

Growth performance of wild cherry (*Prunus avium* L.) clones in planted forests under different managements in Galicia, NW Spain

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Abstract

Wild cherry (*Prunus avium* L.) is one of the main valuable temperate broadleaved species from Europe considering the market appreciation of their timber. In the present study we analyzed the growth performance of different wild cherry clones under different management treatments. A field trial was settled in Bosques Naturales S.A. "Sendelle" forests (Arzúa, Galicia, NW Spain) with a multifactorial design to analyze the effect of clones (4 clones), pruning intensity (33 % and 50 % of total height) and fertilization (3 treatments). It was monitored for 8 years. Clone was found out to be the most important variable in this study while tree growth was neither significantly affected by the pruning intensity nor the fertilization treatments. Clone selection is highlighted as a key issue in wild cherry commercial planted forests for timber production and the selected C-15 clone shows an excellent field performance compared to other clones based on the trial and the literature, reaching a DBH of 14 cm after eight years.

Keywords: clone; clonal forestry; forest plantations; valuable broadleaved; *Prunus avium*; wild cherry

Introduction

Wild cherry (*Prunus avium* L.) is one of the main valuable temperate broadleaved species from Europe (Cisneros 2004, Spiecker et al. 2009, Coello et al. 2013). The interest in wild cherry as a forest species has increased since 1980s-1990s and many

intensively managed commercial planted forests have been established through Europe since then, especially in former agricultural land (Pryor 1988, Cisneros 2004, Spiecker et al. 2009), even though it is a species susceptible to several pests and diseases (e.g., Coello et al. 2013). These new timber-oriented plantations are different to the agricultural plantations of cherry trees (oriented to fruit production) and they are also different to the traditional role of cherry trees in the forest sector, which was usually managed in mixed stands in natural forests (Ducci & Santi 1997, Cisneros 2004, Spiecker et al. 2009). This increased interest in wild cherry for timber production was driven, in addition to subsidies for former agricultural land reforestation (e.g., EEC Regulation 2080/92), by the quality of the timber and its high appreciation from the market (Pryor 1988, Cisneros 2004). Cherry wood has been traditionally one of the most appreciated for the market and consequently high timber prices were expected (Cisneros 2004, Coello et al. 2013). However, market demand is determined by fashion and it fluctuates with time; consequently, there are periods when the market demands and the prices are lower than in others (Pryor 1988, Luppold & Bumgardner 2007, AITIM 2015) and thus the forest managers may take this into consideration.

Several research programs were conducted in Europe to improve the timber quality and production of *Prunus avium* (Pryor 1988, Ducci & Santi 1997, Kobliha 2002, Nocetti et al. 2010, Ducci et al. 2013). In Spain, a long-term breeding program for this species was started in the 90's by the Lourizán Forest Research Center (in Galicia, NW Spain) (Díaz et al. 2007, Fernández-Cruz et al. 2014) and a clonal selection was performed by the company Bosques Naturales S.A. As a consequence of this clonal selection, the company Bosques Naturales S. A.

has 4 clones registered in the Spanish National Catalogue of Qualified Forest Reproductive Material: Eurocherry A-01, Eurocherry B-15, Eurocherry C9 and Eurocherry G (MAPAMA 2017a).

Different silvicultural approaches have been tested for wild cherry planted forests, including the usual single-species plantations and other systems such as mixed plantations and silvopastoral systems (e.g., Chiffot et al. 2006, Coello et al. 2013, Loewe et al. 2013, Ferreiro-Domínguez et al. 2016). In addition, some research has been done regarding pruning intensity (Kupka 2007, Springmann et al. 2011) and soil and water management (Molina et al. 2016). However, more research is needed in order to improve silvicultural management in such valuable broadleaved species in order to maximize timber production both in quantity and quality. Hence, the present study analyzes a field trial in the Bosques Naturales S. A. "Sendelle" planted forests (in Galicia, NW Spain) with the objective to evaluate the best fertilization scheme and the best pruning intensity to maximize wild cherry timber production, taking into account the effect of different clones.

