Study on growth and sprouts of Oak Forest for Forest fire site in South Korea

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Abstract: The objective of this study was to investigate the growing characteristics of oak species (*Quercus variabilis, Quercus serrata, Quercus acutissima, Quercus mongolica*). The data was retrieved from the province of Chungnam Yeasn where it was once devastated by fire in 2003. Stump diameter (cm) of the oak species and the number of sprouts found in the study areas ranged between 7.58~12.92 and 5.12~10.94 respectively. *Q. acutissima* was found having the highest Diameter Breast Height (DBH) (3.64cm) and *Q. serrata* and *Q. mogolica* showed the lowest (2.48cm). Within the oak species mentioned in this study, *Q. serrate* and *Q. variabilis* were found to have high number of sprouts with an average height of 2.45m and 3.23m respectively whereas *Q. acutissima* showed the lowest sprout occurrence but with the highest stump diameter growth rate. This results indicates that both DBH and height growth rate are highly dependent on the abundance level of sprout. Therefore, research into the relationship between sprout occurrence rate and characteristics of growth rate in each species can potentially provide essential information for the management of oak species after fires.
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1. Introduction

There are numerous factors that can alter forests in various ways. Amongst these factors are fires. Forests are extremely vulnerable to fire and can affect not only the physical surroundings, but also the growth rate (Cho 2000). The impact of forest fire has been increased rapidly over the past few decades, resulting in fires being responsible for approximately 1 % of forest area loss globally (Reference about FAO report rather than Lee et al. 2012). Therefore, it is of importance to investigate regeneration and growth characteristics after fire, especially when each oak species has different patterns for regeneration after such destructive event (Lim et al. 2009).

In recent years, oak species have become an important source of wood chips, bed logs and charcoal in the forestry industry (Lee 2007). Its popularity is due to its high hardness and density and residual time of fire lasting longer than other species such as coniferous species (Aguilar et al. 2012). High demand on oaks creates more significance and importance to undertake various studies to investigate sprouting capacity of each oak species.

Productivity of oak forests where fire has occurred can be estimated based on the growth rate of sprouts in the stump roots that contain the largest variation (Kim et al. 1991) as well as investigate if any oak species exhibit faster growth rate in sprout forests compared to seedling forests (Blake 1983). This information can be used to aid the production of small-diameter oak timber as its popularity is mainly due to its strong resistance property against various damages (David 1986).

Moreover, in response to the insufficient research on sprout forests in Korea, Studies about Management System of Oak Coppice Forest on Forest Fire Site (Lim et al. 2009), Coppice Regeneration of Oak Stands (Kwon et al. 1998), Sprout growth of *Quercus acutissima* after forest fires(Lee et al. 2007), Structure of coppice forest in Quercus aliena(Kim et al. 1982) and structure of secondary coppice(Kim et al. 1995) were conducted

These studies were intended to examine how to manage oak forests and the best method for producing small-diameter timber based on the analysis of sprout generation, DBH, and height in oak species found in forest fire sites.

2. Material and Methods

2.1. Study area

The study areas are located in southwest of Korea, including Seochojeong-ri, Sinyang-myeon, Yesan-gun and Chungcheongnam-do. These locations are 75m above sea level with 15° slope. Four different oak species (*Q. variabilis*, *Q. serrata*, *Q. acutissima* and *Q. mogolica*) were found in the sprout forests of these locations. Based on meteorological data collected over 30 years in this study area, annual mean temperature and precipitation were found to be 11.5℃ and 1,228.9mm respectively (Meteorological Administration 2013).

2.2. Methods

This study examined the growth of sprouts in the southern aspect of the study area that was struck by fire in 2003. The growth data was measured in February 2008, 5 years after the fire when sprout growth ceased. The size of a particular sampling plot in this southern aspect area was 40m x 40m along a ridge and the diameter of the stumps in the plot was measured. In order to analyze the growing characteristics of the sprouts of four oak species, a number of sprouts on stumps in a sample area, including the DBH and heights of sprouts were measured. DBH was measured precisely down to 1/100mm scale using a digital caliper while the height was measured down to 1cm scale using an object staff. The growing characteristics of sprouts were compared and analyzed by species through the variance analysis that depended on the stump diameter and Duncan's multiple range test within 5% significance level using survey data and a statistical program (SAS 2004).

