± 1.11 a–d	992.5 ± 384.4 ab
	'3309C'	20.48 ± 2.80 ab	8.65 ± 0.60 e–h	461.5 ± 203.2 d	616.5 ± 266.1 d	75.7 ± 8.6 de	6.85 ± 1.22 ijk	215.0 ± 92.7 d
	'420A'	27.07 ± 8.83 ab	11.58 ± 1.64 ab	942.1 ± 423.0 a–d	1037.8 ± 463.3 bcd	91.4 ± 5.9 abc	8.63 ± 0.99 b–j	746.5 ± 399.0 a–d
	'5A'	23.43 ± 4.60 ab	10.90 ± 1.65 a–e	943.3 ± 519.1 a–d	1013.3 ± 570.6 bcd	95.0 ± 5.3 ab	10.49 ± 0.59 a–e	590.8 ± 275.8 a–d
	'5BB'	27.12 ± 3.48 ab	11.32 ± 1.05 a–d	1634.2 ± 476.5 a	2020.9 ± 498.2 a	81.3 ± 6.0 b–e	11.52 ± 1.29 a	1096.1 ± 473.2 a
	'5C'	23.48 ± 2.94 ab	10.76 ± 1.24 a–e	1380.0 ± 330.3 abc	1512.0 ± 413.1 a–d	92.6 ± 5.3 abc	10.78 ± 1.33 a–d	802.5 ± 215.7 abc
	'8B'	24.24 ± 4.35 ab	8.75 ± 1.50 e–i	1275.7 ± 516.3 abc	1400.0 ± 558.9 a–d	91.7 ± 4.7 abc	11.15 ± 2.60 ab	685.0 ± 357.6 a–d
	'BR2'	24.23 ± 4.79 ab	9.13 ± 1.45 b–i	837.7 ± 353.1 bcd	983.8 ± 428.3 bcd	83.3 ± 7.7 b–e	9.50 ± 2.05 a–i	485.7 ± 221.3 bdc
	'Barrett50'	-	-	-	-	-	-	-
	'Beaumont'	28.94 ± 6.12 a	10.61 ± 1.50 a–f	1112.4 ± 375.6 a–d	1264.0 ± 390.9 a–d	87.5 ± 6.2 a–d	7.95 ± 0.67 e–k	638.5 ± 336.2 a–d
	'Beta'	30.04 ± 4.37 a	11.74 ± 1.28 a	895.7 ± 595.9 a–d	941.4 ± 620.3 cd	95.1 ± 5.3 ab	9.14 ± 1.03 a–i	750.0 ± 476.6 a–d
	'Dogridge'	25.97 ± 2.84 ab	11.08 ± 1.38 a–e	1029.4 ± 373.6 a–d	1095.4 ± 414.0 bcd	94.5 ± 5.1 ab	8.13 ± 1.48 d–k	833.0 ± 421.3 abc
	'Fercal'	29.33 ± 7.31 a	11.66 ± 1.92 a	912.4 ± 375.1 a–d	1113.7 ± 415.1 bcd	79.3 ± 6.4 cde	7.77 ± 1.52 f–k	735.5 ± 476.3 a–d
	'Ganzin1'	21.10 ± 8.74 ab	8.91 ± 1.26 d–i	943.9 ± 372.4 a–d	1252.9 ± 435.0 a–d	72.0 ± 9.1 e	5.95 ± 0.66 k	450.0 ± 232.8 bdc
	'Gloire'	22.86 ± 6.08 ab	9.69 ± 1.17 a–h	927.2 ± 574.1 a–d	1120.2 ± 666.8 a–d	82.1 ± 6.3 b–e	6.81 ± 1.16 ijk	387.5 ± 236.9 cd
	'du Lot'	21.60 ± 3.68 ab	9.17 ± 0.55 b–i	1516.6 ± 495.5 ab	1648.4 ± 506.7 abc	91.4 ± 5.7 abc	9.12 ± 1.41 a–i	724.6 ± 299.7 a–d
	'Saltcreek'	17.65 ± 3.37 b	11.48 ± 2.08 abc	816.7 ± 279.3 bcd	816.7 ± 279.3 cd	100.0 ± 0.0 a	8.29 ± 0.84 c–k	790.0 ± 236.4 a–d
	'Shadi'	26.19 ± 8.32 ab	10.70 ± 1.28 a–f	1143.0 ± 694.4 a–d	1452.5 ± 741.3 a–d	75.5 ± 6.5 de	7.21 ± 1.28 g–k	862.5 ± 411.2 abc
	'Shanhe1'	24.70 ± 4.98 ab	6.73 ± 0.44 i	832.7 ± 363.2 bcd	1022.1 ± 495.4 bcd	83.0 ± 9.7 b–e	8.87 ± 1.41 a–j	370.6 ± 158.0 cd