Materials and Methods

Study area

The study was established in the "Sendelle" planted forests, from the company Bosques Naturales S.A. in Galicia, NW Spain (Lat. 42.993°, Long. -8.156°, WGS 84, EPSG: 4326). The study site was located at an altitude of 430-450 m asl over an area which was previously an eucalyptus (*Eucalyptus nitens* H. Deane & Maiden) planted forest. The climate is considered Atlantic, with long periods of rainfall during the winter and a short dry period in summer (July-September); even though once around each 5 years, a longer summer dry period used to occur. The average total annual precipitation is 1400 mm and the mean annual temperature is 12 °C (MAPAMA 2017b). Yearly rainfall along the eight-year study period (from 2007/2008 to 2015/2016) was: 1012 mm, 888 mm, 1972 mm, 1234 mm, 699 mm, 1515 mm, 1932 mm, 1311 mm, 1917 mm. Meteorological data was obtained from the Boimorto meteorological station [X 81094, Y 4777420, UTM 29N, EPSG: 32629] (MAPAMA 2017c). The soils of the study area are generally acidic and rich in organic matter, classified as *Humic Dystrudepts* or *Umbrisols*, although they have drainage problems in some areas. More details of the physicochemical soil properties of 2 soil pits in the "Sendelle" area can be observed in Table 1. Tree density was 5 x 6 m (333 trees ha⁻¹). Mechanized mowing was done periodically for weed control. No herbicides were applied.

Experimental design and field measures

A multifactorial design was settled to analyze the effect of 4 clones, pruning intensity (33 % and 50 % of the total height) and fertilization (3 treatments variable through time as it is further explained) on the growth of *Prunus avium* selected for timber production (i.e. no associated cherries production). Table 2 summarizes the details of the different treatments established in the 24 plots (of 10 trees each).

The 4 cherry tree clones are: C-15, C-1, C-9 and C-G (Garri-gosa); all of them were selected by Bosques Naturales S.A. and are registered in the Spanish National Catalogue of Qualified Forest Reproductive Material (MAPAMA 2017a). The two pruning treatments were 33 % or 50 % of the total height of the trees. The 3 fertilization treatments varied through time as detailed in Table 3. In 2008 (at establishment) there was no difference among treatments and the dosage was 450 g tree⁻¹ of 0-14-18-3(Mg) and 450 g tree⁻¹ of 9-12-24 and 135 g tree⁻¹ of Mg sulfate. Similarly, in 2011 there was no difference among treatments and the dosage was 100 kg ha⁻¹ of granulated dolomite [58(Ca)-35(Mg)] and 200 kg ha⁻¹ of 14-7-12-2(Mg)-20(S). No fertilizer was applied in 2014 in any of the trial treatments. The fertilization in 2012, 2013, 2015 and 2016 was variable, as it is detailed in Table 3.

A total of 176 trees were planted divided in a total of 24 plots, without taking into account the outer trees of each plot as a border effect. The trees' DBH were measured every year from February 2008 (establishment time) to 2016. DBH was the chosen variable analyzed in the present study to evaluate tree growth because it is the main variable considered by the company on a daily basis. The average total tree height in 2014 (i.e. 6-year-old trees) was 7.1 m, with a 10 % variation coefficient. Height was not considered in the analysis because total tree height is not used in the plantation management. This is explained as the final merchantable timber volume is fixed by the height of bole without branches, which is similar for all the trees of the plantation since it is conditioned by the pruning management rather than the total tree height.

