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Comparison of the winter bud productivity, rooting and shoot development parameters of some *Vitis* spp. with single bud

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Abstract

Grapes belonging to the *Vitis* species are growing worldwide for many years for different purposes. Determining the bud productivity values of varieties belonging to this species for product programming during winter pruning is of great importance for high-quality production. Therefore, our study investigated bud productivity, rooting and shoot development parameters of single-bud cuttings taken from the first and ninth buds of 12 grape varieties with different species and polyploidy levels. In the study, Atak 77, Muscat Bleu, Rizpem, Kyoho (4N), Regent, Isabella, Heukboseok (4N), Özer Beyazı, Superior Seedless, Crimson Seedless, Kismish Rozovyi and Müşküle varieties were compared. Winter bud productivity was evaluated to clarify the winter pruning levels. In addition to cluster number, root development level and shoot length parameters were compared in the same single-bud cuttings. According to the values obtained from all buds regarding bud productivity, especially the interspecific hybrid Regent variety and the *V. labrusca* species, Isabella variety stood out as more productive than other varieties. In addition, very low bud productivity values were obtained in seedless varieties. Regarding the rooting status of single bud cuttings, Regent and Muscat Bleu, interspecific hybrids, were the most successful varieties. In evaluating shoot length, the interspecific hybrid Muscat Bleu variety gave the longest shoot according to the values obtained from almost all buds. According to these results, varieties obtained from cross-breeding different *Vitis* species, in particular, could generally have better bud productivity and rooting and shoot development values. This situation should be considered for quality and efficient production, especially during pruning applications.

Keywords: Buds, Grape, Interspecies varieties, Quality production, Crop loading, Bud fertility

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INTRODUCTION

Grapes are among the most cultivated fruits in the world, and their cultivation is important for the economies of many countries, including Türkiye (Shahzad et al., 2019; Daskalakis et al., 2018). Türkiye, among the gene centres of cultivated grapevines, is an important country in world viticulture with its rich grapevine genetic resources and ecological characteristics for viticulture culture (Atak et al., 2021). Viticulture is the source of income for many producers throughout the country due to the suitability of climate and growing conditions. Grape varieties with different botanical properties and rich in health components are widely consumed in many countries (Akram et al, 2019).

Grape varieties and genotypes of the *Vitis* species have been cultivated for many years for different purposes. The bud productivity values of the varieties belonging to this species should be determined for product programming during winter pruning. Bud productivity values of different grape varieties belonging to the *Vitis* species differ. This difference should be determined, and the most appropriate winter pruning should be decided. Otherwise, it may not be possible to reach the desired yield values. For this purpose, different researchers have determined the bud productivity values of grape varieties.

In viticulture, researchers use different pruning and loading applications to efficiently use unit areas and obtain higher-quality products (Başaran, 2006). The term yield in vineyard refers to the number of clusters the buds carry on annual shoots. There may be 0-4 cluster primordia in the primary bud of the winter buds of the vine. However, usually 1-2 cluster primordia can be seen (Çelik, 1999; Şen and Atak, 2020). Grape yield in vineyards vary depending on the winter bud positions on annual branches. Nodes at different levels are important in determining winter bud productivity (Dardeniz and Kısmalı, 2005). To ensure yield and quality, pruning levels should be determined according to the bud productivity of the varieties (Akın et al., 2011). Pruning balances between vegetative development and product yield (Şen and Atak, 2020). Knowing the bud productivity helps to adjust the number of buds to be left on the vine and the fruit load during winter pruning and also to increase fruit quality (Çelik and Kök, 1998; Dardeniz and Kısmalı, 2005).

Different methods are used to determine the bud fertility of grapevine. Among these, the most preferred method is forcing bud bursts and detecting clusters on each bud. Most of the researchers preferred forcing bud bursts and detecting clusters (Akın et al. 2011; Taşçı, 2015)

In this study, the winter bud productivity and rooting/shoot development parameters were examined to determine the optimum pruning and vine loads of 12 grape varieties belonging to different *Vitis* species. It is aimed to recommend the appropriate pruning level to grape producers who produce with these varieties to obtain high yield and quality products.

MATERIAL and METHOD

In this study, cuttings were taken from one-year-old shoots of a total of 12 grape varieties belonging to different species and polyploidy levels from the Vineyard Genetic Resources parcel located in the Yalova Atatürk Horticultural Central Research Institute in winter period. The trial area is situated on the borders of Yalova center, between 40◦39′40″ North latitude and 29◦17′22″ East longitude. The altitude is 3 m above the sea level, and the distance to the sea is 150 m. These cuttings were kept in the cold storage of the Department of Horticulture, Faculty of Agriculture, Bursa Uludağ University, at +4°C and 80% humidity until the time of the study (Figure 1).

Material

The study material consisted of 12 grape varieties belonging to different *Vitis* species. Two of these varieties are tetraploid (4N), while the other grape varieties are diploid (2N). In addition, 4 of the varieties are seedless, while the other eight are seeded (Table 1). The study evaluated the 1st and 9th buds of these 12 grape varieties.

Table 1. Grape varieties and species used in the study.

No	Variety	Species	Poliploidy Level	Seeded/Seedless
	Atak 77	*V.vinifera*	2N	Seeded
	Crimson Seedless	*V. vinifera*	2N	Seedless
	Heukboseok	Türlerarası melez	4N	Seeded
	Isabella	*V. labrusca*	2N	Seeded
	Kismish Rozovyi	*V. vinifera*	2N	Seedless
	Kyoho	Türlerarası melez	4N	Seeded
	Muscat Bleu	Türlerarası melez	2N	Seeded
	Müşküle	*V. vinifera*	2N	Seeded
	Özer Beyazı	*V. vinifera*	2N	Seedless
	Regent	Türlerarası melez	2N	Seeded
	Rizpem	*V. labrusca*	2N	Seeded
	Superior Seedless	*V. vinifera*	2N	Seedless

Method

Determination of Bud Productivity

To determine the winter bud productivity of the varieties, the method of counting the cluster primordia on the shoots that emerged by forcing the bud awakening was used according to the method used by Şen and Atak (2020). Cuttings were prepared by cutting them as single buds in the Climate Room of the Horticulture Department of the Faculty of Agriculture of Bursa Uludağ University by paying attention to the bud rows. The prepared cuttings were planted in plastic containers to determine the bud productivity and root and shoot developments. A small amount of activated charcoal was also added to the plastic containers. The containers were covered with plastic film to fix the single bud cuttings and ensure they all contacted the water equally.

Planting operations were carried out in plastic containers with 3 replications for each variety and 3 buds in each replication. When all the buds were considered for a variety, 90 single bud cuttings were used. A total of 90*12= 1080 single bud cuttings were used in the study. The buds on the shoot were cut according to the sequence number starting from the cutting points and planted in the container according to this bud order (Figure 2). The containers were filled with pure water so the bottom parts of the planted single-bud cuttings could contact the

water as equally as possible. The planted containers were kept in the climate room at +25°C for 4 weeks (Figure 3).

