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Full Length Research Paper

Early growth performances of various seed sources of black (*Prunus serotina* Erhr.) and wild cherry (*Prunus avium* L.) seedlings on low and high elevation sites in the western Black Sea Region of Turkey

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The growth performances of one-year old seedlings of various black cherry (BC) and wild cherry (WC) seed sources (SSs) that were planted on low elevation sites (LES) and high elevation sites (HES) in the western Black Sea Region (BSR) of Turkey were assessed one and five years after planting (YAP). Significance between and within-species variations were found for seedling growth. On species basis, WC was superior to BC for seedling groundline diameter and height growth for the low elevation sites (LES) of one and five years after planting (YAP), whereas no substantial survival and growth differences were found between the species for the high elevation sites (HES) of five YAP. Generally, seedlings averaged a greater survival on the LES, when compared with those on the HES. Local WC SSs (Tefen, Yayla and Dirgine) demonstrated an enhanced seedling survival and growth on LES than the other SSs. Unlike the LES results, a collection of BC (Michigan 1 and Ukraine) and WC SSs (Dirgine, Germany, and Tefen) displayed the best seedling growth over five years. The HES seedlings frequently experienced diebacks and forking due to heavy snow fall and wildlife browsing. Selection of the local WC SSs was vital for the LES. However, BC SSs may present a potential for planting on the HES with harsher environmental conditions.

Keywords: Black cherry, provenance test, seedling growth and survival, wild cherry.

INTRODUCTION

Globally, quality wood prices are on a sharp increase. As the largest global timber exporter, Russia's recent decision on increasing its tax rate on round wood in 2010 will reduce the supply of wood in the main markets including Europe (Eastin and Turner, 2009). Therefore, there is a growing incentive to increase domestic wood production (Eastin and Turner, 2009; Hemery et al., 2010).

Due to their multiple benefits, including high-priced wood, black (*Prunus serotina* Ehrh.) and wild cherry (*Prunus avium* L.) receive high interests from tree growers on both sides of the Atlantic (Savill, 1991; Brown et al., 1996; Eşen et al., 2005, 2007; Hemery et al., 2008).

Reaching 1 m in diameter and 30 m in height, wild cherry (WC) is a native, fast-growing "scattered broadleaved" tree species with ecological, economical and cultural significance in both Europe (Savill, 1991; Hemery et al., 2008, 2010) and Turkey (Yaman, 2003; Eşen et al., 2005; 2006, 2007, 2009). WC's wood is especially high-prized in the furniture, veneer and cabinet industry (Savill, 1991; Joyce et al., 1998; Russell, 2003).

Industrial plantations with the genetically improved plant materials of valuable tree species including native WC and non-native black cherry (BC) species cannot only help narrow the gap between demand for and supply of quality wood but also reduce production pressure on natural forests in Turkey (TGRP, 2003). These cherry species demonstrate significant survival and growth differences among different plantation sites (Walters, 1985;

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Table 1. Geographic information and sources of the seeds of different black and wild cherry used in the study.

Seed source[1]	Species[2]	Source[3]	Geographic location	Elevation (m)	Aspect[4]
Çaykara	PA	Trabzon RFD Turkey	Çamlıbel Village, Sürmene, Trabzon, TURKEY	900	N
Tefen	PA	Zonguldak RFD Turkey	Pazarlıoğlu Village, Devrek, Zonguldak, TURKEY	650	SE
Dirgine	PA	Zonguldak RFD Turkey	Elemen Plateau, Dirgine, Zonguldak, TURKEY	1100	-
Kocaman	PA	Zonguldak RFD Turkey	Halli Village, Kdz. Ereglisi, Zonguldak, TURKEY	1000	-
Yayla	PA	Zonguldak RFD Turkey	Kızılcakese Village (Toptasi), Zonguldak, TURKEY	389	SE
Germany	PA	NFV Germany	Mittelgebirge (Polle), Germany; N 51,9290 E 9,3890	260	GD
Michigan-1U.S.A.	PS	Sheffield's Seed Co., Inc. U.S.A.	NA	NA	NA
Michigan-2 U.S.A.	PS	Lawyer Nursery Inc. U.S.A.	NA	NA	NA
West Virginia-LE U.S.A.	PS	US Forest Service NFRS U.S.A.	79°42'30'' N; 39°10'00'' W	488	NA
West Virginia-ME U.S.A.	PS	US Forest Service NFRS U.S.A.	79°38'00'' N; 39°06'00'' W	622	NA
West Virginia-HE U.S.A.	PS	US Forest Service NFRS U.S.A.	79°31'30'' N; 39°07'30'' W	860	NA
Hungary	PS	Lawyer Nursery Inc. U.S.A.	48° N; 19° E	NA	NA
Ukraine	PS	Lawyer Nursery Inc. U.S.A.	50° N; 30° E	140-200	NA