Statistical analysis

A Linear Model (LMs) was adjusted to analyze the effect on the DBH in 2016 (eight-year-old trees) of the three treatments described above and their interactions: (1) Clones (4 levels), (2) fertilization treatments (3 levels) and (3) pruning intensity (2 levels). Mixed models were also adjusted using the plot as random effect but it did not improve the models so it was finally not taken into account. An analysis of the residuals of the model was conducted to ensure the hypothesis of the LMs. As the explanatory variables of the models were categorical, the adjusted LMs were afterwards analyzed as ANOVAs of multiple factors. All the analyses were performed using R (R Core Team 2017). All statistical tests are considered significant throughout the text with $\alpha = 0.10$.

Results

A lack of effect of the pruning intensity was observed (p -value=0.49) over the DBH in 2016 (8-year-old trees) (Figure 1). The model fitted with the clones and the fertilization treatments as explanatory variables showed a significant effect (p -value<0.01 for both of them) over the DBH in 2016 (8-year-old trees) and also of the interaction between them

Table 1

Soil attributes from the 2 soil pits in the "Sendelle" wild cherry (*Prunus avium* L.) planted forest from the company Bosques Naturales S.A. in Arzúa region (Galicia, NW Spain)

Soil attribute	Soil pit #1			Soil pit #2		
	0-20 cm	40-60 cm	60-150 cm	0-20 cm	40-60 cm	60-150 cm
Clay (%)	0.94	1.44	1.66	1.44	1.73	1.44
Sand (%)	44.02	51.87	33.87	49.94	38.5	47.66
Silt (%)	55.04	46.69	64.47	48.82	59.77	50.9
pH	4.99	4.96	4.91	5.5	4.7	4.99
EC (mmhos cm ⁻¹)	0.09	0.06	0.03	0.13	0.04	0.02
OM (%)	4.62	2.51	0.3	3.51	0.76	0.31
Carbonates (%)	0	0	0	0	0	0
N (%)	0.546	0.215	0.049	0.335	0.118	0.049
P (mg kg ⁻¹)	24	22	22	18	12	8
K (meq 100 g ⁻¹)	0.15	0.08	0.06	0.12	0.04	0.04
Ca (meq 100 g ⁻¹)	0.75	0.26	0.33	5.12	0.33	0.39
Mg (meq 100 g ⁻¹)	0.24	0.17	0.35	0.62	0.16	0.15
Na (meq 100 g ⁻¹)	0.27	0.24	0.29	0.26	0.24	0.23
Fe (mg kg ⁻¹)	21.4	30	9.7	21.1	14.1	11.1
Cu (mg kg ⁻¹)	0.3	0.4	0.2	0.5	0.3	0.1
Mn (mg kg ⁻¹)	75.9	141	28.8	58.6	15.5	6.7
Zn (mg kg ⁻¹)	0.1	0.1	0.4	0.1	0.2	0.1
B (mg kg ⁻¹)	0.1	0.04	0.05	0.14	0.04	0.02
Cl (mg kg ⁻¹)	8.12	3.12	24.7	7.59	19.7	23.9
CEC (meq 100 g ⁻¹)	1.41	0.75	1.03	6.12	0.77	0.81
C:N ratio	4.92	6.79	3.56	6.09	3.74	3.68
Ca:Mg ratio	3.13	1.53	0.94	8.26	2.06	2.6
K:Mg ratio	0.63	0.47	0.17	0.19	0.25	0.27

Table 2

Trial design established in the "Sendelle" wild cherry (*Prunus avium* L.) planted forest from the company Bosques Naturales S.A. in Arzúa region (Galicia, NW Spain). Tree density was 333 trees ha⁻¹ in all cases (i.e. 5 x 6 m spacing), resulting in 10 trees per plot. Details about the fertilization treatments are summarized in Table 3.