The dormant single-bud cuttings of the varieties were forced to shoot at the end of 4 weeks. After the buds burst, the bud productivity (number of buds/bud), rooting status of the buds and shoot lengths were evaluated according to Şen and Atak 2020 by counting the cluster primordia formed on the shoot.

Figure 1. Cuttings taken by pruning and storage in cold storage.

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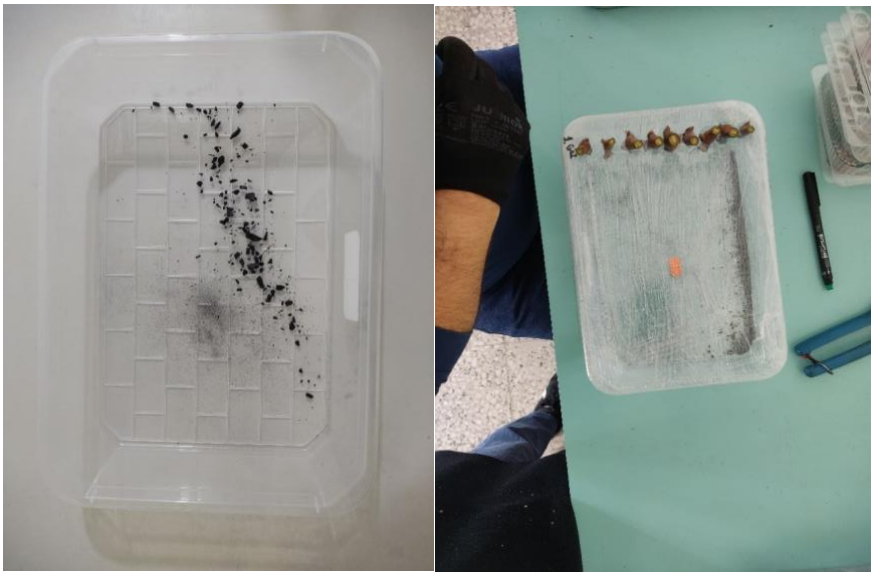

Figure 2. Preparation of plastic containers for planting to determine bud productivity

Figure 3. Photos of buds planted in plastic containers in the climate chamber

Evaluated Parameters

Rooting Development Level (0-3 Scale): The root development level in cuttings of various varieties was evaluated using a 0-3 scale. Roots of cuttings developing 0.5 cm and above were evaluated according to the scale values given in Figure 4.

Figure 4. Rooting scale used in the study for single bud cuttings (0-3)

Shoot Length (cm): The lengths of shoots sprouting from single-bud cuttings were measured. The distance between the bud and the shoot tip was measured with the help of a ruler (Figure 5).

Number of Cluster (Number of cluster/Bud): The cluster primordia on the developing shoots following the burst of the buds were counted, and the bud productivity of each variety and bud was determined (Figure 5).

Statistical Analyses

The experiment was established according to the completely randomized plots experimental design with 3 replications. The obtained data were subjected to variance analysis in the JPM-16 package program and the differences between the applications were statistically evaluated using the LSD test at a significance level of 0.05.

Figure 5. Photos of varieties with shoot length and cluster numbers counted

RESULTS AND DISCUSSION

In the study, while determining the bud productivity for each variety, data on root development level and shoot length were also determined. According to the results obtained, root development level (0-3 scale), shoot length and cluster number data were found to be statistically significant.

When the varieties were compared in terms of the location of the buds (according to the cluster number) in determining the bud productivity, the most productive variety in the 1st bud was the Regent variety, which is an interspecific hybrid. The Superior Seedless and Kishmish Rozovyi varieties from the *V. vinifera* species were determined as the varieties with the lowest bud productivity in the 1st bud. The Kyoho variety, an interspecific hybrid with a 4N polyploidy level, was found to be the most productive variety in the 2nd bud. The Superior Seedless variety from the *V. vinifera* species was determined as the variety with the lowest bud productivity in the 2nd bud. In the interspecific hybrid Regent variety, the 3rd bud is the most productive variety, while the Superior Seedless and Kishmish Rozovyi varieties belonging to the *V. vinifera* species are seen to have the lowest 3rd bud yield. In the Isabella variety belonging to the *V. labrusca* species, the 4th bud was found to be the most productive. The Superior Seedless and Kishmish Rozovyi varieties belonging to the *V. vinifera* species were found to have the lowest 4th bud yield. The most productive 5th bud was the Isabella variety belonging to the *V. labrusca* species, and the least productive variety was the Superior Seedless variety belonging to the *V. vinifera* species. While the Atak 77 variety belonging to the *V. vinifera* species had the highest bud productivity in terms of the 6th bud, the 6th bud was the lowest in the Kishmish Rozovyi variety from the same species. The Regent variety, an interspecific hybrid, was found to be the most productive variety in terms of the 7th, 8th and 9th buds. The lowest yielding variety was Superior Seedless, belonging to the *V. vinifera* species, for the 7th bud and the lowest yielding variety was Kishmish Rozovyi, belonging to the same species, for the 8th bud. The lowest yielding variety was Heukboseok, which is an interspecific hybrid and has 4N polyploidy, for the 9th bud (Table 2). The productivity values of the buds by variety are given in Figure 6. When the results obtained in determining the most productive buds based on varieties were examined, the following results were obtained: In the interspecific hybrid and 4N polyploidy level Kyoho variety, the most productive bud was determined as the 2nd bud. In contrast, the least productive bud was determined as the 5th bud (Figure 6). In the Atak 77 variety belonging to the *V. vinifera* species, the most productive bud was determined as the 7th bud. The same variety's least productive buds were determined as the 1st and 2nd buds. In the Özer Beyazı variety belonging to the *V. vinifera* species, the 8th bud was productive, while the 1st bud was the least productive.

Table 2. The bud productivity values of the varieties.

