A Study on Fire Characteristic of Cork Oaks for Forest Fire Identification in Korea

PARK, Young-Ju
Dept. of Fire & Emergency Management, Kangwon National University | Laboratory of Forest Resources Management, Division of Forest Environmental Sciences, Department of Agro-Environmental Sciences, Faculty of Agriculture, Kyushu University

LEE, Si-Young
Professional Graduate School of Disaster Prevention, Kangwon National University | Laboratory of Forest Resources Management, Division of Forest Environmental Sciences, Department of Agro-Environmental Sciences, Faculty of Agriculture, Kyushu University

OHGA, Shoji
Laboratory of Forest Resources Management, Division of Forest Environmental Sciences, Department of Agro-Environmental Sciences, Faculty of Agriculture, Kyushu University

https://doi.org/10.5109/1955392

出版情報：九州大学大学院農学研究院紀要. 63 (2), pp.259-264, 2018-09-01. 九州大学大学院農学研究院
バージョン：
権利関係：

J. Fac. Agr., Kyushu Univ., **63** (2), 259–264 (2018)

A Study on Fire Characteristic of Cork Oaks for Forest Fire Identification in Korea

Young–Ju PARK[1], Si–Young LEE[2]* and Shoji OHGA

Laboratory of Forest Resources Management, Division of Forest Environmental Sciences, Department of Agro–Environmental Sciences, Faculty of Agriculture, Kyushu University, Fukuoka 811–2415, Japan

(*Received May 1, 2018 and accepted May 8, 2018*)

This study conducted an analysis of fire load of forest fuels to predict forest fire intensity and forest fire behavior. Fifth–grade cork oaks were selected for analyzing fire load. After measuring amounts of biomass, total weight found 428.9 kg, branch parts was 57.93 wt.%, and weight percentage was 42.07 wt.%. Branch parts (248.4 kg) emitted heats as 324,390.0 MJ/m^2 and stem parts (180.4 kg) generated heats as 2,720,432.2 MJ/m^2 based on the assumption that burning efficiency sets to 100%, branch parts emitted 1.84 times higher heat amounts than stem parts and total heat release of cork oaks turned out 596,433.2 MJ/m^2. For total smoke release, branch parts emitted 1.36 times more smoke than stem parts and total smoke release was reported to emit 1,044,128.6 m^2/m^2. In addition, total carbon dioxide release of fifth–age class cork oaks was 865.3 kg and total emissions of carbon monoxide found 39.7 kg.

Key words: Cork oaks, Forest fire identification, Biomass, Carbon monoxide, Carbon dioxide, Cone calorimeter, Ignition temperature

INTRODUCTION

Countries actively conduct research and development by quantifying absorption and emission of Carbon dioxide(CO_2) and Non–carbon dioxide(non CO_2) generated by forest disturbance including forest fire and forest degradation not to be economically retarded after the Kyoto Protocol was released. In response to this global trend, the Ministry of Forest in South Korea released forest comprehensive measures for responding to the climate change and research on the establishment of forest carbon emission right transaction basis in Green Trading and management of Post–2012 forest absorption resources and launch Certificated Emissions Reduction for forestation business are underway(Korea 2008 ; IPPC 2003).

However, basic research to estimate and evaluate carbon dioxide and non carbon dioxide directly emitted by forest fire in quantitatively and scientifically has not been carried out. Korean territory is calculated as 100,033 km^2 and forests accounts for nearly 63.67% reaching 63,688.43 km^2 (Korea 2011). Due to geographical conditions, forest fire frequently occurs. In average, 478 fires have occurred over the past decade from 2001 to 2010(Korea 2011;Yim K. G 2007). Therefore, practical quantitative measures of carbon emission are needed from performing a burning experiment applied with Korean forest plants in order to estimate greenhouse gas emissions caused by forest fire(KOREA 2008).