3. Results and Discussion

3.1. Sprout growth in forest fire site

There were a total of 121 stumps in the site consisting of 30 *Q. variabilis* stumps, 31 *Q. serrata* stumps, 32 *Q. acutissima* stumps, and 28 *Q. mogolica* stumps. The stumps had a total of 739 sprouts including 185 *Q. variabilis* sprouts, 196 *Q. serrata* sprouts, 105 *Q. acutissima* sprouts, and 232 *Q. mogolica* sprouts. Sprouts appeared irregular, even though they were more abundant in the upper centre and side regions of the stump.

The average stump diameter was 12.92cm for *Q variabilis*, 7.58cm for *Q. serrata*, 11.77cm for *Q. acutissima*, and 10.56cm for *Q. mogolica*, and the average sprout diameter was 5.23cm for *Q variabilis*, 3.16cm for *Q. serrata*, 4.98cm for *Q. acutissima*, and 3.82cm for *Q. mogolica* (Table 1). The average number of sprouting was 8, 8, 5, and 11 for *Q variabilis*, *Q. serrata*, *Q. acutissima*, and *Q. mogolica* respectively (Fig. 1). According to previous studies conducted by (Lee 2007), *Q. serrata*, *Q. acutissima*, and *Q variabilis* presented with the largest number of sprouting during the first year post fire however, showed some decline due to natural competition. In contrast to previous studies, this investigation has revealed that the number sprouts did not decline in the site 5 years post forest fire, and is even suggesting that the growing stocks in the area need to be controlled.

Table 1. The oak species characteristics of the study site

Species	Trees	Sprout	Stump diameter (cm)	Ground diameter (cm)
Q. variabilis	30	185	12.92 (5.86)	5.23 (2.66)
Q. serrata	31	196	7.58 (4.12)	3.16 (2.08)
Q. acutissima	32	105	11.77 (6.50)	4.98 (2.95)
Q. mongolica	28	232	10.56 (4.85)	3.82 (2.04)

Mean : Standard deviation

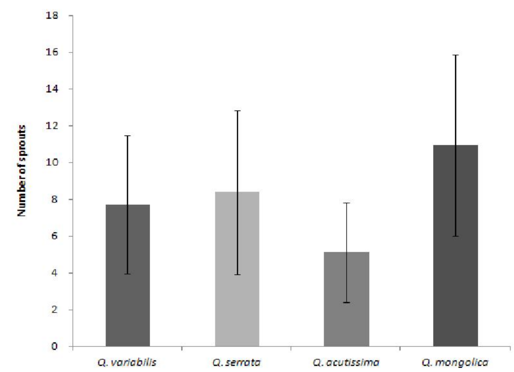

Figure 1. The oak species of number of sprouts

3.2. Sprout generation rate by stump diameter class

Sprout generation is analyzed based on stump diameter of each species by classifying the diameter by a 5cm scale. This study revealed that the number of sprouts were likely to increases when diameter class for *Q. variabilis* was higher and decreased when diameter class was between 21~30cm. Furthermore, sprout numbers also increase when diameter classes were lower for *Q. serrata* and decreased when diameter class was between 16~20cm. Also, reduced number of sprouts were noticed when diameter class increased for *Q. acutissima* while sprout numbers rose when diameter class was between 21~30cm. Moreover, *Q. mogolica* did not show a specific tendency in relation to the class (Fig. 2).

Although Kim et al. (1991) found that the occurrence of sprouts generally declined with higher diameter class for *Q. acutissima, Q. variabilis,* and *Q. mogolica,* our study indicated differently. However our study did have similar findings to that of Sato et al. (1996) on the relationship between the number of sprout occurrence and stump diameter. Similarly, this study also showed that the number of sprouting of *Q. serrata* has little correlation of 0.1932 with stump diameter.

Unlike the study conducted (Kim et al. 1984), *Q. acutissima* and *Q. acutissima* revealed high sprout generation rate when stump diameter was 15cm and declined with a 25~30cm diameter class, whereas, according to (Lee 1997) the *Q. acutissima* in the exhibited site differently suggested that high number of sprouting could be found when the class was 21~30cm.

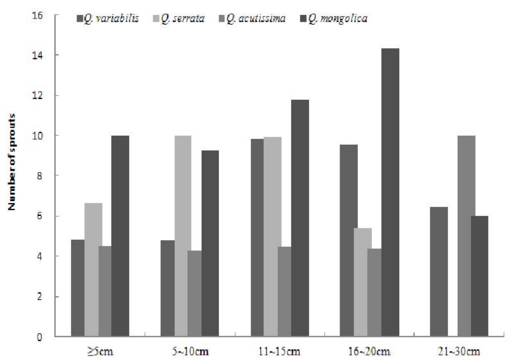

Figure 2. The number of sprouts oak species analyzed after 5 treatments and stump diameter class.