Clon	Fertilization treatment	Pruning intensity	Treatment code
C-15	F-1	33%	C-15/F-1/33
		50%	C-15/ F-1/50
	F-2	33%	C-15/F-2/33
		50%	C-15/F-2/50
	F-3	33%	C-15/F-3/33
		50%	C-15/F-3/50
C-1	F-1	33%	C-1/F-1/33
		50%	C-1/F-1/50
	F-2	33%	C-1/F-2/33
		50%	C-1/F-2/50
	F-3	33%	C-1/F-3/33
		50%	C-1/F-3/50
C-9	F-1	33%	C-9/F-1/33
		50%	C-9/F-1/50
	F-2	33%	C-9/F-2/33
		50%	C-9/F-2/50
	F-3	33%	C-9/F-3/33
		50%	C-9/F-3/50
C-G	F-1	33%	C-G/F-1/33
		50%	C-G/F-1/50
	F-2	33%	C-G/F-2/33
		50%	C-G/F-2/50
	F-3	33%	C-G/F-3/33
		50%	C-G/F-3/50

Table 3

Details about the fertilization treatments applied in the research trial established in the "Sendelle" wild cherry (*Prunus avium* L.) planted forest from the company Bosques Naturales S.A. in Arzúa region (Galicia, NW Spain). In 2008 there was no difference between treatments and the treatment was 450 g tree⁻¹ of 0-14-18-3(Mg) and 450 g tree⁻¹ of 9-12-24 and 135 g tree⁻¹ of Mg sulfate. Similarly, in 2011 there was no difference between treatments and the treatment was 100 kg ha⁻¹ of granulated dolomite [58(Ca)-35(Mg)] and 200 kg ha⁻¹ of 14-7-12-2(Mg)-20(S). No fertilizer was applied in 2014 in any of the trial treatments.

Year	Treatment	Product	Dosage (kg ha ⁻¹)	Composition (%)						
				N	P2O5	K2O	CaO	MgO	SO3	
2012	F-1	Fertilizer	300		10	25	22			
		Fertilizer	300	20	7	7				
		Fertilizer	31.8					17	32	
	F-2	Fertilizer	200		10	25	22			
		Fertilizer	200	20	7	7				
		Fertilizer	31.8					17	32	
	F-3	Fertilizer	100		10	25	22			
		Fertilizer	100	20	7	7				
		Fertilizer	31.8					17	32	
	2013	F-1	Dolomite	1000				50	23	
			Fertilizer	100		10	25	22		
		F-2	Dolomite	2000				50	23	
Fertilizer			200		10	25	22			
F-3		Dolomite	3000				50	23		
		Fertilizer	300		10	25	22			
2015	F-1	Dolomite	1000				33	18		
		Fertilizer	400		10	10	20	2	1.5	
	F-2	Dolomite	1000				33	18		
		Fertilizer	---							
	F-3	Dolomite	---							
		Fertilizer	---							
2016	F-1	Dolomite	1000				33	18		
		Fertilizer	400		10	10	20	2	1.5	
	F-2	Dolomite	1000				33	18		
		Fertilizer	---							
	F-3	Dolomite	---							
		Fertilizer	---							

(p-value<0.01), with a relatively high model fitness (R^2 adjusted=0.81).

Clone was the most important explanatory variable, being C-15 the one with highest DBH, reaching 14 cm for 8-year-old trees while the other clones have 10 cm (C-1) and 9 cm (C-9 and C-G) (Figure 1). Regarding the effect of the fertilization treatments, even though it is statistically significant, it is not significant in practical terms because the average DBH of the three treatments is very similar (around 10 cm) (Figure 1), being the F-3 treatment DBH slightly bigger than F-2 (Figure 1). The analysis of the interactions between clone and fertilization effects (Figure 1) shows how F-2 treatment is worse than F-1 and F-3 for C-15 and how F-3 seems the best treatment for C-1 (Figure 1).

Figure 2 shows the effect of clones and fertilization treatment on DBH in each year between 2008 and 2016. There is no noticeable effect on DBH during the first two years of the plantation (2008-2009) and the difference between C-15 and the other clones is getting bigger since 2010 - 2011 (Figure 2).