Fire intensity of forest fire and forest fire behavior risk system marks four artificial forest fire index that helps fire control activity plans and dangerous routes by providing fire occurrence index by lighting, burning index, and burning quantity index (Lee S. Y., 2004). Furthermore, BEHAV program developed to predict the burning risk of surface fire fuel and forest fire spread defined fire intensity as generated heat release per unit area (Btu/ft^2) and presents how to quantify it. To predict these risk in case of forest fire, an investigations should be conducted to analyze forest fire–related factors including plants, geography and climate, accumulate basic documents through indoor and outdoor experiments, and establish the scientific and systematic forest fire management (Lee *et al.*, 2001). Forest territories in South Korea are estimated to 6,368,643 ha and broad–leaved trees accounts for nearly 27% amounting to 1718916 ha (Korea 2011). In general, broad–leaved trees are excellent for fire–resistance than needle–shaped trees. Vulnerability to forest fire or strong difference is caused by ignition temperature of leaves(Kang *et al.*, 2002).

Therefore, this study aims to measure amounts of biomass among cork oak, which is the representative oak tree in Korea among broad–leaved trees and analyze fire load of species needed for predict forest fire intensity and forest fire behavior by performing burning experiment. Moreover, it aims to estimate amounts of carbon emission from each tree in case of forest fire by measuring actual amounts of carbon emission.

RESEARCH CONTENT AND METHOD

1. Experiment and selecting of fuels

A burning experiment to analyze fire load used the cone calorimeter (ISO 2002) and Ignition Temperature tester (Hong *et al.*, 1992). Cork oak was selected for fuel known as fire resist species. fifth–age class (41–50–year–old) trees were pricked in Samcheok, Gangwon–do

[1] Dept. of Fire & Emergency Management, Kangwon National University, Samcheok–Si, Gangwon–Do 245–711, Republic of Korea

[2] Professional Graduate School of Disaster Prevention, Kangwon National University, Samcheok–Si, Gangwon–Do 245–711, Republic of Korea

* Corresponding Author (E–mail:lsy925@kangwon.ac.kr)

where forest fire frequently occurs in accordance with grade (first to fifth–age class). Trees were collected in April the following day after five sunny days. Original fuels were adopted to apply identical fuel forms and conditions in case of forest fire. Specific experimental conditions are presented in Table 1 and 2.

2. Analysis of amounts of biomass

Conducting burning experiment, biomass amounts of cork oaks were measured and weights of branch and stem parts as crown fire and subject fuels were drawn through steps presented in Fig. 1. The climate in Korea is characterized by cold and dry weather in winter and intensive rainfall in summer that features the temperate monsoon region. cork oak is a broad–leaved tree that falls leaves during winter in a temperate region. Thus, green leaves were excluded from the measurement of biomass amounts. Results of biomass amounts by parts were applied in an analysis of carbon emission and mean values from three experiments were used.

Table 1. Experimental conditions of cone calorimeter

Items	Contents
Size (mm)	100 × 100
Weight (g)	50
Heat flux (kW/m^2)	50
Test time (s)	Time until there was no more weight decrease
Material condition	Raw

Table 2. Experimental conditions of ignition temperature

Items	Contents
Model	KRS–RG–9000
Method of measurement	Group type
Weight (mg)	20
Condition of material	Raw
Waiting time of Ignition (s)	4

3. Measurement of the percentage of moisture content

The measurement of green moisture contents of fuels followed ASTM D 2016 (American Society for Testing and Material) [5] and weight was measured by quantifying 200 g, drying them on a drier with 105°C until no weight variation was identified every four hour. Mean values from three measurements were used.

4. Analysis of fire characteristics

An analysis of fire load applied outcomes from total heat release of cork oaks. Before analyzing total heat release, it measured total biomass amounts of cork oaks. Fire load was drawn by applying total heat release outcomes obtained from the experiment on total biomass amounts. Moreover, this study analyzed the characteristics of ignition at the beginning of burning as well as vulnerability caused by smoke release since release heats vary according to the characteristics of ignition at the beginning of burning while burning.

5. Analysis of carbon emission amounts

We used the Cone Calorimeter to conduct an analysis of carbon emission amounts (Lee *et al.*, 2001). Specific experimental conditions are presented in Table 1 and the experiment ended when weight variation is no longer identified. Results were used as mean value obtained from three experiments. Based on the assumption that burning efficiency is 100%, carbon dioxide and carbon monoxide emissions on 50 g weight by parts were analyzed and total emissions of carbon dioxide and carbon monoxide on biomass amounts of cork oaks were drawn by applying biomass amounts.