[1]LE, Low elevation; ME, middle elevation; HE: high elevation. [2]PA, *P. avium*; PS, *P. serotina*; [3]RFD, Regional Forestry Directorate; NFV, Niedersächsische Forstliche Versuchsanstalt; NFRS, Northeastern Forest Research Station; [4]NA, not available.

Curnel et al., 2003). Therefore, selecting the proper seed source(s) for a spesific site is vital for successful cherry plantations (Curnel et al., 2003; Hemery et al., 2008).

However, no study has investigated the geographic variation within wild cherry in Turkey and compared the performance of different cherry seed sources on different plantation sites in the country.

This study investigated the first and fifth year survival and growth of the young seedlings of different seed sources of BC and WC tree species planted on low and high-elevation sites in the mesic western Black Sea Region (BSR) of Turkey. The study aimed to evaluate the genetic variability in both cherry species and to identify appropriate cherry seed sources with enhanced early survival and growth abilities in two different altitudes in the region. The study was also aimed to help esta-blish necessary basis for the genetic improvement of WC in the future, where the main management goal would be to produce high-quality industrial wood.

MATERIALS AND METHODS

For WC, mature fruits were collected from open-pollinated single mature trees and trees in close proximity growing in four different locations (Dirgine, Kocaman, Tefen, and Yayla) in the province of Zonguldak in the mesic western Black Sea Region (BSR) and one location in the province of Trabzon in the mesic eastern BSR of Turkey between July and August, 2003 (Table 1). After extraction, seeds were dried at room temperature for 48 h at the Forestry Faculty of Düzce University. Seeds were then stored in a refrige-rator at 3°C. In addition, an improved German seed source (SS) collected from Mittelgebirge (Polle) seed orchard in 1999 was kindly donated for the study by the Lower Saxony Forest Genetics Resources Research Institute (NFV) in Germany. In total, six SSs were used for wild cherry in this study. For BC, the seeds of three West Virginia (low-, middle- and high-elevation) SSs were obtained from the US Forest Service Northeastern Forest Research Station. The seeds of other BC SSs were purchased from commercial seed suppliers in the US (Table 1).

All the cherry seeds were cold-stratified at 3°C in a cold room for 120 days and then sown in beds in the Hendek Forest Nursery (Adapazarı) in April, 2004. In 2005 fall, all the one-year old seedlings were excavated from the nursery beds and immediately potted. They were later transferred to plantation sites.

Four plantation sites were selected in the western Black Sea Region (Figure 1 and Table 2). Two of them were low-elevation sites and the remaining two sites had relatively high elevations. Before planting, all of the sites were mechanically prepared with a rake-equipped bulldozer in