NUMBER OF BUNCHES*									
VARIETY	**1st bud**	**2nd bud**	**3th bud**	**4th bud**	**5th bud**	**6th bud**	**7th bud**	**8th bud**	**9th bud**
Kyoho (4N)	0,78^{e}	**2,17^{a}**	0,57^{e}	1,00^{d}	0,38^{g}	0,63^{d}	0,83^{d}	0,43^{f}	0,50^{e}
Atak 77	0,44^{h}	0,44^{g}	0,88^{c}	1,25^{c}	1,25^{b}	**1,40^{a}**	1,57^{c}	1,44^{c}	1,22^{c}
Özer Beyazı	0,14^{j}	0,40^{g}	0,22^{f}	0,56^{g}	0,44^{f}	0,50^{e}	0,56^{f}	0,67^{e}	0,44^{e}
Heukbseok (4N)	0,29^{i}	0,11^{j}	0,60^{e}	0,22^{i}	0,57^{e}	0,14^{g}	0,20^{i}	0,20^{j}	0,00^{h}
Regent	**2,11^{a}**	1,43^{c}	**1,38^{a}**	1,56^{b}	1,14^{c}	0,88^{c}	**2,38^{a}**	**2,50^{a}**	**2,44^{a}**
Superior Seedless	0,14^{j}	0,00^{k}	0,00^{g}	0,00^{j}	0,00^{i}	0,11^{g}	0,00^{k}	0,33^{h}	0,11^{g}
Crimson Seedless	0,89^{d}	0,67^{f}	1,00^{b}	1,00^{d}	0,56^{e}	0,11^{g}	0,38^{g}	0,38^{g}	-
Isabella	1,63^{b}	1,00^{e}	1,00^{b}	**2,00^{a}**	**2,00^{a}**	1,20^{b}	1,75^{b}	2,00^{b}	2,00^{b}
Rizpem	0,63^{f}	0,33^{h}	0,22^{f}	0,44^{h}	0,29^{h}	0,30^{f}	0,22^{i}	0,25^{i}	0,50^{e}
Kishmish Rozovyi	0,14^{j}	0,25^{i}	0,00^{g}	0,00^{j}	0,25^{h}	0,00^{h}	0,33^{h}	0,11^{k}	0,33^{f}
Müşküle	1,00^{c}	1,14^{d}	**1,33^{a}**	0,75^{e}	0,75^{d}	0,29^{f}	0,11^{j}	0,71^{d}	-
Muscat Bleu	0,56^{g}	1,50^{b}	0,78^{d}	0,67^{f}	1,25^{b}	0,67^{d}	0,78^{e}	0,67^{e}	1,00^{d}

* Lowercase letters indicate that the difference between varieties is statistically significant. LSD is significant at the 0.05 level.

In the interspecific hybrid and 4N polyploidy level Heukboseok variety, the most productive bud was the 3rd bud, while the least productive bud was the 9th bud. In the interspecific hybrid Regent variety, whose 8th bud was the most productive, the 6th bud was found to be the least productive. The 8th bud of the Superior Seedless variety belonging to the *V. vinifera* species was determined to be the most productive. All the other buds except the 1st and 9th buds of the same variety were the least productive. It was observed that the 6th bud of the Crimson Seedless variety belonging to the *V. vinifera* species, whose 3rd and 4th buds were productive, was least productive. It was determined that the 4th, 5th, 8th and 9th buds of the Isabella variety belonging to the *V. labrusca* species were productive, while the 2nd and 3rd buds were least productive. It was determined that the 1st bud of the Rizpem variety belonging to the same species was productive, while the 3rd and 7th buds were least productive. It was observed that the 7th and 9th buds of the Kishmish Rozovyi variety belonging to the *V. vinifera* species were productive, while the 3rd, 4th and 6th buds were least productive. In the Müşküle variety of the same species, the 3rd bud was found to be productive, while the 7th bud was determined to be least productive. In the interspecific

hybrid Muscat Bleu variety, the 2nd bud was found to be productive, while the 1st was determined to be least productive.

Along with bud productivity, root development level in single-bud cuttings was also evaluated based on bud and variety. The following results were obtained in the evaluations based on bud: 1st bud of interspecific hybrid varieties Muscat Bleu and Regent showed the best result in root development level. It was determined that the root development level in all buds was weak in the Atak 77 variety belonging to *V. vinifera* species. Root development level in 2nd bud of interspecific hybrid varieties Muscat Bleu and Özer Beyazı varieties belonging to *V. vinifera* species showed the best result in root development level in 3rd bud of interspecific hybrid varieties Muscat Bleu. Interspecific hybrid Regent showed the best result in root development level between the 4th and 9th buds. Isabella variety belonging to *V. labrusca* species stood out with 5th bud in root development level (Table 3).

Table 3. Average root development level values of the buds based on variety

ROOT DEVELOPMENT LEVEL*									
VARIETY	**1st bud**	**2nd bud**	**3th bud**	**4th bud**	**5th bud**	**6th bud**	**7th bud**	**8th bud**	**9th bud**
Kyoho (4N)	2,44^{e}	1,89^{d}	2,11^{f}	1,67^{g}	2,11^{d}	2,22^{d}	1,56^{g}	0,89^{i}	1,22^{g}
Atak 77	1,22^{i}	1,11^{h}	0,78^{j}	0,88^{i}	0,56^{i}	0,50^{k}	0,50^{k}	0,44^{k}	0,33^{i}
Özer Beyazı	2,57^{c}	**2,90^{a}**	2,67^{b}	2,89^{b}	2,78^{b}	2,44^{c}	2,78^{c}	2,67^{c}	2,56^{c}
Heukboseok (4N)	1,86^{g}	1,44^{g}	2,10^{g}	2,00^{e}	2,00^{e}	1,43^{j}	1,43^{i}	1,20^{h}	0,75^{h}
Regent	**3,00^{a}**	2,33^{b}	2,67^{b}	**3,00^{a}**	**2,89^{a}**	**2,89^{a}**	**2,88^{a}**	**3,00^{a}**	**3,00^{a}**
Superior Seedless	2,00^{f}	2,11^{c}	1,89^{h}	2,22^{d}	2,11^{d}	1,89^{g}	2,22^{e}	2,22^{d}	1,67^{e}
Crimson Seedless	1,56^{h}	1,78^{e}	2,22^{e}	1,89^{f}	1,89^{f}	2,00^{f}	2,00^{f}	1,56^{f}	-
Isabella	2,50^{d}	2,33^{b}	2,44^{d}	2,88^{b}	**2,89^{a}**	2,20^{e}	2,80^{b}	2,90^{b}	2,00^{d}
Rizpem	2,00^{f}	2,11^{c}	1,56^{i}	1,56^{h}	2,50^{c}	1,80^{h}	1,22^{j}	0,88^{j}	1,50^{f}
Kishmish Rozovyi	1,56^{h}	2,11^{c}	2,22^{e}	1,89^{f}	1,44^{h}	2,00^{f}	2,78^{c}	1,89^{e}	2,67^{b}
Müşküle	2,67^{b}	1,67^{f}	2,56^{c}	0,89^{i}	2,00^{e}	1,78^{i}	1,44^{h}	1,38^{g}	-
Muscat Bleu	**3,00^{a}**	**2,90^{a}**	**3,00^{a}**	2,78^{c}	1,75^{g}	2,78^{b}	2,33^{d}	1,56^{f}	1,71^{e}

* Lowercase letters indicate that the difference between varieties is statistically significant. LSD is significant at the 0.05 level.