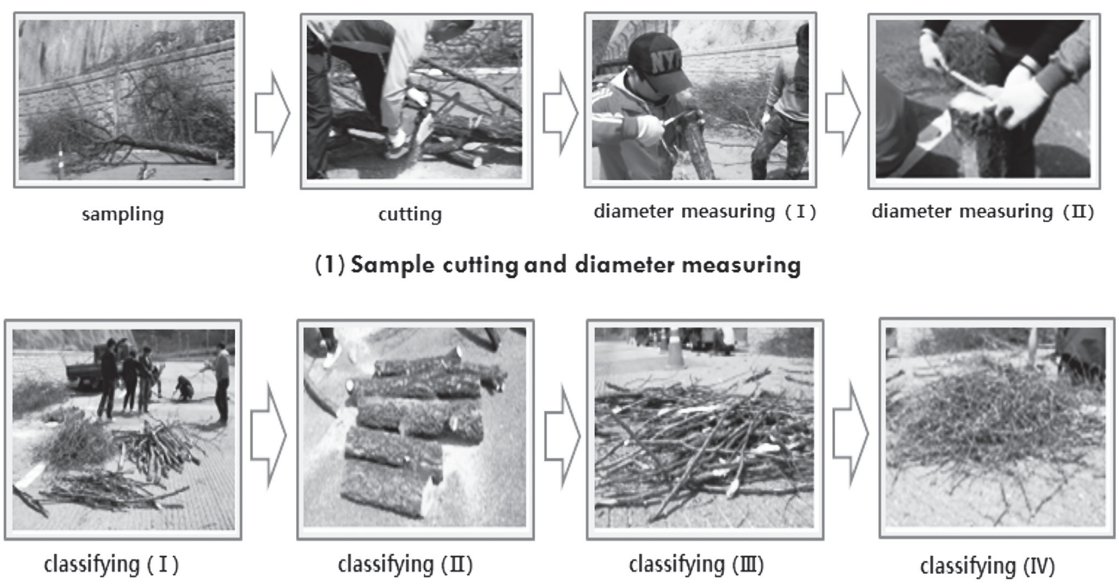

Fig. 1. Measurement of biomass amounts of cork oaks.

RESULTS AND DISCUSSION

1. Characteristics of the percentage of moisture content

Percentages of moisture contents in branch and stem parts were presented in Table 3. The percentage of moisture content in April when forest fire frequently occurs ranged between 42.62% and 49.84%, the result showed that the difference by parts was not significant.

2. Characteristics of Biomass Amounts

Biomass amounts by parts are shown in Figure 2. Mean diameter 1.78 cm was 38.70 kg, weight ratio turned out 9.03 wt.%, and 2.42 cm turned out 85.20 kg. Weight ratio was found 19.87 wt.%, 5.64 cm was 124.50 kg, and weight ratio was estimated as 29.03 wt.%. In short, branch parts turned out 248.40 kg with 57.93 wt.%. Stem parts was 180.4 kg and weight ratio turned out 42.07 wt.%. Weight ratio of Branch parts therefore showed 8% higher than branch parts. Table 4 shows quantitative values.

3. Characteristics of carbon emission amounts

Regarding emission amounts of carbon dioxide, branch parts emitted 489.90 kg and branch parts emitted 375.37 kg. For emissions of carbon monoxide, branch parts generated 2.20 kg and stem parts emitted 17.46 kg. Therefore, this result found that branch parts emitted 1.7 times more carbons than stem parts. Total carbon dioxide emissions by cork oak species turned out 865.28 kg and carbon monoxide emissions found 39.68 kg. Specific information is shown in Table 5.