	'Shanhe2'	25.23 ± 4.94 ab	10.46 ± 1.21 a–f	703.7 ± 230.1 cd	860.2 ± 323.3 cd	84.7 ± 5.9 b–e	9.54 ± 0.86 a–h	432.0 ± 170.9 bdc
	'Shanhe3'	26.78 ± 4.04 ab	7.55 ± 1.06 hi	1059.0 ± 301.6 a–d	1222.6 ± 339.8 a–d	87.5 ± 11.0 a–d	10.94 ± 3.56 abc	474.5 ± 162.6 bdc
	'Shanhe4'	27.92 ± 8.98 a	8.26 ± 0.73 f–i	783.8 ± 320.2 bcd	944.5 ± 356.3 cd	84.0 ± 7.6 b–e	6.39 ± 1.39 jk	400.0 ± 203.6 cd
	'SO4'	23.37 ± 6.71 ab	9.40 ± 1.28 a–h	959.0 ± 372.7 a–d	1175.0 ± 512.1 a–d	82.4 ± 8.6 b–e	9.89 ± 1.28 a–g	615.5 ± 196.7 a–d
	'Wumao'	24.02 ± 3.49 ab	11.10 ± 1.44 a–e	998.2 ± 184.8 a–d	1086.4 ± 208.9 bcd	91.6 ± 7.7 abc	10.32 ± 1.41 a–f	749.5 ± 181.3 a–d
2018	'101-14M'	28.40 ± 4.90 a–d	10.54 ± 1.16 ab	1035.7 ± 558.2 abc	1258.0 ± 564.9 ab	78.2 ± 16.5 c–i	8.28 ± 1.15 e–h	642.0 ± 413.0 abc
	'1103P'	27.45 ± 6.41 a–d	8.72 ± 1.91 b–h	1101.5 ± 699.2 abc	1237.5 ± 751.3 ab	64.0 ± 5.9 ijk	12.12 ± 2.01 ab	712.5 ± 410.4 abc
	'110R'	24.80 ± 5.13 a–d	9.18 ± 1.30 a–h	1282.6 ± 585.4 ab	1444.2 ± 637.6 a	89.1 ± 5.9 a–g	10.80 ± 0.95 a–e	864.0 ± 394.4 ab
	'1202C'	19.31 ± 3.54 cd	7.38 ± 0.54 h	833.7 ± 288.7 abc	1205.5 ± 403.6 ab	68.9 ± 6.5 hij	8.53 ± 1.48 d–h	490.0 ± 174.6 abc
	'140Ru'	29.33 ± 2.68 abc	9.31 ± 1.06 a–h	1216.5 ± 468.1 abc	1351.5 ± 486.3 ab	89.6 ± 5.2 a–f	10.23 ± 2.21 a–f	580.5 ± 254.2 abc
	'1613C'	29.25 ± 5.11 abc	9.29 ± 0.71 a-h	615.0 ± 49.5 bc	1115.0 ± 162.6 ab	56.5 ± 10.6 jk	6.77 ± 1.59 h	405.0 ± 106.1 bc
	'188-08'	27.66 ± 4.45 a–d	8.34 ± 1.30 c–h	1140.3 ± 441.3 abc	1273.0 ± 518.6 ab	90.1 ± 6.8 a–e	8.56 ± 1.09 d–h	484.0 ± 283.6 abc
	'225Ru'	31.43 ± 2.88 a	9.82 ± 1.17 a–g	1382.0 ± 338.7 ab	1593.0 ± 427.8 a	87.7 ± 4.4 a–g	12.64 ± 0.93 a	979.5 ± 326.2 a
	'3309C'	20.54 ± 3.30 bcd	8.82 ± 0.91 a–h	821.5 ± 284.9 abc	906.0 ± 296.2 b	89.6 ± 5.9 a–f	8.01 ± 1.10 fgh	375.5 ± 129.6 bc
	'420A'	29.80 ± 7.75 ab	8.97 ± 0.98 a–h	1063.0 ± 507.0 abc	1106.0 ± 509.7 ab	95.5 ± 5.7 a	9.25 ± 1.05 c–h	658.5 ± 248.3 abc
	'5A'	26.74 ± 3.74 a–d	9.83 ± 1.89 a–f	1004.0 ± 544.2 abc	1246.8 ± 567.8 ab	76.6 ± 22.0 e–i	10.16 ± 1.92 a–f	750.0 ± 416.1 abc
	'5BB'	27.39 ± 6.47 a–d	10.24 ± 1.16 a–d	1317.0 ± 431.1 ab	1408.0 ± 457.2 ab	93.5 ± 2.3 ab	12.29 ± 0.88 ab	883.0 ± 335.9 ab
	'5C'	27.61 ± 4.86 a–d	8.39 ± 0.93 b–h	1199.2 ± 524.7 abc	1457.3 ± 603.0 a	80.9 ± 6.5 b–h	11.20 ± 3.10 a–d	441.0 ± 318.2 abc
