Turkish Journal of Computer and Mathematics Education Vol.12 No.13 (2021), 6032-6039

Research Article

Effects of Calorific Value of Pine Wilt Infected Trees on the Spread of Wildfire

Hyuk, Kwon [a], Ha Sung, Kong [b]

[a] Graduate student, Dept. of Fire Protection and Disaster Prevention, Woosuk Univ
[b] Associate professor, Dept. of Fire and Disaster Prevention, Woosuk Univ. Korea, 119wsu@naver.com(Corrseponding Author[b])

Abstract: This study was aimed to analyze the effects of pine wilt infected trees on the spread of wildfire measuring water content and calorific value by piling up terms of infected trees. The test results are as follows. First, little difference of water content was found by piling up terms among 5 samples of pine wilt infected trees over 4 years and less than 5 years, showing 19.8% of mean value with not more than 8% of deviation, which is about one sixth compared to the water content of domestic live pine trees 115%. Second, calorific value of pine wilt infected trees showed the mean value of 4860kcal/kg ranging from 4680kcal/kg at the samples over 3 years and less than 4 years up to 5340kcal/kg at the samples over 1 year and less than 2 years, reflecting beyond the mean value of general pine trees. Lastly, with respect to the effects of calorific value of pine wilt infected trees on the spread of wildfire, the factors to affect the spread of large-scale fire were sufficient oxygen, infected piled trees which are inflammables, colonies of pine trees, strong wind, pine resin, and so on, regardless of piling up terms.

Keywords: Pine wilt, infected tree, wildfire, water content, calorific value, piling up terms

1. Introduction

Pine wilt which was discovered at the first time at Kumjung mountain in Busan in 1988 found in Japan, China, Taiwan, Korea, Portugal, and Spain.[1] It is a serious pest especially for pine trees, hence, the government enacted the special act for pest control of pine wilt disease in May 2005.[2] In Korea, pine trees infected by pine wilt disease were cut down and its spread was prevented by pest control and vinyl covering, however, the damaged area has been expanded every year to be spread to 9 metropolitan cities and provinces, 55 cities, counties, and gus in February 2007, and to Jeju, Youngju and Gyungju in North Gyungsang province, and Seoul in 2014. Green Korea United, an environment movement organization, claimed the prospect in January 2015 that pine trees would be extinct within 3 years if the present spread rate was sustained.[3] Prior studies related to pine wilt disease to date focused on the defenses and responses to keep the pine trees and slow down the spread rate of pint wilt disease by pest control, mothproofing, and so on.

Neglected piled infected trees that were cut down to prevent infection and covered by vinyl for fumigation process can be a spread factor in case of large-scale wildfire, which makes difficulty in firefighting.[4][5]

This study was aimed to prevent the disaster by spread of large-scale wildfire by combustion test analysis of calorific value from water content by piling up terms of infected trees.

With respect to the prior studies related to pine wilt disease**, Jung YJ (2002)[6]** studied the characteristics of pine wilt disease damages, spread status such as infection routes, spread factors, and pest control standards; **An SH et al (2011)[7]** classified the characteristics by transverse section and radial section for infected pine trees by pine wilt disease and compared with normal trees by naked eyes and microscopy. **Youn SR et al (2009)[8]** reviewed the utilization potential of damaged trees after precipitation and fumigation tests as the timber so as to provide the basic data on the utilization of damaged trees as a forest resource. **Lee SY (2007)[9]** studied the effects of thinning-out trees which are the outcomes of forest development project on wildfire, and **Kim DH et al (1999)[10]** revealed the resistance of pine trees against the heat was lower than oriental oaks upon the analysis results of calorific test with pine trees and oak trees in their study on wildfire investigation in Gosung and calorific analysis of main trees. **Park YJ et al (2011**)[11] suggested the vulnerability of combustion products from the analysis of carbon emission by wildfire in the subjects of inflammables in the forest, and **Lee SY et al (2006**)[12] reviewed the characteristics of combustion causing large-scale wildfire and risk of fire spread to the adjacent areas upon generation of turbulent air due to high temperature and irregular geography, drastic change of fire advancement direction, and spotting fire up to several kilometers. **Park WH et al (2018)[13]** investigated the spread status of newly infected trees and changes of the least distance to the infected trees from the previous year based on the forecasting data of newly infected trees from 2008 to 2015 conducted by Gyunggi-do Forest Environment Research Center. **Kim JW (2005)[14]** studied the distribution of pine trees in Korea, problems, pine trees and wildfire, choice of species, and so on.