4. Characteristics of ignition

The characteristics of ignition by parts of cork oaks are shown in Table 6. Ignition temperature by parts ranged between 490℃ and 550℃ that showed the temperature difference. Observing ignition time, branch parts showed 24 seconds, which was the fastest; whereas, 1.78 cm twigs in average showed 175 seconds, which was the longest flaming ignition time. Faster flaming ignition proceeded in stem parts due to relatively low percentage of moisture contents and flaming ignition temperature. Ignition risk is assumed to be relatively higher than branch parts in case of forest fire. However, thick branches with 5.64 cm in average were flamed at 664 seconds after igniting at 86 seconds, which lasted relatively longer for burning. Twigs were flamed at 592 seconds after igniting at 175 seconds, which continued burning for 417 seconds and showed relatively shorter burning time. Therefore, it was revealed that ignition risk at the beginning of burning in stem parts is relatively higher

Table 3. Percentage of Moisture Contents by Parts of Cork Oaks

Cork oaks		Percentage of moisture contents(%)
Branch	Diameter Less than 2.10 cm (Mean diameter 1.78 cm)	49.84
	Diameter 2.10~4.00 cm (Mean diameter 2.42 cm)	46.45
	Diameter 4.10~8.00 cm (Mean diameter 5.64 cm)	42.62
Stem	Diameter over 8.00 cm (Mean diameter 17.30 cm)	45.96

Table 4. Analysis of Biomass Amounts by Parts of Cork Oaks

Mean diameter by parts(cm)		Weight (kg)	Weight ratio (%)
Branch	1.78	38.70	9.03
	2.42	85.20	19.87
	5.64	124.50	29.03
Stem	17.30	180.40	42.07
Total weight		428.80	100.00

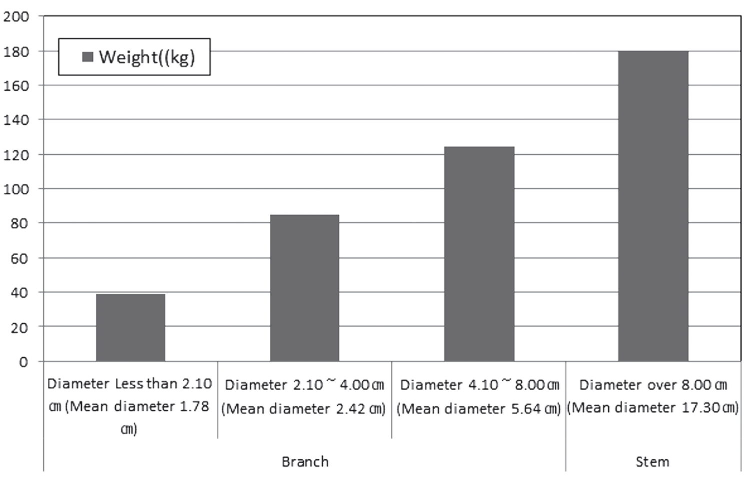

Fig. 2. Biomass amounts by parts of Cork oaks.

Table 5. Analysis of Carbon Emissions of Cork oaks

Mean diameter by parts (cm)		Weight (kg)		CO (kg)	CO_2 (kg)
Branch	1.78	Burning weight	0.05	0.04	0.96
		Biomass amounts	38.70	3.10	74.42
	2.42	Burning weight	0.05	0.05	0.98
		Biomass amounts	85.20	8.26	166.91
	5.64	Burning weight	0.05	0.04	0.10
		Biomass amounts	124.50	10.87	248.59
Stem	17.30	Burning weight	0.05	0.05	0.10
		Biomass amounts	180.40	17.46	375.37
Biomass amounts		Total biomass amounts	428.80	39.68	865.28

Table 6. Characteristics of Ignition by Part of Cork Oaks

Cork oak		Percentage of moisture contents (%)	Ignition temperature (°C)	Ignition time (sec)	Anti–inflammation time (sec)
Branch	Twig(Average diameter 1.78 cm)	49.84	549	175	592
	Medium–sized branch(Average diameter 2.42 cm)	46.45	496	78	540
	Thick branch(Average diameter 5.64 cm)	42.62	498	86	664
Stem (Average diameter 17.30 cm)		45.96	513	24	477