	'8B'	23.68 ± 2.88 a–d	9.12 ± 1.08 a–h	1449.7 ± 467.3 a	1608.8 ± 521.4 a	91.1 ± 4.4 a–d	11.69 ± 0.99 abc	781.7 ± 285.3 abc
	'BR2'	27.85 ± 4.72 a–d	9.21 ± 0.93 a–h	1286.3 ± 492.3 ab	1322.3 ± 503.3 ab	97.6 ± 2.4 a	11.21 ± 1.38 a–d	858.5 ± 345.4 ab
	'Barrett50'	24.27 ± 3.88 a–d	9.36 ± 1.38 a–h	1119.5 ± 514.2 abc	1150.5 ± 533.1 ab	96.9 ± 4.0 a	10.63 ± 1.64 a–f	574.5 ± 323.1 abc
	'Beaumont'	29.43 ± 7.68 abc	9.41 ± 1.42 a–h	974.0 ± 494.4 abc	1141.0 ± 491.0 ab	84.4 ± 11.3 a–g	8.36 ± 0.99 e–h	499.5 ± 318.0 abc
	'Beta'	26.92 ± 3.41 a–d	10.92 ± 1.07 a	1234.1 ± 355.2 abc	1275.1 ± 380.7 ab	97.5 ± 1.8 a	9.30 ± 1.23 c–h	758.5 ± 216.5 abc
	'Dogridge'	26.62 ± 5.68 a–d	9.49 ± 0.92 a–h	1068.5 ± 328.1 abc	1143.5 ± 398.2 ab	96.3 ± 5.1 a	7.34 ± 0.52 gh	716.0 ± 300.5 abc
	'Fercal'	33.69 ± 7.54 a	10.36 ± 1.41 abc	1154.5 ± 558.6 abc	1272.0 ± 689.8 ab	92.2 ± 5.8 abc	9.07 ± 1.29 c–h	668.0 ± 526.4 abc
	'Ganzin1'	19.48 ± 3.47 cd	7.96 ± 0.84 e–h	747.9 ± 237.7 abc	968.9 ± 233.9 ab	75.7 ± 4.5 f–i	7.95 ± 1.64 fgh	282.8 ± 209.0 c
	'Gloire'	27.95 ± 2.04 a–d	8.07 ± 0.89 d–h	721.2 ± 177.8 abc	1112.5 ± 243.2 ab	88.0 ± 4.1 a–g	9.53 ± 1.66 b–h	249.0 ± 85.8 c
	'du Lot'	-	-	-	-	-	-	-
	'Saltcreek'	18.42 ± 4.33 d	9.63 ± 1.16 a–g	810.0 ± 213.4 abc	822.0 ± 224.3 b	98.2 ± 2.7 a	9.79 ± 1.09 b–g	624.0 ± 424.0 abc
	'Shadi'	31.96 ± 13.92 a	8.33 ± 1.31 c–h	459.0 ± 243.0 c	852.9 ± 398.2 b	52.6 ± 15.9 k	8.00 ± 3.13 fgh	240.7 ± 150.2 c
	'Shanhe1'	29.90 ± 7.31 ab	7.82 ± 1.05 fgh	1242.8 ± 486.2 abc	1277.8 ± 493.1 ab	96.7 ± 4.3 a	11.01 ± 0.83 a–e	598.3 ± 275.0 abc
	'Shanhe2'	28.98 ± 4.77 abc	9.35 ± 1.47 a–h	724.5 ± 280.0 abc	927.1 ± 346.6 ab	77.9 ± 8.6 d–i	6.92 ± 1.08 h	509.8 ± 225.1 abc
	'Shanhe3'	29.52 ± 4.19 abc	7.84 ± 1.13 fgh	873.0 ± 402.5 abc	885.1 ± 405.9 b	98.0 ± 3.3 a	10.10 ± 0.91 a–g	447.5 ± 243.8 abc
	'Shanhe4'	28.07 ± 8.25 a–d	8.07 ± 0.76 d–h	747.9 ± 210.7 abc	998.3 ± 289.2 ab	75.0 ± 7.0 ghi	6.94 ± 1.01 h	355.6 ± 109.8 bc
	'SO4'	27.74 ± 2.38 a–d	10.02 ± 1.39 a–e	1361.0 ± 457.0 ab	1454.0 ± 440.1 a	93.0 ± 6.8 ab	10.09 ± 0.83 a–g	901.0 ± 340.7 ab
	'Wumao'	25.20 ± 3.09 a–d	7.65 ± 0.49 gh	1219.1 ± 334.3 abc	1383.5 ± 360.7 ab	86.3 ± 8.3 a–g	11.46 ± 1.62 abc	645.0 ± 213.7 abc