Discussion

Effect of pruning intensity

Pruning is considered as a mandatory operation in order to achieve high quality woods in commercial planted forests (e.g., Coello et al. 2013). However, a DBH growth reduction has been observed after pruning in wild cherry plantations and low or moderate pruning intensities are recommended in order to minimize this growth loss (Kupka 2007, Springmann et al. 2011). However, the results of the present study do not show a relevant effect of the pruning intensity (Figure 1).

Effect of clones

Wild cherry diameter growth in this study was higher than the reported by other authors: an average DBH of 14 cm in an 8-year-old plantation (considering the best treatments of the study - C-15 -) (Figure 1) compared with a DBH ranging between 3-10 cm in other studies where plantation age ranges between 6 and 11-year-old (e.g., Chiffot et al. 2006, Springmann et al. 2011, Loewe et al. 2013). These growth rates reported in literature are relatively similar to the other clones of this

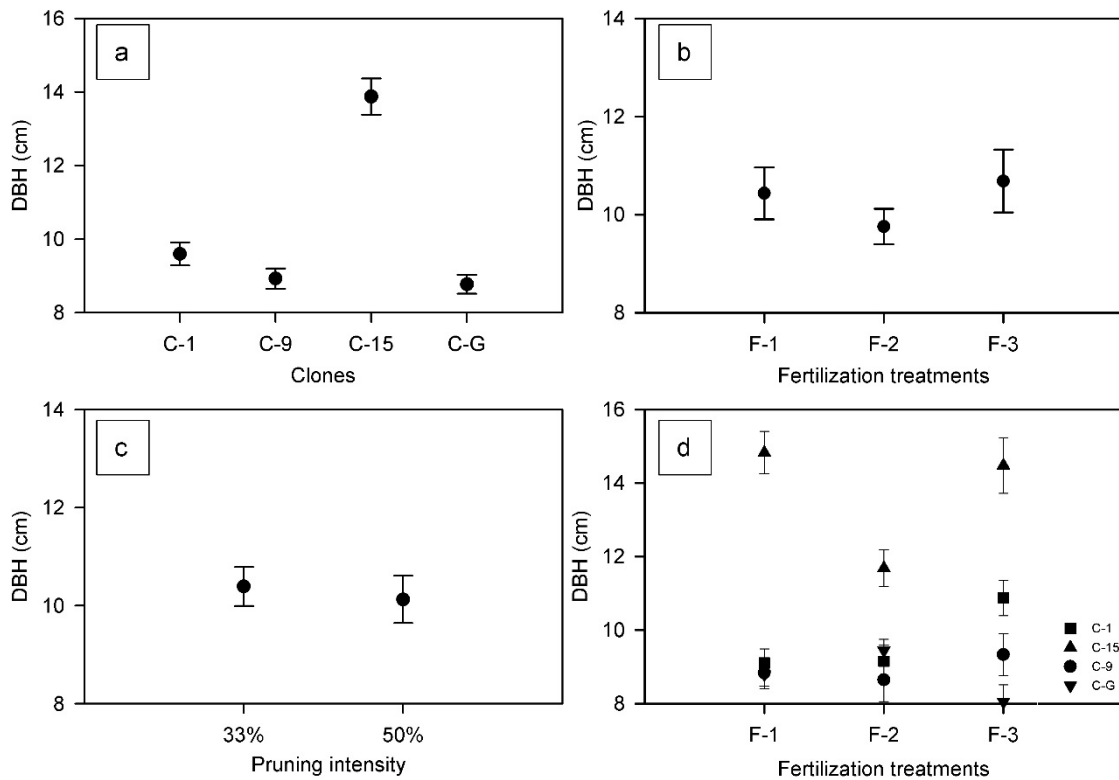


Figure 1

Effect of clones (a), fertilization treatments (b) pruning intensity (c) and interaction between clones and fertilization treatments (d) on the DBH in the 8-years-old trial established in the “Sendelle” wild cherry (*Prunus avium* L.) planted forest from the company Bosques Naturales S.A. in Arzúa region (Galicia, NW Spain). Data corresponds with measurements in 2016 and the trial was established in 2008. Error bars show the Confidence Interval at 90 % confidence level.

study: 10 cm for C-1 and 9 cm for C-9 and C-G (Figure 1). Indeed, the rotation period considered by other authors are between 40-50 and 70 years in order to achieve logs with merchantable sizes (DBH > 40-45 cm) (e.g., Cisneros 2004, Spiecker et al. 2009, Coello et al. 2013), while the rotation period considered by Bosques Naturales S.A is between 25-30 years.