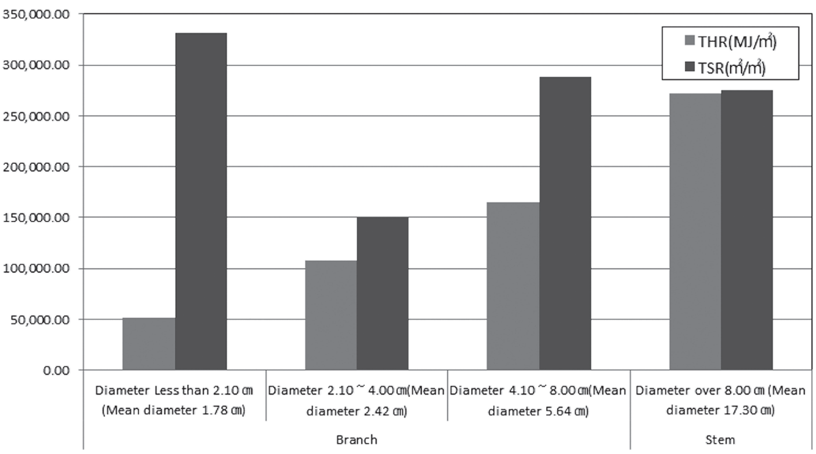

Fig. 3. Characteristics of THR and TSR of Biomass amounts by parts of Cork oaks.

than stem parts. Although early forest fire risk is low as medium–sized branches and thick branches continued burning for longer periods, those branches were more vulnerable to fire when forest fire broke out.

5. Characteristics of fire load

Figure 3 shows results from total heat release by parts from biomass amounts of cork oaks and total heat releases from species. Regarding total heat release by parts, branch parts with 1.76 cm in average was 38.7 kg and emitted 51,780.6 MJ/m^2 heats. Medium–sized branches with 2.42 cm in average turned out 85.2 kg and emitted 107,522.4 MJ/m^2 heats. Thick branches with 5.64 cm in average showed 124.5 kg and emitted 165,087.0 MJ/m^2 heats. Therefore, branch parts with 48.4 kg biomass amounts emitted 324,390.0 MJ/m^2 heats based on the assumption of 100% emission. Furthermore, 180.4 kg stem parts generated 2,720,432.2 MJ/m^2 heats. Stem

Table 7. Analysis of Heating Value by Cork Oaks Parts

Cork oak		Weight (kg)		Total heating value(MJ/m^2)	Total smoke value (m^2/m^2)
Branch	Twig(Mean diameter 1.76 cm)	Burning weight	0.05	66.9	427.5
		Biomass amounts	38.7	51,780.6	330,885.0
	Medium-sized branch(Mean diameter 2.42 cm)	Burning weight	0.05	63.1	87.8
		Biomass amounts	85.2	107,522.4	149,611.2
	Thick(Mean diameter 5.64 cm)	Burning weight	50	66.3	115.8
		Biomass amounts	124.5	165,087.0	288,342.0
Stem (Mean diameter 17.30 cm)		Burning weight	50	75.4	76.3
		Biomass amounts	180.4	272,043.2	275,290.4
Sum		Total biomass amounts	428,800	596,433.2	1,044,128.6

parts emitted 1.84 times more heats than branch parts and total heat release of cork oaks turned out 596,433.2 MJ/m^2. Quantitative values are shown in Table 7. Heat release by branch parts corresponded with fire continuing time and stem parts showed highest heat releases in spite of shorter fire continuing time than thick branches. This difference is assumed to be derived from different biomass amounts and burning size. Therefore, stem parts seem to show higher fire loads due to relatively higher ignition risk and heat releases than branch parts when forest fire occurs.

6. Fire vulnerability

Amounts of smoke emission by parts of cork oaks were shown in Table 4. Observing smoke release by parts, branch parts emitted 768,838.2 m^2/m^2 smoke and stem parts emitted 275,290.4 m^2/m^2 smoke. It indicated that branch parts generated 1.36 times more smokes than stem parts. Total smoke release of cork oaks emitted 1,044,128.6 m^2/m^2 smokes. Twigs that emitted relatively more total smoke releases were assumed to be influenced by incomplete burning and crown fire is assumed to be vulnerable when forest fire breaks out.