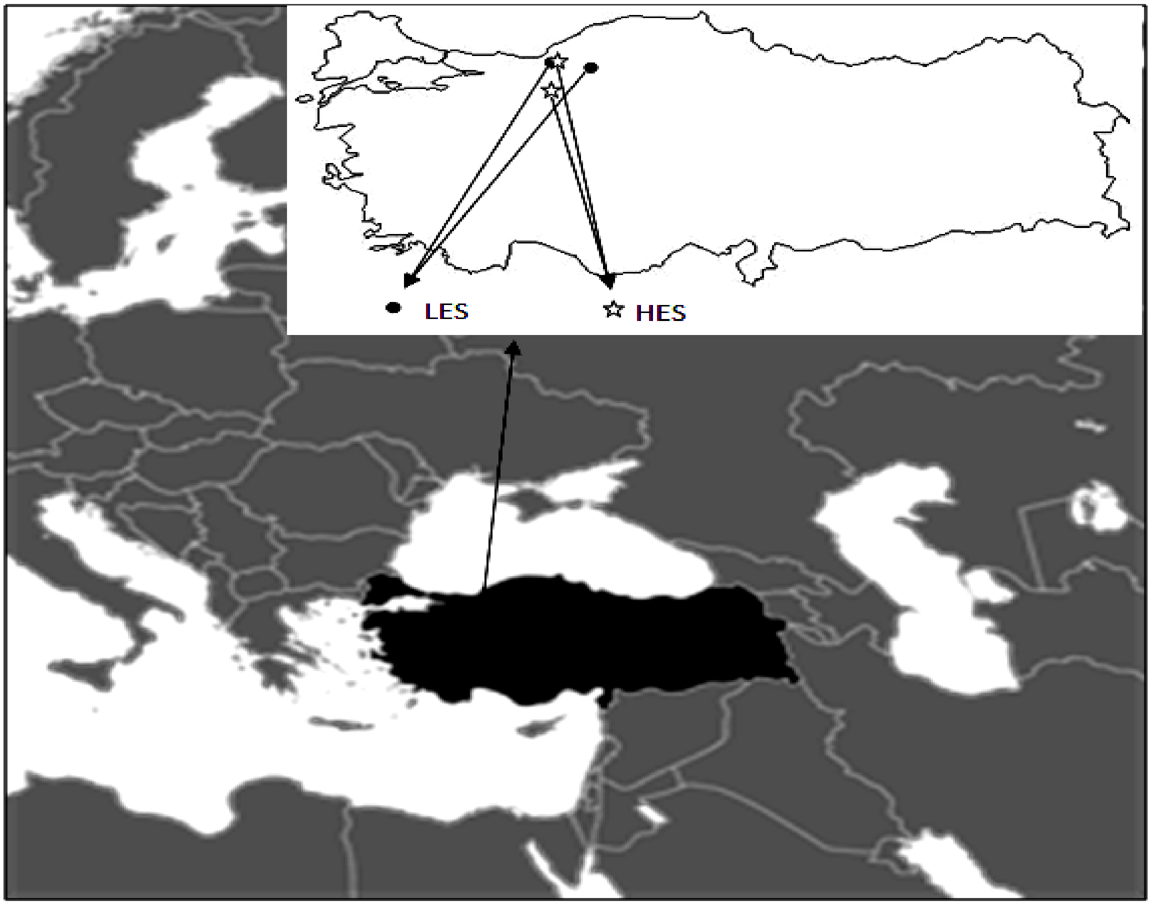

Figure 1. The low- and high elevation (LES and HES, respectively) experimental sites where one-year old seedlings of different seed sources of black and wild cherry seedlings were planted in the western Black Sea Region of Turkey.

Table 2. Plantation sites of one-year old seedlings of various *P. avium* and *P. serotina* seed sources in the western Black Sea Region of Turkey.

FRD[1]	FMD[2]	FMU[3]	Location	Latitutde/Longitude	Aspect	Elevation (m)
Bolu	Bolu	Bolu	Yayla Mevkii, Çömlekçiler Yaylası	40°47' 50.7'' N 31°35' 39.5'' E	SW	High (1194)
Zonguldak	Dirgine	Merkez	Merkez Orman Emval Deposu	41°03' 14.9'' N 31° 50' 25.6'' E	N	Low (280)
Zonguldak	Dirgine	Manzut	Çalca mah.	41° 07' 28.0'' N 31° 19' 17.7'' E	N	High (828)
Zonguldak	Ereğli	Kocaman	11. Bölme Yanık saha	41° 07' 28.0'' N 31° 19' 17,7'' E	NW	Low (125)

[1] Regional Forestry Directorate; [2] Forestry Management Directorate; [3] Forestry Management Unit.

2004 fall. The soil on the plantation sites ranged from clayey to loamy. The soil acidity (pH) of the sites ranged from 5.5 to 6.5. Weed control was regularly carried out by the Turkish forest service from the beginning of the planting.