Jung YJ (2002)[15] reviewed the status of pine tree damages and their spread. **Park HS (2019)[16]** developed the equipment to contribute to the prevention of wildfire using disposable IoT technology currently undergoing, and studied to develop the scenario to prevent the damages of humans and properties, and to use the firefighting resources efficiently. **Lee SY (2006)[17]** analyzed the characteristics of wildfire and damage trend in Korea using the statistical data of the Korea Forest Service over the recent 14 years.

Also, **Kim YG (2019)[18]** reviewed the status of air firefighting system to cope with large-scale wildfire. **Lee SY et al (2009)[19]** proposed 11 models of water scattering technique from helicopters to maximize the safety and efficiency of firefighting wildfire.

Lee BD et al (2009)[20] analyzed the slope direction of ignition spots, spread direction, and wind direction in 101 fire forests occurred in the springs from 2007 to 2009. **Song JC (2000)[21]** studied the prevention as the basic measure of safety in the research of fire causes. **Lee SY (1998)[22]** researched the case comparisons on the recent status of fire forests in the world. **Bae TH et al (2010)[23]** proposed the shape of fire line for air firefighting of 13 wildfires and the methods of firefighting based on the experiences of air firefighting.

Nonetheless, there is no study on the effects of calorific value of pine wilt infected trees remained in the forest after fumigation on the spread of large-scale wildfire, while there are a variety of studies on the prevention of pine wilt disease spread and pest control for pine wilt disease, and a study that the cause of large-scale fire spread was the wildfire ignited by the highly inflammable pine tree colony which shared 63% out of needleleaf tree colonies, 70% of forests in Baekdudaegan Mountain Range, due to the local gales by Yanganjipoong and Yangangjipoong in East Sea.[24-26]

Hence, the purposes of this study are to compare the characteristics between infected pine trees with pine wilt disease and non-infected trees, and to prevent the spread of large-scale forests upon testing the differences of calorific value by water content of infected trees by their piling up terms, and analyzing the effects of infected trees containing 20% of lipid components in the resin of pine trees on the spread of wildfire. [27]

2. Thermodynamic properties of forest byproducts

2.1 Handling methods of infected trees

According to the Korea Forestry Promotion Institute, handling methods of pine trees infected by pine wilt disease are fumigation, crushing, incineration, burying, peeling, shielding with net, and so on. Fumigation method, which is the most commonly used, is cutting down the infected or suspicious trees, piling up them with the size of 1-2 m^3, putting the chemicals such as dimethyl disulfide that were proven efficacy to kill the larvae of pests such as pine wilt and Japanese pine sawyer, its intermediary insect, and then sealing them with vinyl cover. It is a method to be used in the areas where crushing, incineration, and burying methods are difficult. Pine wilt withers the trees by blocking the transportation channels of water and nutrients and there is no curative way from this disease.

2.2 Handling status of infected trees

Upon the investigation of fumigation status by visiting pine wilt control area in Gyunggi Province before the parliamentary inspection of Korea Forest Service by Wan Ju Park, a member of National Assembly from the Democratic Party of Korea, fumigation was revealed to be poorly controlled by Korea Forest Service, and he pointed out, “fumigation harms covering materials, hence, thorough follow-up management for fumigation is crucial because pine wilt disease may be spread if the dead trees are exposed or exported without authorization,” and added, “fumigated trees that were not identified by when, whom, how were piled up here and there.” In case of the fumigation site where Mr. Park investigated, mandatory recording items on all the covering materials for fumigated trees were missing despite the guideline to record serial number, operating date, operator’s name, and treatment chemical. He addressed the negligence, “Korea Forest Service does not know where are fumigated piles and when they were made, and also it does not know how many piles were destroyed and incinerated while the record showed the 2,661,938 piles had been made nationwide from 2012 up date.” In fact, the location of piles is not required to be reported after fumigation work in the guideline of pest control by Korea Forest Service, hence, it is controlled with coordinates of damaged tree stumps using the fact that fumigation piles are prepared typically near the damaged trees. Moreover, Korea Forest Service claimed that fumigation works were responsible for the local governments and they only collected the status data, which was criticized not to care about pest control of pine wilt disease.

Mr. Park mentioned, "Without clear understanding of the location of piles, Korea Forest Service cannot monitor well on the fumigation results or follow-up control," and added, "the agency that reserved all the responsibilities from planning up to inspection of fumigation to the local governments and collected the data only is the biggest missing part of complete pest control of pine wilt disease."