Note: Different lowercase letters within each column for each season represent significant differences at $p < 0.05$ by Tukey's test.

The trunk diameter increased by year, with the three-season average of these rootstocks ranging from 18 to 30.4 mm. The trunk diameter remained the smallest on 'Saltcreek', followed by 'Ganzin1' and 'du Lot', and the largest on 'Shadi'. Half of the rootstock varieties produced canes with a diameter of over 10 mm, while 'Shanhe1' and 'Shanhe3' developed canes with a diameter of less than 8 mm. Total cane length, i.e., the lignified shoot length per tree, ranged from 791.2 to 1861.1 cm with a mean of 1227.5 cm. Outstandingly, the total cane length for each vine of '1103P' was much longer than that of the other varieties, especially those of '1613C', 'Saltcreek', 'Shanhe4', 'Shadi', and 'Gloire'—less than half of it. Furthermore, the canes produced in 2016 were much longer (Table S3). The total shoot length shared a similar variation as the total cane length among rootstocks, of which the coefficient of variations (CVs) were 17% and 20.7%, respectively. The lignified proportion of these rootstocks was located at 64.6–96.1%, with a smaller variation than those of the above-mentioned length attributes. Its variation among seasons was much smaller. The highest lignified proportion of 96.1% was from 'Saltcreek', the shortest shoot producer; the lowest was from 'Shadi', followed by '1613C', another two of the varieties with the shortest canes. The internode length averaged 9.4 cm, ranging from 6.9 cm for 'Ganzin1' to 12 cm for '5BB', and it was smaller in 2017 than in the other two seasons. The pruning weight, as a final growth indicator, revealed the largest variance (CV = 25.3%) among tested rootstocks, with a range of 334.8–1066.7 g. Each plant produced an average of 706.1 g of canes, while 'Gloire' produced less than half of that. Annual pruning weight per plant for half of the varieties was over 735 g, among which '225Ru' produced the largest, followed by '5BB', 'SO4', etc. In addition, a much higher pruning weight was obtained in 2016—nearly 900 g per plant.