The study was grouped into low and high-elevation sites (LES and HES, respectively). For each group, randomized complete block design with eight replications were employed. SSs were randomly assigned to rows. 20 seedlings were used for each replication in each SS. Seedlings were planted on rows by 3 x 3 m spacing. There were no substantial differences among seedlings for diameter at the root collar and height at the planting. Analysis of variance (one-way ANOVA) was used to test the main effect. The Duncan mean comparison test was used to separate treatment means. P-values equal or below the 0.05 level were considered significant throughout the experiment.

At the end of the growing seasons, the groundline diameter (gld)

Table 3. Survival, groundline diameter (gld), height and height/gld ratio of *P. avium* (PA) and *P. serotina* (PS) seedlings on the low-elevation sites in the Black Sea Region of Turkey one (1 YAP) and five years after plantation (5 YAP).

Species[1]	Survival[2] (%)	gld (mm)	Height (mm)	height/gld
1 YAP				
PA	88 (±2)[a]	7.4 (±0.3)[a]	66 (±4)[a]	87 (±2)[a]
PS	85 (±3)[a]	5.7 (±0.3)[b]	49 (±3)[b]	83 (±3)[a]
5 YAP				
PA	62 (±3)[a]	13.1 (±0.5)[a]	93 (±4)[a]	72 (±2)[a]
PS	59 (±2)[a]	9.8 (±0.4)[b]	67 (±3)[b]	71 (±2)[a]

[1] PA: *P. avium*; PS*: P. serotina*.
[2]Means within each column with different letters are significantly different (p≤ 0.05).

Table 4. Survival, groundline diameter (gld), height, and height/gld ratio of *P. avium* (PA) and *P. serotina* (PS) seedlings on the high-elevation sites in the Black Sea Region of Turkey one (1 YAP) and five years after plantation (5 YAP).

Species[1]	Survival (%)	gld (mm)	Height (mm)	Height/gld
1 YAP				
PA	64 (±4)[a]	5.1 (±0.3)[a]	43 (±4)[a]	83 (±1)[a]
PS	57 (±5)[a]	4.0 (±0.3)[b]	34 (±3)[b]	83 (±1)[a]
5 YAP				
PA	41 (±4)[a]	11.8 (±0.7)[a]	91 (±7)[a]	76 (±1)[a]
PS	38 (±3)[a]	11.1 (±1.1)[a]	78 (±5)[a]	75 (±1)[a]

[2] PA, *P. avium*; PS*, P. serotina*.

and height to the terminal bud of each seedling was measured one and five years after planting (YAP). Seedling survival of each SS was also determined. Data were analyzed separately for each elevation group.

RESULTS AND DISCUSSION

On tree species basis, BC and WC seedling survival averaged high (at least 80%) for both LES and HES one year after planting, yet decreased by about 30% in the fifth year. No significant differences were found between the cherry species for seedling survival for any site over the five-year period (Tables 3 and 4). Seedling mortality increased for both species on the HES one and five YAP, when compared to that on the LES (Table 4). It was observed that BC seedlings displayed greater dieback and forking than WC, although this was not quantatively determined. Diebacks and forking was especially pronounced for the HES seedlings. Harsher site conditions (lower temperatures and less water- and nutrient availabilities, heavy snowfall and desiccating winter wind) on the HES resulted in narrower growing season and lower photosynthetic capacity, and this often reduce survival and growth of young tree seedlings (Ürgenç, 1985).

WC seedlings averaged a significantly greater (≥29%) groundline diameter and height growth when compared to BC seedlings on the LES one and five years after planting (Table 3). WC seedlings also had a substantially greater groundline diameter and height growth (≥26%) than BC seedlings on the HES one YAP. However, the growth superiority of WC disappeared five years after planting (Table 4). No significant differences were apparent between the species for height-to- groundline diameter ratio for both elevations one and five YAP (Tables 3 and 4).