The wild cherry plantation performance was mostly determined by clones, being the C-15 the best performing clone from the studied ones (Figures 1 and 2). Clonal forestry has been long recognized as a key factor for the success in commercial planted forests (e.g., Ahuja & Libby 1993, West 2006) and the present study shows the importance of a good clonal selection in order to improve forest productivity. Considering the fast growth of the Bosques Naturales wild cherry in Galicia compared with other data published by other authors (as it has been previously discussed) and taking into account the relatively good site conditions (especially abundant rainfall and moderately good soil properties in spite of the poor chemical fertility), the C-15 clone might be considered by any other potentially interested forest managers for the establishment of wild cherry plantations in other places. However, wild cherry is a species highly susceptible to several pests and diseases (e.g., Coello et al. 2013) and this should be considered as a negative issue before establishing a new plantation.

Effect of fertilization treatments

Even though fertilization had a significant statistical effect on wild cherry growth, the observed difference between the established treatments in 8-year-old trees is so small that it does not seem relevant for the management of the plantations (Figures 1 and 2). Consequently, it can be concluded that the fertilization costs should be minimized in the treatments applied in order to optimize the plantation management.

Even though the fertilization treatments varied through the trial development, F-1 is generally the one with highest nutrient input (N-P-K) while F-2 is the one with highest dolomite input (Ca-Mg) and F-3 is the “poorest” treatment (Table 3). Considering the initial low soil fertility (Table 1), a bigger fertilization effect was expected. However, the lack of a clear response to fertilization (Figures 1 and 2) is explained by: (1) the application of amendments and fertilizers before the trial was installed, (2) the lack of a clear control (without fertilization) in the trial design (Tables 2 and 3).

The big amount of fertilizer and dolomite applied in 2008 and 2011 (at establishment and when the trees were three years old) might be enough to fulfill the relatively low requirements of the planted trees in these first years (Morhart et al. 2016) and, consequently, all the fertilizers applied in the trial treatments was “luxury consumption”. In accordance with this lack of response due to luxury consumption, Wojcik & Wojcik