3.5. Correlations between Meteorological Data and Vine Growth

Considering the significant effect of the year on vine growth indicators, we summarized the meteorological data and analyzed their correlation with the growth indicators. The daily average temperature, as well as the relative humidity, changed similarly in the three years (Figure S1 and Table S1). The local annual precipitation in 2016, 831.9 mm, was 45% and 82% heavier than those in 2017 and 2018, respectively. Around 80% of the precipitation occurred from June to August. In total, sunshine duration reached 2006.5 h for the whole growing season in 2018, close to that in 2016, and nearly 180 h more than that in 2017.

The correlation between meteorological data and growth data was not significant (Figure 3). Despite that, the meteorological effects can be recognized on the figure. Rainfall contributes largely to nearly all growth indicators. The temperature positively correlates with cane diameter but negatively with other parameters, while the opposite is true for humidity and sunshine duration.

3.6. Principle Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) for the Rootstocks Based on the Growth Indicators

The PCA for growth parameters (trunk diameter, cane diameter, cane length, total shoot length, lignified proportion, internode length, and pruning weight) yielded seven principal components (PC) to explain 100% of the variance (Table S4). The first two PCs explained 73.6% of the total variance (Figure 4A). PC1 is highly influenced by longitudinal growth parameters (cane length, total shoot length, and internode length), pruning weight, and lignified proportion, while PC2 is highly influenced by lateral growth parameters, including cane diameter and trunk diameter. Variables within longitudinal or lateral parameters positively correlate with each other, and correlations between longitudinal variables are significant. Pruning weight also donates a smaller loading to PC2 and is highly correlated with cane diameter and longitudinal variables. No correlation exists between longitudinal and lateral parameters.

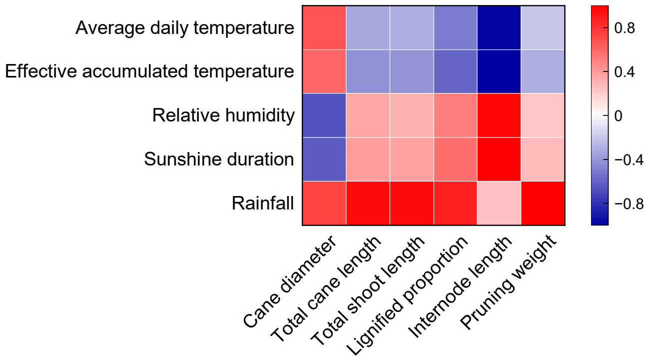

Figure 3. Heat maps of the correlations between growth-related traits of the adult vines and the meteorological factors.

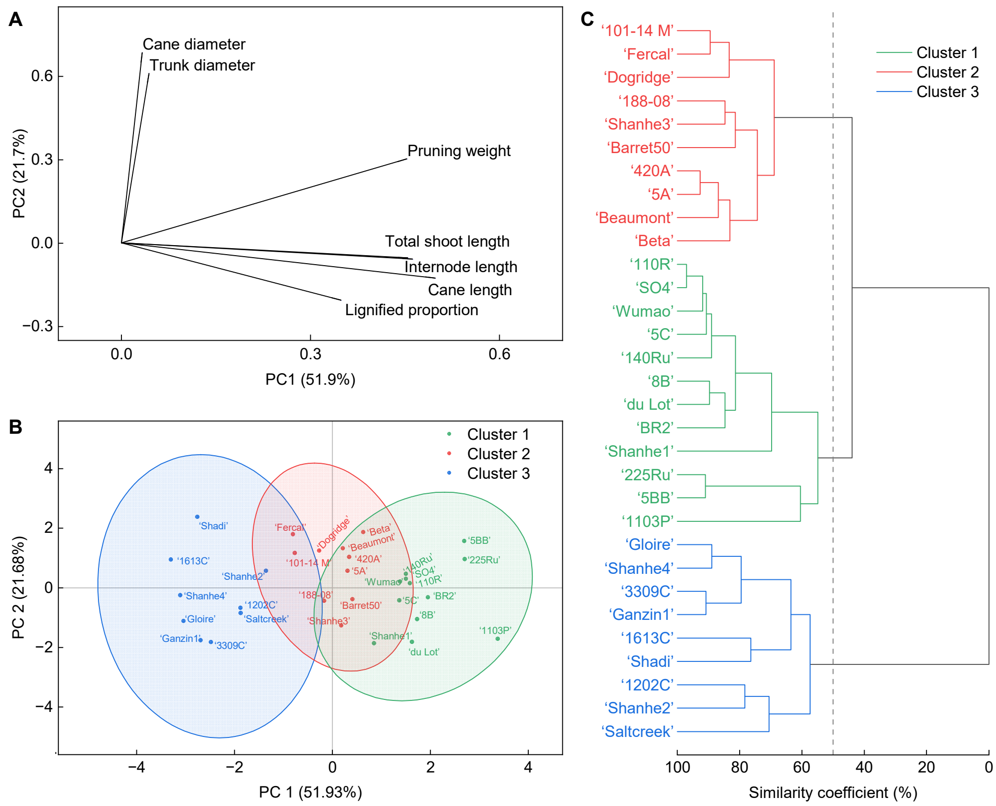

Figure 4. Principal component (PC) analysis of seven vigor-related variables for 31 grapevine rootstocks and hierarchical clustering (HC): (**A**) PC loading plot; (**B**) score plot; (**C**) dendrogram based on seven PCs. A confidence ellipse (95%) is drawn on each cluster on the score plot in a corresponding color.