When the growth performances of the individual SSs were analyzed, significant differences were found for both elevation sites. Also, the performances of the SSs varied from the first to fifth-year following planting (Tables 5 and 6). The Yayla (WC) and Hungary (BC) SSs had the best survival rates, with significant differences from the SS group with the lowest survival rates (Kocaman, Michigan-1, Çaykara and Michigan-2) one year after planting on the LES (Table 5). The Michigan-2 SS averaged almost a 38% lower seedling survival rate than the best SS. The intermediate SSs did not exhibit significant survival differences from the best and lowest SS group for survival (Table 5). The WC SSs, mostly the native SSs (Dirgine, Tefen, Yayla and Germany) of WC, had significantly greater groundline diameter growth than the rest of the SSs in the first year following planting. The Michigan-2 seedlings had again the lowest groundline diameter growth. The best height growth performances were shown by the native Tefen and Dirgine WC SSs. The

Table 5. Survival, groundline diameter (gld), height and height/gld ratio of the seedlings of different seed sources of *P. avium* (PA) and *P. serotina* (PS) on the low-elevation sites in the Black Sea Region of Turkey one (1 YAP) and five years after plantation (5 YAP).

Seed Source[1]	Species[2]	Survival[3] (%)	Groundline diameter (mm)	Height (cm)	Height/Groundline diameter
1 YAP					
Yayla	PA	98 (±1)[a]	7.9 (±0.5)[a]	73 (±7)[ab]	91 (±5)[abc]
Hungary	PS	97 (±2)[a]	5.9 (±0.7)[b]	48 (±5)[de]	82 (±2)[bcde]
Dirgine	PA	94 (±2)[ab]	8.1 (±1)[a]	78 (±12)[a]	94 (±5)[ba]
Virginia-HA	PS	92 (±1)[abc]	5.7 (±0.4)[b]	50 (±5)[de]	87 (±4)[abcd]
Virginia-LA	PS	92 (±2)[abc]	5.8 (±0.4)[b]	57 (±5)[dc]	98 (±3)[a]
Germany	PA	92 (±3)[abc]	8.2 (±0.6)[a]	66 (±9)[bc]	78 (±6)[dce]
Tefen	PA	92 (±3)[abc]	8.3 (±0.7)[a]	81 (±10)[a]	94 (±4)[ab]
Ukraine	PS	89 (±3)[abc]	5.3 (±0.8)[b]	40 (±8)[e]	71 (±5)[e]
Virginia-MA	PS	88 (±4)[abc]	5.9 (±0.5)[b]	52 (±8)[d]	84 (±7)[bcd]
Kocaman	PA	77 (±6)[bc]	5.5 (±0.6)[b]	49 (±7)[de]	87 (±3)[abcd]
Michigan-1	PS	77 (±8)[bdc]	5.8 (±0.5)[b]	52 (±7)[d]	86 (±6)[abcd]
Çaykara	PA	74 (±4)[dc]	6.2 (±0.4)[b]	48 (±6)[de]	77 (±5)[de]
Michigan-2	PS	61 (±15)[d]	5.2 (±1.3)[b]	48 (±13)[de]	77 (±13)[de]
5 YAP					
Tefen	PA	73 (±5)[a]	15.3 (±1.1)[a]	110 (±7)[a]	73 (±4)[a]
Germany	PA	63 (±5)[abc]	12.6 (±1.4)[bcd]	90 (±11)[bc]	71 (±6)[a]
Dirgine	PA	73 (±6)[a]	13.5 (±1.0)[abc]	96 (±9)[ab]	72 (±4)[a]
Michigan-2	PS	64 (±7)[abc]	10.1 (±0.7)[de]	70 (±6)[de]	69 (±5)[a]
Yayla	PA	69 (±3)[ab]	14.4 (±0.7)[ab]	99 (±7)[ab]	69 (±5)[a]
Michigan-1	PS	51 (±8)[bcd]	9.8 (±1.3)[e]	90 (±8)[ab]	76 (±5)[a]
Hungary	PS	68 (±3)[abc]	10.0 (±1.5)[de]	64 (±7)[de]	67 (±5)[a]
Virginia-HA	PS	59 (±5)[abcd]	9.0 (±0.6)[e]	65 (±5)[de]	74 (±5)[a]
Virginia-MA	PS	56 (±7)[abcd]	10.7 (±1.6)[de]	77 (±9)[bcd]	77 (±5)[a]
Ukraine	PS	63 (±7)[abc]	9.0 (±1.2)[e]	58 (±7)e	68 (±5)[a]
Kocaman	PA	49 (±8)[dc]	11.6 (±1.1)[cde]	82 (±8)[bcd]	72(±5) [a]
Çaykara	PA	44 (±6)[d]	11.1 (±1.0)[cde]	80 (±8)[bcd]	73 (±5)[a]
Virginia-LA	PS	50 (±5)[dc]	9.7 (±0.8)[e]	66 (±5)[de]	69 (±4)[a]