3.3. Growth rate of DBH of sprout in forest fire site

The average DBH of sprouts in the forest fire site was 3.23cm, 2.48cm, 3.64cm and 2.48cm for *Q variabilis*, *Q. serrata*, *Q. acutissima*, *Q. mogolica* respectively (Fig. 3). The DBH of *Q. acutissima* appeared to be taller than other species, while the number of sprouts in the stump of *Q. acutissima* was limited. Sprout abundance appear to directly influence sprout growth, in that fewer sprout count equates to a relatively taller DBH. In comparison with the study conducted by Kim et al. (1991), artificial inducement promote the growth of sprouts while the species with small number of sprouts exhibited better diameter growth due to natural competition instead of induction. According to the average DBH growth of sprouts per stump diameter, variance analysis, and Duncan's multiple range test (Table 2), *Q variabilis* showed 2.29cm difference when the stump diameter was 5cm whereas there was no difference when stump diameter was 5cm or greater. Overall F-values for *Q variabilis* and *Q serrate* were 0.1255 and 0.2161 respectively indicating that there is no significant difference of average value in each sampling plot. *Q. acutissima* also did not show difference in DBH of sprouts (F-value: 0.7798). *Q. mogolica* showed similar values between when diameter is 5cm or smaller and when diameter is within 10~15cm; however, a clear difference was discovered by class (F-value: 0.0001).

Categorization by class did not show significance of difference on DBH growth of sprouts in relation to stump diameter, which imposes that the class of the stump diameter needs to be set in a wider scale in future studies as this study was limited in young growing stock areas. However, the four species considered in this study did show to have higher DBH when diameter class increased

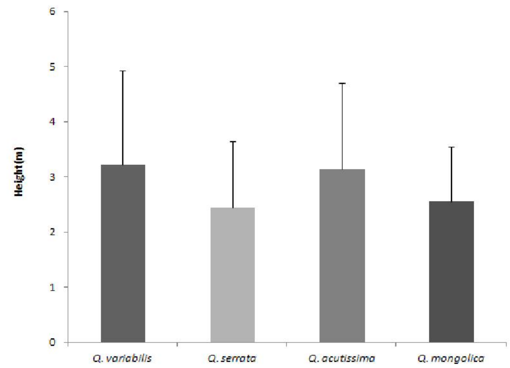

Figure 3. The diameter of breast height growth characteristics of sprouts in oak species.

Table 2. The diameter of breast height growth of sprouts oak species analysed after 5 treatments and stump diameter class.

Stump diameter class	*Q. variabilis*	*Q. serrata*	*Q. acutissima*	*Q. mongolica*
≥5cm	2.29 b	1.84 a	3.17 a	1.68 c
5~10	3.37 a	2.70 a	3.70 a	2.42 cb
11~15	3.31 a	3.11 a	3.37 a	2.23 c
16~20	3.34 a	2.67 a	4.15 a	3.15 ba
21~30	3.52 a		3.55 a	3.92 a
ANOVA F-value	0.1255	0.2161	0.7798	0.0001

3.4. Height growth of sprouts in forest fire site

The average height of sprouts in the forest fire site measured to be 3.23m, 2.45m, 3.14m and 2.55m for *Q variabilis*, *Q. serrata*, *Q. acutissima* and *Q. mogolica* respectively (Fig. 4). *Q variabilis* showed the best height growth followed by *Q. acutissima*. This result showed some similarity to that of a study conducted by (Cho, 2000) on a forest fire site in Goseong where *Q variabilis* showed the highest growth rate and where the best height growth was found when 8~10 sprouts on average grew competitively. *Q. acutissima* also exhibited higher diameter growth with smaller number of sprout occurrence, however, less growth for height growth may occur when there is strong competition within the sprouts. Moreover, *Q variabilis*, *Q. acutissima*, and *Q. mogolica* showed 70% or higher suitability for height growth tendency when related to the stump diameter of each species (Fig. 5~8).

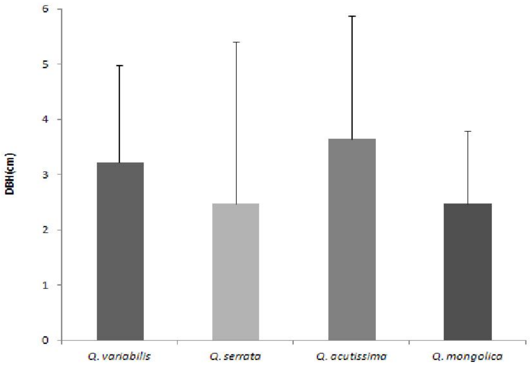

Figure 4. The height growth characteristics of sprouts in oak species.