Calculated scores obtained by multiplying factor scores by eigenvalues were subjected to hierarchical cluster analysis (HCA). The average linkage method and Euclidian distance were used to separate the rootstocks. The dendrogram was separated into three clusters at 50% similarity, and Clusters 1, 2, and 3 consisted of 12, 10, and 9 varieties, respectively (Figure 4C). The classification was then used to group the varieties on the score plot, which in turn revealed the relationship between these rootstocks (Figure 4B). Cluster 1, including '5BB', '225Ru', '1103P', etc., lies in the positive direction of PC1, the largest component donated by length- or weight-related parameters. Hence, varieties in cluster 1 are characterized by high vigor. Those rootstocks composing Cluster 3, such as 'Ganzin1', '3309C', 'Gloire', etc., distributed in the negative direction of PC1, are characterized by low vigor. Cluster 2 lies between Clusters 1 and 3 and should be classified as the medium-vigorous cluster, in which six rootstocks are scattered on the positive side of PC2, indicating their relatively high vigor in lateral growth. The confidence ellipse of Cluster 2 overlaps with that of Cluster 1 or Cluster 3, while barely overlapping between Clusters 1 and 3. Regardless, according to the figure, varieties in Cluster 1 are more vigorous than those in Cluster 3 (Figure 4B).

3.7. Genetic Background Effects on Tree Growth

Cultivars with the same parentage were grouped, and the groups containing one genotype were excluded. A total of eight groups were then compared on growth parameters (Figure 5). Raw data from each plant were used for the analysis. What stands out in the figure is the *V. berlandieri* × *V. riparia* group (in red), in which all the growth-related parameters reach the highest level. *V. berlandieri* × *V. rupestris* (in blue) is comparable to *V. berlandieri* × *V. riparia* on these traits. *V.* × *champinii* produced the largest cane diameter and lignified proportion and yielded a pruning weight as large as *V. berlandieri* × *V. riparia*. On the other hand, *V. rupestris* yielded the lowest pruning weight and length-related indicators. *V. vinifera* × *V. rupestris* had a smaller trunk and cane diameter. *V. amurensis* × *V. riparia* had the thickest trunk, but the thinnest cane.