[1] LE, Low elevation; ME, middle elevation; HE, high elevation. [2]PA, *P. avium*; PS, *P. serotina*.

Ukraine, Çaykara, Michigan-2 and the middle-elevation Virginia SS consisted of the group that exhibited the lowest height growth (Table 5).

The native WC SSs, Tefen, Dirgine and Yayla displayed an enhanced survival, groundline diameter and height growth than other SSs on the LES five years after planting (Table 5). The differences between them and the rest of the SSs were mostly significant for survival and the other growth variables. German WC SS exhibited an intermediate growth performance when compared to other SSs. The survival and growth performances of the remaning SSs including the native WC SSs Kocaman and Çaykara were the lowest. Unlike the first year results, the SSs did not show any significant differences from each other for the height to groundline diameter ratio five YAP (Table 5).

Less differentiation was found for SSs for seedling survival and growth on the HES (Table 6). The SSs had no substantial survival differences from each other five YAP (Table 6). BC SSs (Michigan 1 and Ukraine) showed enhanced growth performances on the HES when compared to their performances on the LES five years after planting. The successful SSs of the first-year results (Tefen and Dirgine) and German WC SS exhibited satisfactory growth performances five five years after planting, along with Michigan-1 and Ukraine for groundline diameter and height growth, respectively. Similar to the first-year results, the height-to- groundline diameter (gld) ratio of the SSs did not differ significantly five YAP. The poor performances of two native WC SSs (Kocaman and Çaykara) on both elevation sites were noteworthy (Tables 5 and 6).

This study confirmed the previous studies reporting that BC and WC exhibit substantial within-species variation for survival and growth (Walters, 1985; Curnel et al., 2003; Hemery et al., 2008). The two recent experiments

Table 6. Survival, groundline diameter (gld), height, and height/gld ratio of the seedlings of different seed sources of *Prunus avium* (PA) and *Prunus serotina* (PS) on the high-elevation sites in the Black Sea Region of turkey one (1 YAP) and five years after plantation (5 YAP).