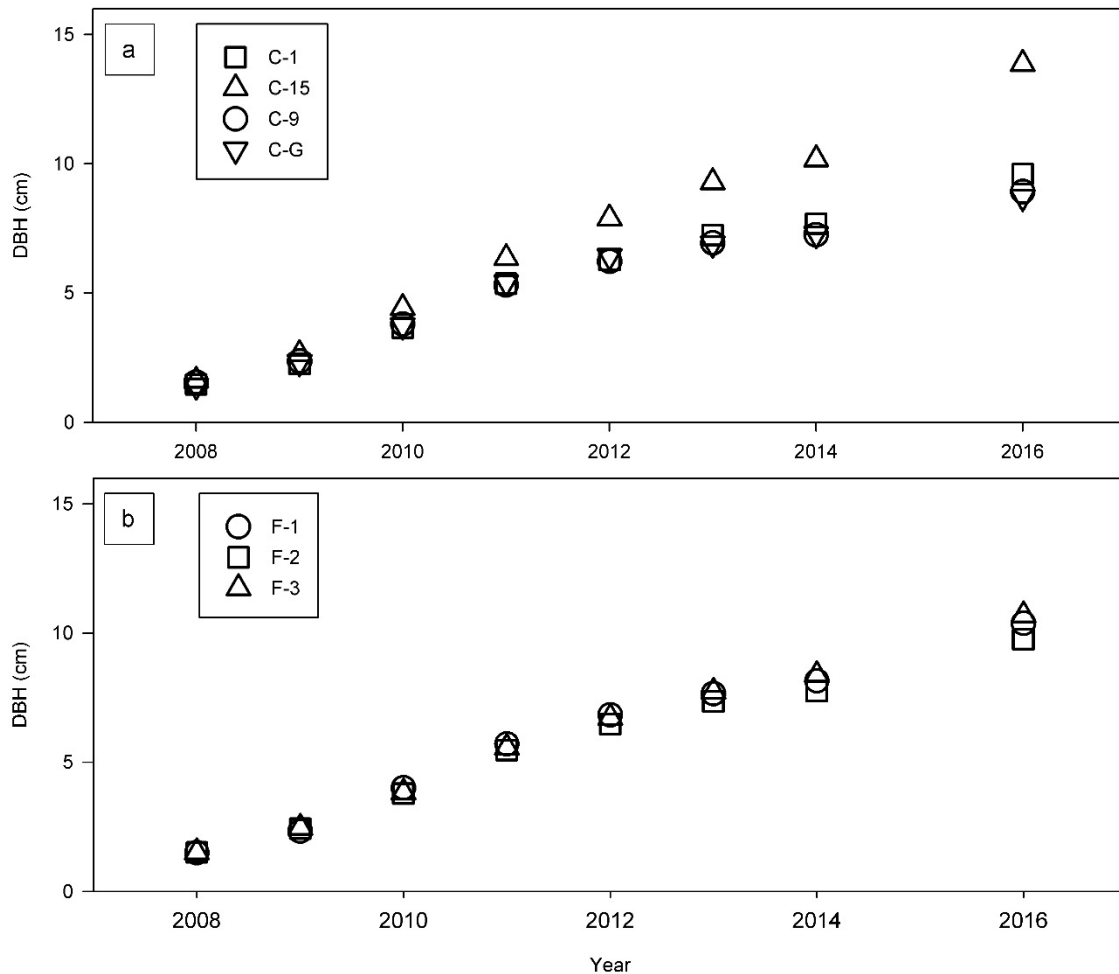


Figure 2

Yearly effect of clones (a) and fertilization treatments (b) on the DBH in the trial established in the "Sendelle" wild cherry (*Prunus avium* L.) planted forest from the company Bosques Naturales S.A. in Arzúa region (Galicia, NW Spain)

(2007) did not find any effect on vigor and yield of sweet cherry trees in a fertilization trial with Boron despite an increased concentration of this microelement in flower and leaf tissues.

Several additional factors should be taken into consideration regarding the low differences in the growth response to fertilization treatments given that, if the nutrient status of the stand is not the limiting factor, no fertilization effect is likely to be observed. For example, tree density might be limiting the tree response to fertilization (e.g., Binkley 1986, Fernández-Moya et al. 2017), among other possible issues such as pests and diseases. In addition, the selection of the fertilizer is another factor affecting the fertilization response. The application of N-P-K alone or combined with liming may be insufficient to address the nutrient deficit, since other nutrients such as Zn may be limiting tree growth as low values of available Zn are observed in the results of the soil analyses from the site (Table 1).

Conclusions

Clone selection has a very important effect on wild cherry (*Prunus avium* L.) growth. The selected C-15 clone (registered in the in the Spanish National Catalogue of Qualified Forest Reproductive Material) show a much higher growth than the other three clones and the growth rates published by other authors. Tree growth was neither significantly affected by the pruning intensity nor the fertilization treatments. However, due to the experimental design of the trial, it is impossible to conclude that there is no effect of fertilization in the trial. It is only possible to estimate that a fertilization regimen based on the application of the minimum dosage within the tested would be as good for the tree growth as the one with maximum application, minimizing the fertilization costs (both economic and environmental) without risking the forest productivity.

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