In the evaluations of root development level based on varieties, the following results were obtained (Figure 7); While the 1st bud of the Kyoho variety, which is an interspecific hybrid and has a 4N polyploidy level, gave the best result in root development level, the 8th bud showed the weakest root development. In the Atak 77 variety belonging to the *V. vinifera* species, the 1st bud showed the best result in root development level. It was observed that the root development level of the 2nd bud of the same variety was the weakest bud. In the Özer Beyazı variety belonging to the *V. vinifera* species, the 2nd bud gave the best result in root development level. In contrast, the weakest root development was detected in the 6th bud. In the Heukboseok variety, an interspecific hybrid with a 4N polyploidy level, the 3rd bud gave the best result in root development level. The 9th bud of the same variety showed the weakest root development. In the Regent variety, an interspecific hybrid, the 1st, 4th, 8th, and 9th buds gave the best result in root development level, while the weakest root development was detected in the 2nd bud. The 4th, 7th and 8th buds of the Superior Seedless variety belonging to the species *V. vinifera* gave the best results in terms of root development, while the 9th bud showed the weakest root development. In the Crimson Seedless variety belonging to the same species, the 3rd bud showed the strongest root development, while the 1st and 8th buds showed the weakest root development. The 8th bud of the Isabella variety belonging to the *species V. labrusca* gave the best results in terms of root development, while the 9th bud showed the weakest root development. In the Rizpem variety belonging to the same species, the 5th bud showed the strong root development, while the 8th bud showed the weakest root development. The 9th bud of the Kishmish Rozovyi variety belonging to the species *V. vinifera* gave the best results in terms of root development, while the 5th bud showed the weakest root development. While the 1st bud of the Müşküle variety belonging to the same species stands out with the strongest root development, the weakest root development was detected in the 4th bud. In the interspecific hybrid Muscat Bleu variety, the 1st and 3rd buds gave the best results in terms of root development, while the 8th bud showed the weakest root development.

In determining bud productivity, the lengths of shoots growing on single-bud cuttings were also evaluated based on bud and variety. When we examined the bud basis, the following results were obtained: Regarding the length of shoots growing between 1 and 8 buds, the interspecific hybrid Muscat Bleu variety gave the best results.

The data obtained from shoot lengths varied depending on the position of the bud. While the lowest shoot length values were obtained in some buds in the Atak 77 and Crimson Seedless varieties belonging to the *V. vinifera* species, the lowest shoot length values were also obtained in some buds in the Rizpem variety belonging to the *V. labrusca* species. It was determined that the Heukboseok variety, an interspecific hybrid with a polyploidy level of 4N, gave the shortest shoots in the 7th bud. When the shoot lengths of the 9th bud were examined, the Özer Beyazı variety belonging to the *V. vinifera* species gave the best result. It was determined that the Kyoho and Heukboseok varieties, which are interspecific hybrids and have a polyploidy level of 4N, the Superior Seedless

variety belonging to the *V. vinifera* species and the Rizpem variety belonging to the *V. labrusca* species gave the shortest shoots in the same bud (Table 4).

Figure 6. Average bud productivity values between 1st and 9th buds of varieties.

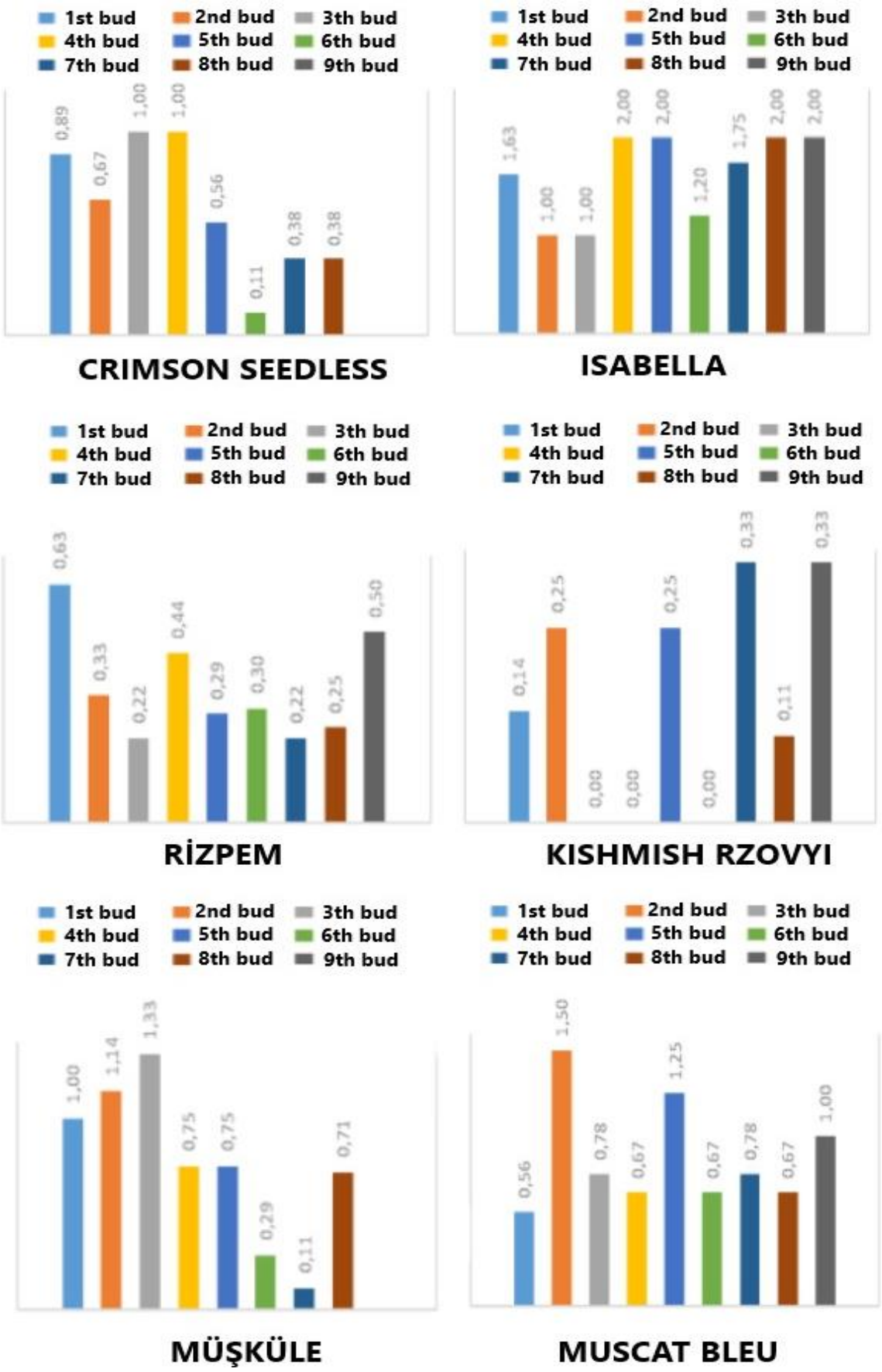

Figure 6. Average bud productivity values between 1st and 9th buds of varieties (continue).