Also, he empathized, "GIS-based control system should be established by improving the system to record the related information including the locations of fumigated piles, quantity, operator's name, size, etc. on the integrative control system of forest pests. Immediate executions of complete investigation on the control practices of fumigated piles nationwide and post-hoc control of completed fumigated piles are urged." [28]

2.3 Thermodynamic properties of pine trees

The lowest and highest calorific values of pine tree biomass with 5-6% of water content were 4680 kcal/kg and 6790 kcal/kg, respectively, showing higher value than that of live pine trees with 2700 kcal/kg, demonstrating the reason to suggest spotting fire that inflammables of pine trees fly over hundreds of meters due to the gale in case of wildfire, as a main factor of fire spread. Combustion rate showed the difference more than double in the combustion test between the trees with 10% and 35% of water content, during a Gosung wildfire in 2019. [29-33]

Because of national and social indifference in the utilization plans of piled infected trees after fumigation and impractical policies, the fumigation process may be continued to the disaster from spread of wildfire, leading economic and social loss as well as the damages on people and properties which are hardly quantified. It is necessary to study this as well as unreviewed social impacts such as psychological loss, depression, and so on from devastated forests, with multiple viewpoints.

3. Test setup and conditions

3.1 Test setup

3.1.1 Sample collection

In this study, 5 samples with the size of not more than 20 cm length and diameter per each, which were piled trees infected by pine wilt after cutting down and fumigation at the hills of XXX mountain in XX City under control by XX branch of the Korea Forest Service, were collected by the terms from less than 1 year up to less than 5 years as seen in Figure 1. The sample were crushed to wood chips and grinded to fine powders rather than the original forms to meet the analysis condition to measure water content and calorific values.

Figure 1. Samples by piling up terms

(a) Less than 1 year (b) ≥1 year <2 years (c) ≥2 years <3 years

(d) $\geq$3 years <4 years (e) $\geq$4 years <5 years

3.1.2 Measuring equipment

Figure 2 shows the measuring equipment of water content that calculates the percentage of water content from the weight difference before and after drying divided by the weight after drying when the sample reaches the equilibrium of water content at the standard condition.

Figure 2. Measuring equipment of water content

Table 1 shows the specification of water content measuring equipment used in the test. It is used in multiple purposes including thermal modification of the samples, elimination of moisture in the samples for enhancement test. The equipment shows high efficiency with fan motor 1/16 Hp, rapid heat diffusion, and excellent temperature distribution without noise and vibration, and consists of triple tempered glasses that are easy to monitor inside with insulating property.

Table 1. Specification of water content measuring equipment

Item	Specification
Heater Capacity	1.4KW
Type	Forced Convection Oven
Temp Range	Amb + 10℃ To 200℃ Max. 250℃
Temp Regulator	SSR Controller

Fan Motor	1/16 HP
Power	AC 220V, 50/60Hz, 1ø
OUT Size (W×D×H)	670×660×1070mm

It is important to understand the feature of fire by measuring the calories generated from the complete oxidization of certain substances. Figure 3 shows the measuring equipment of calorific value to measure the calories from samples generated by combustion reaction.

Figure 3. Calorimeter

Table 2 shows the specification of calorimeter used in the test. Calorimeter is used to measure calorific values of solid and liquid flammables including petroleum, coals, cokes, foods, biomass products, and so on. Its measuring range is up to 40 MJ/kg; heat capacity stability is not more than 0.2% within 2 years; resolving power of temperature is 0001℃; type of oxygen filling is automatic; and it is used in power plants, coal mines, metallurgy, chemical industry, commercial tests, scientific researches, and so on.

Table 2. Specification of calorimeter

Item	**Specification**
Measuring range	Up to 40MJ/kg
Heat Capacity Stability	≤0.2% within one year
Temp. Resolution	0.0001℃
Ignition Method	Patented Laser Technology
Oxygen Filling	Automatic
Net Weight	50kg
Dimensions(L×W×H)	480mm×500mm×420mm

3.2 Test conditions

Test conditions are shown in **Table 3** Temperature and humidity at the lab were 20℃±1℃ and 75%±5%, respectively; analysis time per each sample was 8 minutes and sustaining temperature was 27.1℃. Interfering factors around the equipment to affect the test were eliminated to minimize the measurement errors, and sample collection, crushing, and grinding works were completed within two days to secure the accuracy of the sample analysis. 1 kg of a sample per each term was weighted, and daily water content and calorific value were measured by the equipment to measure water content **(Fig 2)** and calorimeter **(Fig 3)** on the same day, avoiding the test with different samples on the same day. 10 times of tests to measure water content and calorific value were performed for a total of 5 samples for 5 days to check the reliability of the measured data, while untested samples were sealed and stored.