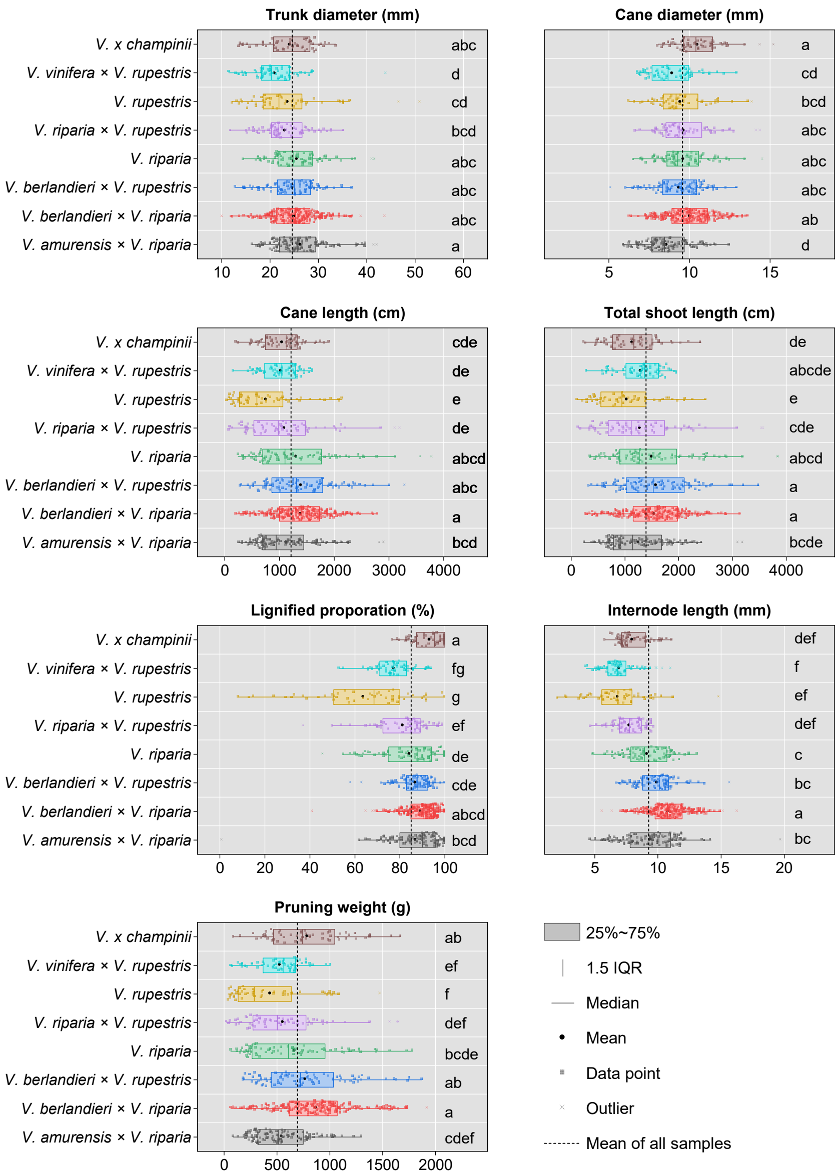

Figure 5. A comparison of the effects of eight parentages on the growth indicators of adult vines. Different lowercase letters on each figure indicate significant differences at $p < 0.05$ (adjusted by Bonferroni correction) by the nonparametric median test. Each data point corresponds to a single plant in one of the seasons. IQR, interquartile range.

4. Discussion

Well-formed callus tissue from the cambium shows as a ring on the bevel section of the cutting base where rooting can then occur, which ensures the nutrient uptake and vegetative growth of the cutting once it is planted in the field. Thus, cuttings with less callus may not generate adequate roots. However, the least-CFI gainer, '188-08', had more roots (1.6 roots per cutting) than some high-CFI genotypes such as '101-14M', '420A', or 'BR2' (Table 1). The irrelevance between CFI and rooting performance (Figure S2) might be attributed to the varying time requirements for callusing or rooting, i.e., some cultivars can form callus quickly or easily but may need more time for rooting than others, and vice versa. Waite et al. [27] reported excessive callus tissue impedes the xylem and phloem from forming across the graft union. The same goes for the perspective from Hartmann et al. [28] that callus tissue should not accumulate over 2–3 mm out from the graft union, and this might occur on those cuttings with a well-formed callus but sparse roots. On the other hand, cuttings rooted early tend to lose their roots when transplanted into the field, and re-rooting will cost the plant's stored reserves. In this case, more calluses but fewer roots may be the desired status for cuttings to grow in the field. 'Beta', '188-08', '1103P', and Shanhe series gained larger bud lengths and budbreak rates but smaller CFIs or root numbers, while the opposite occurred for rootstocks like '225Ru', 'Wumao', 'Saltcreek', or '8B' (Table 1), indicating a likely vegetal balance between the upper and lower parts of the cutting. It might be the reason for the slight negative correlation between CFI/root number and bud-related traits, despite the correlation being unnoticeable (Figure S2).

The nature of multiplication seems independent of growth because it did not promote vine growth in the field either in the current season or in adulthood (Figure S2). Even so, no clear relevance was observed between the growth indices of young and adult vines. The internode length could be a relatively stable trait because it showed a positive correlation between young vines and adult vines. Interestingly, the internode length for the current season is also correlated with the longitudinal growth and pruning weight of the adult vines (Figure S2), so it could be used as one of the potential indicators of growth vigor. A previous study by Köse et al. [29] on the current seasonal growth of grafted 'Merzifon Karasi' grapevines on nine rootstocks showed that the root numbers of '5BB', '140Ru', and 'SO4' were 19.5, 15.5, and 16.1, respectively, which was surprisingly close to the related results in the present study. Despite that, the roots of vines grafted on '8B' or '110R' are longer than those of the corresponding rootstocks we investigated. Apart from the soil type and regional climate, the effect of the scion on the rootstock could be one factor that caused the difference.