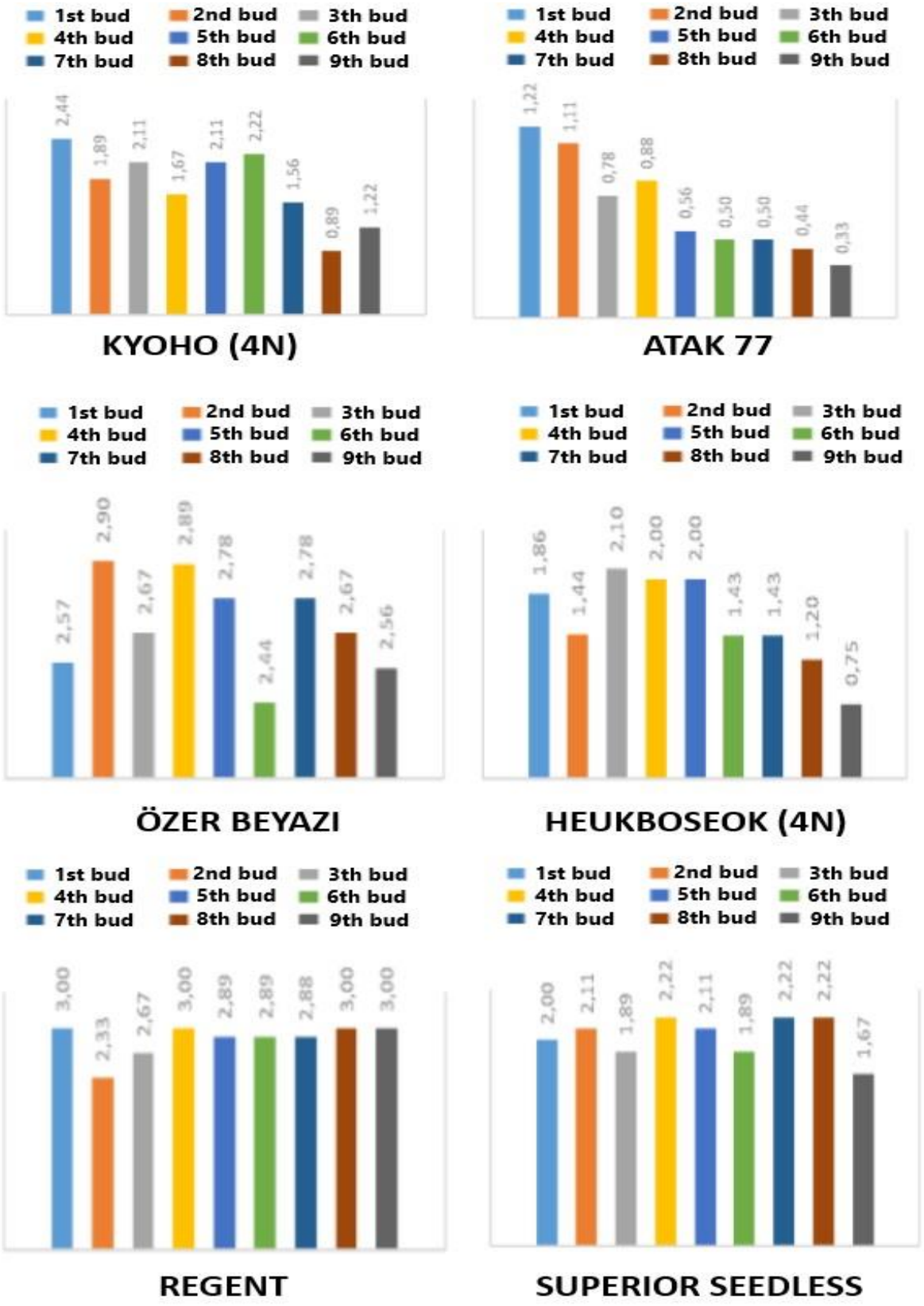

Figure 7. Root development level values of the buds according to the variety. a) Kyoho (4N), b) Atak 77, c) Özer Beyazı, d) Heukboseok (4N), e) Regent, f) Superior Seedless, g) Crimson Seedless, h) Isabella, ı) Rizpem, j) Kishmish Rozovyi, k) Müşküle and l) Muscat Bleu