CONCLUSION

1. Regarding the characteristics of moisture content, cork oaks in April when forest fire frequently occurs were found to contain water ranging between 42.62% and 49.84%. In addition, branch parts of total amounts of biomass was 248.40 kg, accounting for 57.93 wt.%. As stem parts turned out 180.4 kg and weight ratio was identified as 42.07 wt.%, branch parts showed 8% higher of weight ratio than stem parts.

2. Igniting temperature of cork oaks ranged between 490°C and 550°C. Stem parts are likely to be fired at the beginning of burning than stem parts. As medium–sized branch and thick branch showed longer burning after ignition, early forest fire risk is low, yet more vulnerable to fire when forest fire continues.

3. In regard to the characteristics of fire load, branch parts of 248.4 kg biomass emitted 324,390.0 MJ/m^2 heats and stem parts of 180.4 kg biomass emitted 2,720,432.2 MJ/m^2 heats. This indicated that branch parts emitted 1.84 times more heats than stem parts. On top of that, it was revealed that cork oaks emitted 596,433.2 MJ/m^2 heats.

4. Observing the characteristics of smoke releases, branch parts emitted 768,838.2 m^2/m^2 smoke and stem parts generated 275,290.4 m^2/m^2 smoke. This demonstrates that branch parts generate 1.36 times more smoke than stem parts. Total smoke release of oaks was found to emit 1,044,128.6 m^2/m^2 smoke.

5. In regard to carbon dioxide emissions of cork oaks, branch parts emitted 489.90 kg and stem parts released 375.37 kg carbon dioxide. In addition, branch parts emitted 2.20 kg and stem parts emitted 17.46 kg of carbon monoxide. This showed that total release of carbon dioxide by species turned out 865.28 kg and that of carbon monoxide found 39.68 kg.

AUTHOR CONTRIBUTIONS

Y. J. PARK designed the research, experimental design and experimental supervision were conducted for experimental study. S. Y. LEE wrote an English paper, experimental supervision was carried out. and S. OHGA designed the study, supervised the research. All authors assisted in editing the manuscript and approved the final version.

ACKNOWLEDGEMENTS

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education(No. 2016R1D1A1B02008374).

REFERENCES

Hong, Y. M. and G. S. Jung, “Safety Engineering Experiment”, Donghwa Technology, pp. 9–11, (1992)

IPCC, “National Greenhouse Gas Inventories Programme”, Good Practice Guidance for Land, (2003)

ISO 5660–1, Reaction to fire part 1, rate of heat release from building products (Cone Calorimeter), (2002)

Kang J. Y, S. W. Kim, Y. C. Kim, J. G. Kim, J. S. Kim, S, C. Park, Y. G. Park, S. W. Lee, S. Y. Lee, Y. S. Lee, C. H. Lee, H. H. Lee, S. B. Jeong and J. G. Hyeon, Studies on Forest Environment Preservation, Hyangmunsa: Seoul, pp. 34–58, (2002)

Korea Forest Service, Forest Basic Statistics in 2010, pp. 1–48, (2011)

KOREA Forest Service, Forest Comprehensive Measures in Response to Climate Change: Practices by Fields, (2008).

Korea Forest Service, Recent Trend in Forest Fire Occurrence: 2001–2010, Use, Land–Use Change and Forestry, http://fire.forest.go.kr /main/index.asp. (Accessed on 2011).

Lee B. D, and J. S. Jeong, H. H. Kim, S. Y. Lee, An Analysis of Forest Fire Spreading Speed in Samcheok Forest Firest in 2006 by GIS Application, Journal of The Korean Forestry Society, Vol. 90, No. 6, pp. 781–787, (2001)

Lee S. Y, Forest Fire Preventive System in Foreign Countries, Special Cover in Preventing Forest Fires by Korea Forest Research Institute, Vol. 6, No. 4, pp. 25–33, (2004).

Yim K. G., “Forestation Theory”, Hyangmoonsa, pp. 120–174, (2007).