Seed source[1]	Species[2]	Survival[3] (%)	Groundline diameter (mm)	Height (cm)	Height/ Groundline diameter
1 YAP					
Tefen	PA	73 (±10)[a]	6.2 (±0.7)[a]	64 (±11)[a]	100 (±8)[ab]
Hungary	PS	73 (±12)[a]	3.8 (±0.6)[dc]	34 (±6)[cde]	87 (±7)[bc]
Yayla	PA	68 (±10)[a]	5.9 (±0.6)[ab]	49 (±7)[abc]	84(±9) [bcd]
Dirgine	PA	68 (±11)[a]	5.9 (±1.0)[ab]	54 (±11)[ab]	89 (±8)[abc]
Virginia-LA	PS	67 (±11)[a]	4.3 (±0.7)[dc]	44 (±7)[bcd]	103 (±7)[a]
Virginia-HA	PS	67 (±3)[a]	4.0 (±0.6)[dc]	34 (±6)[cde]	88 (±9)[bc]
Virginia-MA	PS	60 (±12)[ab]	3.8 (±0.7)[dc]	33 (±9)[cde]	81 (±11)[cde]
Kocaman	PA	59 (±12)[ab]	3.4 (±0.6)[dc]	28 (±6)[de]	83 (±7)[dc]
Germany	PA	57 (±13)[ab]	4.9 (±1.1)[bc]	33 (±11)[cde]	66 (±12)[e]
Çaykara	PA	56 (±10)[ab]	4.3 (±0.7)[dc]	31 (±8)[de]	69 (±13)[de]
Michigan-2	PS	50(±12)[ab]	4.4 (±0.7)[dc]	36 (±7)[cde]	82 (±10)[cde]
Ukraine	PS	50 (±14)[ab]	4.5 (±1.0)[dc]	31 (±8)[de]	69 (±8)[de]
Michigan-1	PS	36 (±12)[b]	3.3 (±0.8)[d]	24 (±7)[e]	70 (±9)[de]
5 YAP					
Tefen	PA	53 (±12)[a]	12.0 (±1.4)[ab]	96 (±13)[ab]	81 (±5)[a]
Germany	PA	45 (±15) [a]	13.9 (±4.8)[ab]	97 (±48)[ab]	66 (±12)[a]
Dirgine	PA	40 (±1 0)[a]	13.5 (±2)[ab]	104 (±16)[ab]	77 (±5)[a]
Michigan-2	PS	42 (±13)[a]	10.7 (±1.3)[b]	79 (±12)[abc]	73 (±6)[a]
Yayla	PA	35 (±9)[a]	11.0 (±1.5)[b]	88 (±11)[abc]	82 (±6)[a]
Michigan-1	PS	54 (±6)[a]	18.8 (±6.8)[a]	105 (±9)[ab]	85 (±20)[a]
Hungary	PS	32 (±4)[a]	11.0 (±2.1)[b]	77 (±14)[abc]	72 (±4)[a]
Virginia-HA	PS	40 (±14)[a]	7.4 (±1.7)[b]	53 (±16)[c]	65 (±9)[a]
Virginia-MA	PS	42 (±11)[a]	9.9 (±1.8)[b]	64 (±11)[abc]	67 (±5)[a]
Ukraine	PS	33 (±5)[a]	13.7 (±1.2)[ab]	106 (±10)[a]	79 (±7)[a]
Kocaman	PA	35 (±8)[a]	11.1 (±1.5)[b]	92 (±20)[abc]	80 (±10)[a]
Çaykara	PA	38 (±10)[a]	10.0 (±1.8)[b]	69 (±17)[abc]	65 (±11)[a]
Virginia-LA	PS	27 (±4)[a]	7.3 (±1.3)[b]	63 (±15)[bc]	80 (±7)[a]

[1] LE, Low elevation; ME, middle elevation; HE, high elevation. [2]PA: *P. avium*; PS, *P. serotina*.

using some of the same cherry SSs of this study also reported a substantial within-species variation for seed germination behavior for both cherry species (Eşen et al., 2006, 2007). Also, SSs had significant effects on the seed germination, diameter and height growth of Iranian WC seedlings in another recent study (Mollashahi et al., 2009).

The differential growth performances of the BC and WC SSs between the LES and HES confirmed that these hardwood species are very selective of site conditions (Walters, 1985; Curnel et al., 2003). Planting the seedlings of local origins often achieve significantly greater seedling survival and growth performance than the non-native seedlings in forest trees (Wright, 1976; Ürgenç, 1985). In a BC study, local SSs achieved an enhanced tree survival and growth than non-native SSs in North-western Pennsylvania in the US 14 YAP (Walter, 1985). Similarly, this study indicates that choosing local WC SSs including Tefen, Yayla and Dirgine for planting on the LES is vital for success in the western Black Sea Region. On the other hand, a wider collection of SSs including the non-native SSs of BC and WC including Michigan 1, Ukraine and Germany along with the local SSs (Dirgine and Tefen) is suitable for the HES.

In conclusion, both black and wild cherry displayed substantial within-species variations for survival and growth. The growth performances of the seedlings of various seed sources vary across different planting sites. Seedlings of local seed sources of wild cherry are recommended for planting for both low and especially high-elevation sites in the Black Sea Region. The seedlings of some of the black cherry seed sources showed enhanced growth performances in this study. However, their susceptibility to diebacks and forking and the lack of data on their long-term survival and growth performances in the region prevent making a robust recommendation for planting with black cherry seed sources in the region.

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