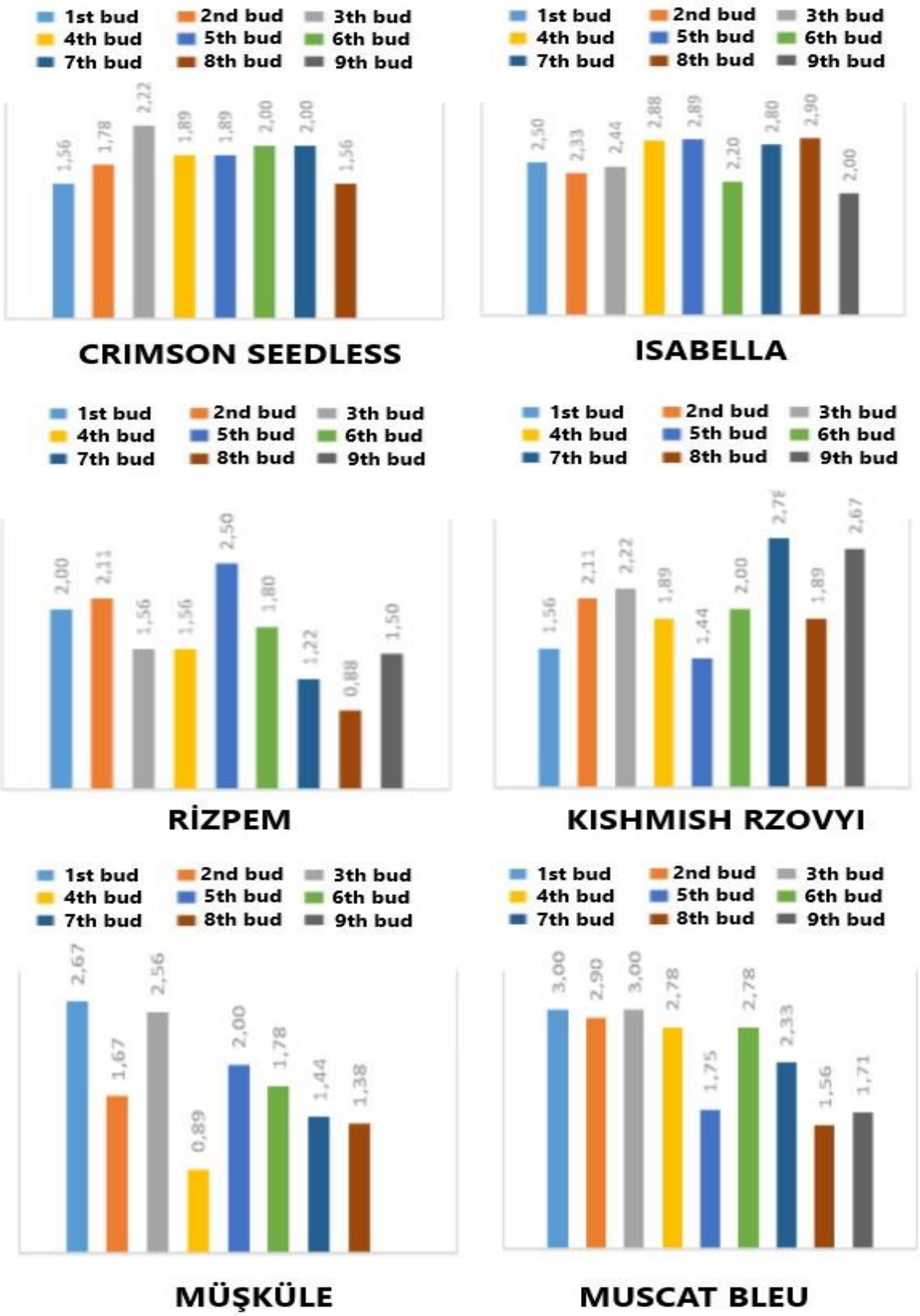

Figure 7. Root development level values of the buds according to the variety. a) Kyoho (4N), b) Atak 77, c) Özer Beyazı, d) Heukboseok (4N), e) Regent, f) Superior Seedless, g) Crimson Seedless, h) Isabella, ı) Rizpem, j) Kishmish Rozovyi, k) Müşküle and l) Muscat Bleu (continue).

When we evaluate the shoot lengths on a variety basis, the results are as follows (Figure 8): While the best result was obtained in the shoot length parameter of the Kyoho variety, which is an interspecific hybrid and has a 4N polyploidy level, the 4th bud gave the best result, the shortest shoots were detected in the 9th bud. When the shoot length values of the Atak 77 variety belonging to the *V. vinifera* species were examined, it was observed that the shoot extending from the 4th bud gave the best result, while the 5th bud had shorter shoots. In the Özer Beyazı variety belonging to the same species, it was observed that the shoot length gave the best result in the 3rd bud, while the 7th bud gave the shortest shoots. While the best result was obtained in the shoot length of the Heukboseok variety, which is an interspecific hybrid with a 4N polyploidy level, the 7th and 9th buds had the shortest shoots.

Table 4. Average shoot length values of the buds based on variety

LENGTH OF SHOOT*									
VARIETY	**1st bud**	**2nd bud**	**3th bud**	**4th bud**	**5th bud**	**6th bud**	**7th bud**	**8th bud**	**9th bud**
Kyoho (4N)	1,33^{h}	1,67^{e}	1,71^{f}	2,20^{d}	1,38^{f}	1,33^{i}	1,43^{h}	1,14^{j}	1,00^{e}
Atak 77	1,00^{k}	1,44^{f}	1,44^{i}	1,63^{g}	0,78^{l}	1,40^{g}	1,57^{f}	1,22^{g}	1,22^{d}
Özer Beyazı	1,86^{d}	2,30^{b}	2,67^{b}	2,33^{c}	1,78^{c}	1,67^{e}	1,56^{g}	2,11^{b}	2,00^{a}
Heukboseok (4N)	1,57^{f}	1,67^{e}	2,20^{d}	2,00^{e}	1,63^{e}	1,43^{f}	1,00^{k}	1,20^{i}	1,00^{e}
Regent	1,78^{e}	1,22^{h}	1,56^{h}	1,56^{h}	1,13^{j}	1,25^{j}	1,63^{e}	1,22^{h}	1,22^{d}
Superior Seedless	1,38^{g}	1,44^{g}	1,56^{h}	1,56^{h}	1,33^{g}	2,11^{c}	1,67^{d}	1,56^{e}	1,00^{e}
Crimson Seedless	1,11^{j}	0,89^{i}	1,44^{i}	1,13^{j}	1,00^{k}	1,22^{k}	1,25^{i}	0,75^{l}	-
Isabella	2,00^{b}	1,50^{f}	2,22^{c}	2,33^{c}	1,71^{d}	1,75^{d}	1,71^{c}	2,00^{c}	**2,00^{a}**
Rizpem	1,25^{i}	1,22^{h}	1,11^{j}	1,33^{i}	1,14^{i}	1,10^{l}	1,10^{j}	1,00^{k}	1,00^{e}
Kishmish Rozovyi	1,78^{e}	1,89^{d}	2,11^{e}	2,38^{b}	2,11^{b}	2,33^{b}	2,22^{b}	1,89^{d}	1,78^{c}
Müşküle	1,89^{c}	2,00^{c}	1,67^{g}	1,67^{f}	1,22^{h}	1,33^{h}	1,56^{g}	1,25^{f}	-
Muscat Bleu	**3,00^{a}**	**2,90^{a}**	**2,78^{a}**	**2,89^{a}**	**3,00^{a}**	**2,67^{a}**	**2,67^{a}**	**2,22^{a}**	1,86^{b}

* Lowercase letters indicate that the difference between varieties is statistically significant. LSD is significant at the 0.05 level.

While the best result was obtained in the shoot length of the Regent variety, which is an interspecific hybrid, in the 1st bud, the shortest shoots were observed in the 5th bud. In the Superior Seedless variety belonging to the species *V. vinifera*, the best shoot length was given in the 6th bud, while the shortest shoots were detected in the 9th bud. While it was observed that the best shoot length was given in the 7th bud of the Crimson Seedless variety belonging to the same species, it was determined that the shortest shoots were given in the 8th bud. In the Isabella variety belonging to the species *V. labrusca*, the 4th bud gave the best shoot length. The shortest shoot length was seen in the 2nd bud in the same variety. While the best results were obtained in shoot length in the Rizpem variety belonging to the same species, the shortest shoots were found in the 8th and 9th buds. While the 4th bud of the Kishmish Rozovyi variety belonging to the species *V. vinifera* showed the best result regarding shoot length parameter, it was determined that the 1st and 9th buds gave the shortest shoots. In the Müşküle variety belonging to the same species, the best shoot length was seen in the 2nd bud, and it was observed that the shortest shoots were given in the 5th bud. In the interspecific hybrid Muscat Bleu variety, the best results were obtained from the 1st and 5th buds in shoot length, while the shortest shoot was found to be from the 9th bud.

Leaving enough bunches on the annual branches during winter pruning is important to create a crop load. One of our main goals in this study was to determine the productivity of the buds on the annual branches and to reveal the most appropriate pruning method. When we look at the studies conducted by different researchers, it is reported that bud productivity values can give different results depending on the variety and the location of the bud on the annual branch. In general, it is stated that there is an increase in bud productivity towards the middle level of the one-year-old branches, but productivity decreases towards the ends of the branch (except for seedless varieties) (Akın et al., 2011; Piras et al., 2014; Uyak and Doğan, 2023). These results are mainly in line with the results obtained in our study. However, it is not very correct to generalize, and it is still helpful to determine the most productive buds with preliminary trials on variety of bases. This way, it can clearly state which varieties should be pruned short, medium and long. Şen and Atak (2020) used some of the table grape varieties we used in our study in their study to determine the bud productivity of some table grape varieties. In the study, while the most productive buds showed similar results to ours in some varieties, they obtained different results in the Atak 77 (2nd or 3rd bud) variety. Different researchers report that many factors affect bud productivity values and that factors such as climate, location, soil and nutritional conditions may be effective.