Our growth-based vigor evaluation for three consecutive seasons confirmed that '1103P' is with higher vigor, while 'Gloire' is with lower vigor—which has been acknowledged by many researchers [10,30,31]. This also enhanced the credibility of the vigor estimation and classification for the tested grape rootstocks. Despite that, our vigor definition for some rootstocks differed from the vigor rating summarized by Zhang et al. [9]. Therein, '3309C' was rated as medium-vigorous, and 'Dogridge' and 'Saltcreek' ('Ramsey') were rated as highly vigorous. These rootstocks were identified as less vigorous, even weak, in our observations. It seems that some rootstocks are more susceptible to growth conditions than others. Soil texture could affect vine vigor indirectly through cation exchange capacity, water holding capacity, root penetration, etc., and vine vigor is considered higher on gravelly soils than on silty loam soils [14,32]. The climatic condition is another major factor affecting shoot growth [33]. As shown in a multi-year and multi-site study by Dodson Peterson et al. [34], the conferred vigor (pruning weight) to Cabernet Sauvignon by '420A' in Mendocino La Ribera and Napa Rutherford was lower than that in the Sacramento Delta. The study also suggested that in most trial sites, '1103P' conferred high vigor while '3309C' conferred low vigor to the scion cultivars, which is consistent with our findings.

Based on the three seasonal growth performances, 31 rootstocks were finally classified into three groups (Figure 4B,C). Most rootstocks in Cluster 2 were also included in the confidence ellipse of Cluster 1 or Cluster 3, except for 'Dogridge'. Therefore, those rootstocks from Cluster 1 also covered by Cluster 2, for example, '140Ru', 'SO4', 'Wumao', '110R', '5C', and 'Shanhe1', could be less vigorous than those uniquely from Cluster 1, including '5BB', '225Ru', '1103P', 'BR2', '8B', and 'du Lot'. Similarly, 'Shanhe2' might be more vigorous than the others in Cluster 3. Interestingly, the Shanhe series, hybrids from *V*. *amurensis* and *V*. *riparia*, are distributed separately into three clusters. It might be a result of progeny segregation on the quantitative trait, as suggested in the transgressive segregation of 'Ramsey' × 'Gloire' progeny on canopy biomass [35].

The vigor comparison based on parentage suggested that genetic background did affect the vines' growth vigor. Vines with a *V*. *berlandieri* genetic background tend to be vigorous, whereas the opposite goes for those with a *V. riparia* ancestry (Figure 4). This corroborates the previous findings that rootstocks derived from the crosses of *V*. *berlandieri* with other species confer a higher vigor to scion than those from crosses of *V. riparia* [36,37]. *V. rupestris* is generally a species with vigorous growth [38], which is contrary to the result revealed in the present study. Apart from the environmental factors, a possible reason could be the smaller sample size—only two rootstocks were included in this species, of which du Lot showed a higher vigor and Shadi showed a lower vigor. Gautier et al. [39] pointed out that the younger age of the vines could be the reason for the difficulty in distinguishing the effects of the genetic background on conferring vigor to the scion. We infer that their limited data—acquired from a single season, with fewer vines and fewer genotypes included in the species could be another reason.

Relations between phenological periods and vine growth were not clear yet, or both altered in response to meteorological changes, as evidenced by the subtle changes in their relations across three seasons (Figure S3). Short-term weather changes, such as rising temperatures, might affect the phenological periods, which could explain the advanced flowering periods in 2017 (Figures 2 and S4). Meteorological factors even played a larger role than rootstock genotype in affecting vine growth, and rainfall seemed to be the major factor. The correlations between meteorological data and growth variables were high but not significant. Further collections of more seasonal data could be helpful to better understand the effect of each meteorological factor on vine growth.

5. Conclusions

The nature of multiplication or current seasonal growth varied largely among these rootstocks and was less connected with the growth indices of adult vines. Interestingly, the internode length of the new shoot developed on the cutting showed positive correlations with not only the internode length but also the cane length, shoot length, and pruning weight of the adult vines. Based on the growth measurements for three years, 31 rootstocks were separated into three clusters. Rootstocks such as '1103P', '5BB', and '225Ru' within Cluster 1 showed significantly higher vigor than those like 'Gloire', '3309C', and 'Ganzin1' within Cluster 3. This study also indicated that *V. berlandieri* could confer high vigor to the progeny.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/horticulturae9020241/s1. Figure S1: Summary of the monthly average meteorological data in the growing seasons of 2016–2018; Figure S2: Correlations among multiplication traits and growth parameters of grapevine rootstocks; Figure S3: Correlations between phenological periods and growth parameters of grapevine rootstocks for three individual seasons; Figure S4: Daily temperature changes before and after flowering in the growing seasons of 2016–2018; Table S1: Meteorological data during growing seasons in 2016–2018; Table S2: Basic composition of the soil; Table S3: Comparison of growth indicators among 31 grapevine rootstocks across three growing seasons (2016–2018); Table S4: Summary of PCA for vigor parameters.

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