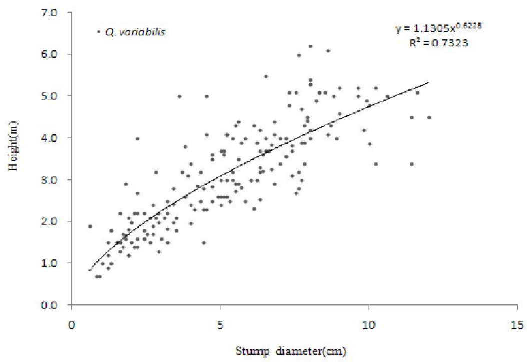

Figure 5. Height growth of *Q. variabilis* coppice after fire in Yesan.

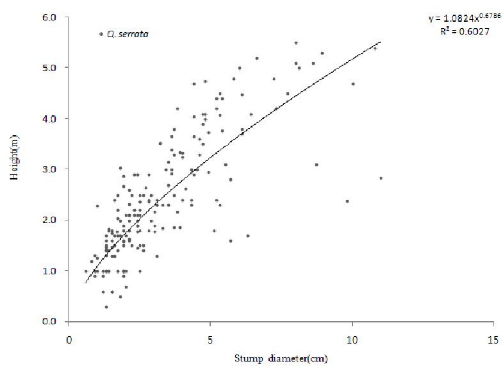

Figure 6. Height growth of *Q. serrata* coppice after fire in Yesan.

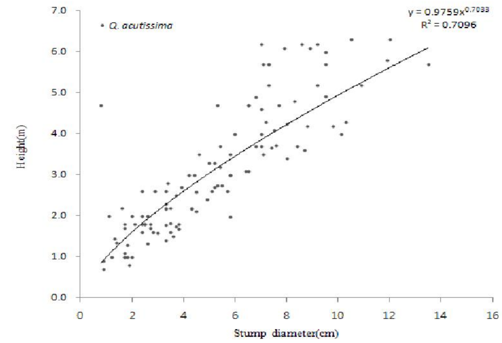

Figure 7. Height growth of *Q. acutissima* coppice after fire in Yesan.

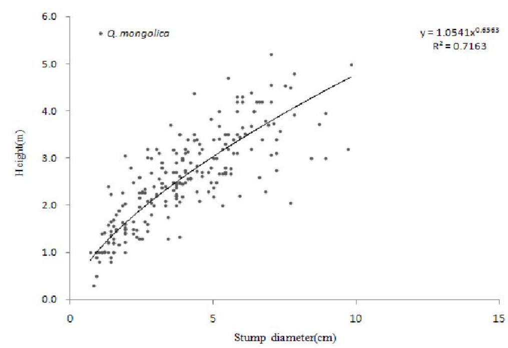

Figure 8. Height growth of *Q. mongolica* coppice after fire in Yesan.

Never the less, according to the measurement of average height growth of sprouts by stump diameter in comparison between the four species using the variance analysis, and Duncan's multiple range test (Table 3), *Q. serrata* and *Q. mogolica* did show clear differences in height growth by diameter class (F-value: 0.0001) and *Q variabilis* also showed difference (F-value: 0.0099). In contrast, *Q. acutissima* did not show difference (F-value: 0.2329) and the height increased with the class. *Q variabilis*, *Q. serrate*. However, *Q. mogolica* did show significant difference in height growth based on diameter class with huge variations, suggesting that the difference by class was larger than DBH. Therefore, based on this study, height can be best measured using stump diameter and this method should be considered for future studies as well.

Table 3. The height growth of sprouts oak species analysed after 5 treatments and stump diameter class.

Stump diameter class	*Q. variabilis*	*Q. serrata*	*Q. acutissima*	*Q. mongolica*
≥5cm	2.32 b	2.18 b	2.45 b	4.68 c
5~10	3.29 a	2.31 b	3.17 ba	2.42 b
11~15	3.61 a	3.33 a	2.95 ba	2.65 ba
16~20	2.91 ba	2.58 b	3.38 ba	3.12 a
21~30	3.73 a		3.70 a	3.13 a
ANOVA F-value	0.0099	0.0001	0.2329	0.0001

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