Also, Çelik et al. (2015) reported that the bud fertility of genotypes belonging to *V. labrusca* species was higher than that of genotypes belonging to *V. vinifera* species. Their study found bud productivity values ranging from 0.34 to 3.82 in *V. labrusca* genotypes. Similarly, in our study, interspecific hybrid varieties carrying *V. labrusca* blood and the *V. labrusca* species İsabella variety showed higher bud productivity than *V. vinifera* varieties.

Gutiérrez-Gamboa et al. (2018) evaluated bud productivity with a Chilean variety (Carménère). Bud productivity reached an average of 1.3 clusters per bud, min. 0.9 and max. 1.7. Accordingly, Carménère showed

low productivity in base buds. In our study, this situation varied by variety and generally, higher bud productivity values were reached

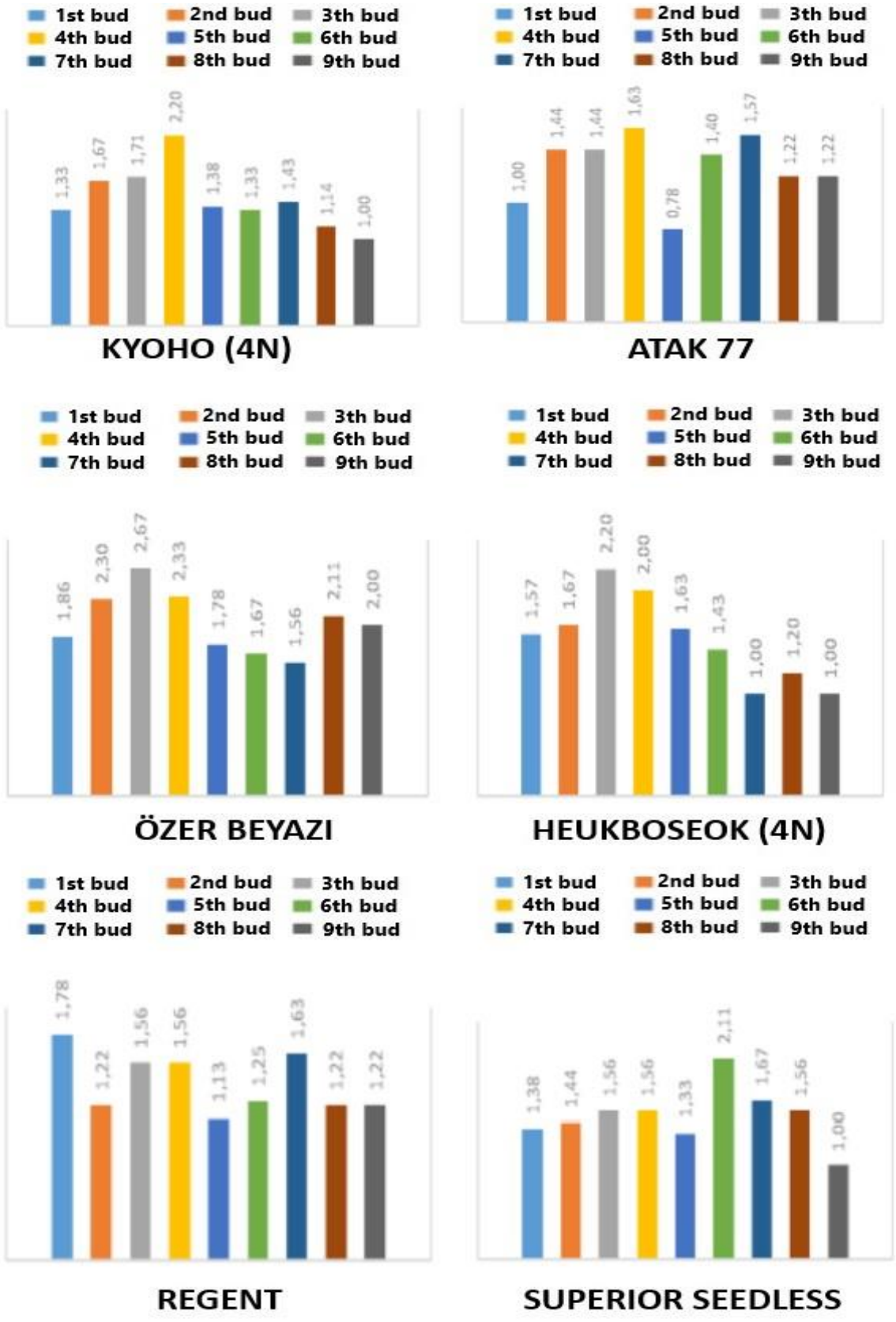

Figure 8. Average shoot length values of the buds based on variety. a) Kyoho (4N), b) Atak 77, c) Özer Beyazı, *d) Heukboseok* (4N), e) Regent, f) Superior Seedless, g) Crimson Seedless, h) Isabella, ı) Rizpem, j) Kishmish Rozovyi, k) Müşküle and l) Muscat Bleu

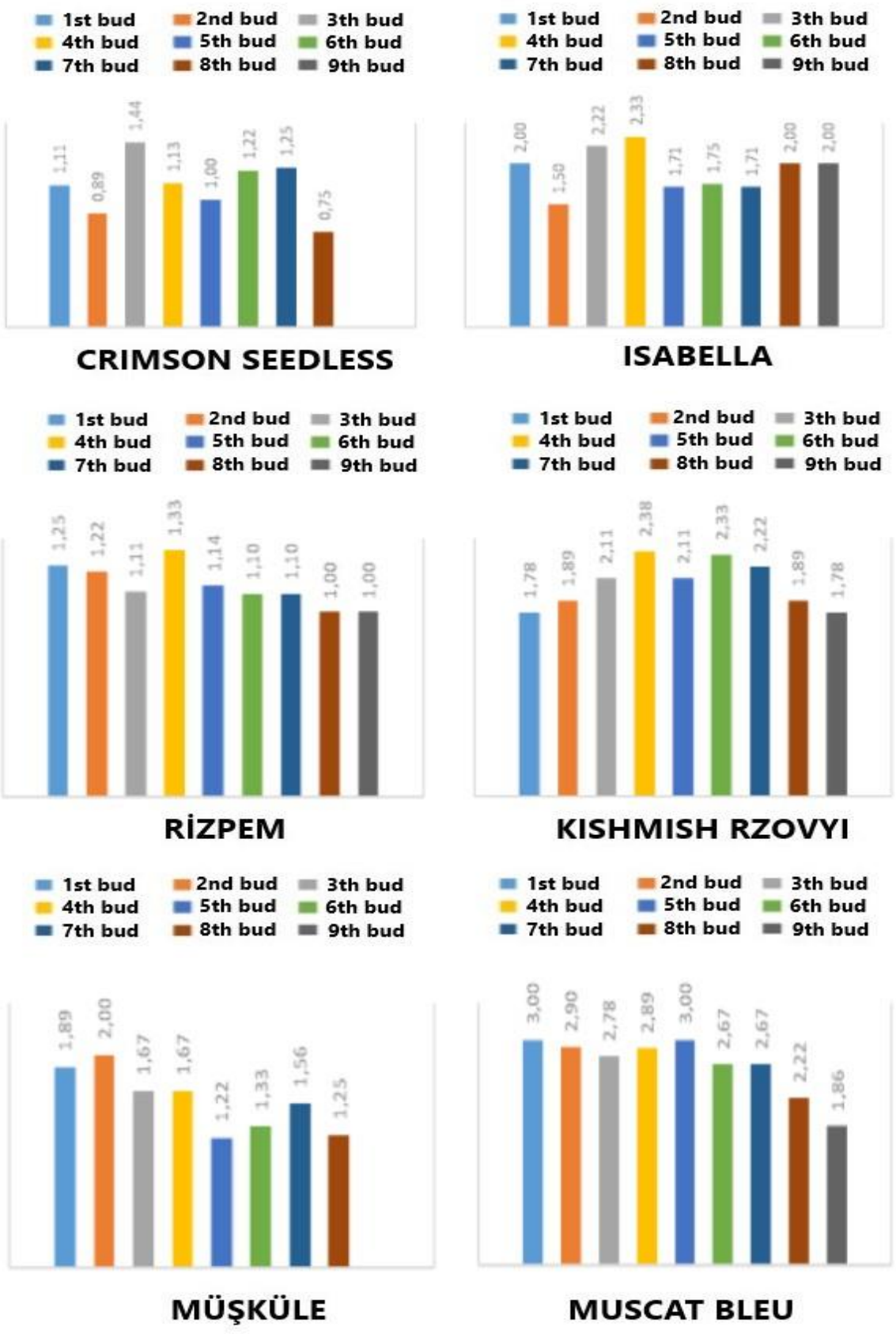

Figure 8. Average shoot length values of the buds based on variety. a) Kyoho (4N), b) Atak 77, c) Özer Beyazı, *d) Heukboseok* (4N), e) Regent, f) Superior Seedless, g) Crimson Seedless, h) Isabella, ı) Rizpem, j) Kishmish Rozovyi, k) Müşküle and l) Muscat Bleu (continue).

Buttrose (1974) reported that when the buds on the annual branch experience water stress, the formation of the flower cluster primordia, which occurs due to carbohydrate deficiency in the buds at the nodes at the tip of the branch, decreases. Our study observed that the water requirement of single-bud cuttings increases when the buds burst and leaf formation begins. This situation may cause differences among varieties and changes in the number of cluster primordia, which may cause changes in bud productivity. According to this prediction, studies on bud productivity should be conducted in the long term, and more definitive results should be obtained with different pruning practices in the field. Kliewer and Dokoozlian (2005) reported that the number of clusters is primarily considered in determining bud productivity and that the difference in the number of clusters is effective not only on yield but also on the quality and size of the fruit. Leao et al. (2017) reported an increase in bud productivity according to the position of the buds on the annual branch in the varieties they studied, and this increase reached the highest productivity in the 8th bud. Similar results were observed in A1105 and BRS Clara seedless hybrid grapes. Similarly, in the seedless Kishmish Rozovyi, Superior Seedless, and Özer Beyazı varieties we used in our study, it was observed that the tip buds were more productive.

It is also reported that pruning practices performed during the growing season may have an effect on bud productivity. For example, it is reported that summer pruning practices (Türk and Köse, 2024) and autumn pruning (De Souza et al., 2024) may have a positive effect on bud productivity.

Zinni et al. (2023) investigated the effects of some applications on bud productivity in two different growing environments in the Michele Palieri grape variety during two vegetation periods. They reported that the 9th and 10th buds maintained in the climate chamber were productive, while the 1st and 2nd buds had the lowest productivity. It was determined that the 5th and 6th buds of the buds maintained in the vineyard were the most productive, while the lowest yield was in the 1st, 2nd, 11th and 12th buds. In our study, the fact that the bud productivity values between the 1st and 9th buds of the 12 varieties we maintained in the climate chamber conditions may sometimes differ from similar studies in the literature can also be explained by this study above. Because the conditions obtained in the field may sometimes not coincide with the results obtained in the climate chamber. For this reason, it is thought that it would be appropriate to make observations in the field for more reliable results in such studies. Şahin and Dardeniz (2023) reported in their study that bud productivity values may sometimes increase up to the 10th node. Therefore, it is recommended that these studies should be carried out with as many buds as possible, as in our study. Dardeniz and Kısmalı (2005) reported that bud productivity studies are carried out not only to reduce product load but also to determine the appropriate pruning to reduce summer pruning practices and positively affect quality. In varieties where sufficient product can be obtained with short pruning, medium or long pruning creates excessive product load and quality decreases. It has been reported that longer pruning can be done in some varieties (especially seedless) to obtain sufficient yield. Our study shows that short or medium pruning is sufficient in seeded varieties, while seedless varieties should be pruned longer. However, sometimes short pruning can be preferred, especially in seeded varieties, to avoid excessive product load and to ensure higher-quality grain formation.

CONCLUSION

Grape varieties and genotypes of the *Vitis* species have been produced for many years for different purposes. The bud productivity of varieties belonging to this species must also be determined for the purpose of product programming during winter pruning. Bud productivity is a very important feature determined by genetic and environmental factors, and adjusting the crop load on the vine with pruning is of great importance for quality production. Bud productivity is important in determining newly developed grape varieties with high yield and potential, but these values vary according to the buds' variety and location. Our study determined bud productivity values and the number of buds left on annual shoots during winter pruning for grape varieties with different species and polyploidy levels.

Crimson Seedless and Superior Seedless varieties belonging to the *V. vinifera* species are less productive than other seedless varieties. Sometimes, the desired results cannot be obtained from long pruning applications because their bud productivity values vary. Therefore, a mixed pruning application may yield better results for these two varieties. Different results were obtained on a variety basis when looking at seeded varieties. Especially if it is planned to obtain high yield with the trellis system, long pruning can give better results in some varieties (such as Atak 77 and Muscat Bleu) as an alternative to short or medium pruning. Short and medium pruning in other varieties seems sufficient when bud productivity values are considered. However, in varieties or years with high yields, sometimes this situation can affect product quality and thinning is needed. Therefore, short pruning applications can also be recommended to increase fruit quality and sometimes to save on thinning labour. Many factors can affect bud's productivity, including pruning, fertilisation, and other cultural practices performed in the previous season. So, it is recommended that all maintenance practices be carried out meticulously throughout the growing season.

Compliance with Ethical Standards

Peer-review

Externally peer-reviewed.

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Declaration of Interests

The authors state there is no competing interest.

Author contribution

The contribution of the authors to the present study is equal. Also this study includes some of the studies from Kevser Çorak's master thesis.

Data availability

Data will be made available on request.

Consent to participate

The authors consent to participate.

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