Table 3. Test conditions

Item	Value
Temperature inside the lab (℃)	20±1
Humidity inside the lab (%)	75±5
Hold Temp of Analysis Time per Sample (℃)	27.1
Analysis Time per Sample (min)	8

Note) No strong interference source nearby

4. Results and discussion

4.1 Results

Tests for water content and combustion were performed at OO Lab to get the data of water contents and calorific values by piling up terms of infected trees and the results are shown in Table 4. Water contents of live timbers showed the differences by multiple factors including seasons, types of species, source of origin, etc.

Upon the analysis results of samples by each term in Figure 1 with the water content measuring equipment in Figure 2, the lowest water content was shown in the sample over 4 years and less than 5 years with 16% and the highest water content in the sample over 2 years and less than 3 years with 24%, demonstrating little difference of water content by piling up terms, deviation not more than 8% and mean value of 19.8%, which is about one sixth compared to the water content of domestic live pine trees 115%.[34]

With respect to the analysis of combustion test by calorimeter, the lowest value was shown in the sample over 3 years and less than 4 years with 4680kcal/kg and the highest value in the sample over 1 year and less than 2 years with 5340kcal/kg, demonstrating the mean value of 4860kcal/kg, which was beyond the mean value of general pine trees.

Table 4. water content and calorific value

Piling up term	Water content (%)	Calorific value(kcal/kg)
Less than 1 year	18	4800
≥1 year <2 years	23	5340
≥2 years <3 years	24	4780
≥3 years <4 years	18	4680
≥4 years <5 years	16	4700
Mean	19.8	4860

Water contents by piling up terms showed the differences by multiple natural factors including seasons, species of trees, source of origin, and so on, damaged status of covering materials for fumigated trees, and lack of follow up control for infected trees; and calorific value of the sample over 1 year and less than 2 years showed the difference approximately by 600 kcal/kg compared to the other samples, causing from the resin in the samples, which did not affect the mean calorific value, significantly.

As seen in **Table 5** in the prior study, mean values of water content and calorific value of infected trees were 19.8% and 4866 kcal/kg, respectively, compared to those of live trees, 90% and 2700 kcal/kg. Ignition rate to infected trees is faster than that to the live pine trees in case of wildfire, hence, infected trees piled and remained in the forests can be the causes of wildfire spread by conduction, convection, and radiation.

Table 5. Comparisons of water contents and calorific values between live and infected trees

Item	Water content (%)	Calorific value (kcal/kg)	Comment
Infected trees	19.8	4866	Mean of 5 samples
Live trees	90	2700	

What the fires in the wooden buildings show the drastic increase of fire spread rate at the growth stage to the maximum stage and then to the declining stage rapidly means the completion of combustion of inflammables and extinguishment. However, in the wildfire, sufficient oxygen and inflammables including piled infected trees, pine tree colonies, gale, resin, and so on can be the main factors of large-scale fire spread.

5. Conclusion

This study was conducted to analyze the effects of pine wilt infected trees on the spread of wildfire, measuring water content and calorific value by piling up terms of infected trees through the test of water content measurement and the combustion test. The test results are as follows.

(1) The lowest water content in the wilt infected trees was shown in the sample over 4 years and less than 5 years with 16% and the highest water content in the sample over 2 years and less than 3 years with 24%, demonstrating little difference of water content by piling up terms, deviation not more than 8% and mean value of 19.8%, which is about one sixth compared to the water content of domestic live pine trees 115%.

(2) The lowest value of calorific value pine in the wilt infected trees was shown in the sample over 3 years and less than 4 years with 4680kcal/kg and the highest value in the sample over 1 year and less than 2 years with 5340kcal/kg, demonstrating the mean value of 4860kcal/kg, which was beyond the mean value of general pine trees.

(3) For the effects of calorific values of pine wilt infected trees on the spread of wildfire, it was found that sufficient oxygen and inflammables including piled infected trees, pine tree colonies, gale, resin, and so on can be the main factors of large-scale fire spread, regardless of their piling up terms. Further studies are required for follow up measures on the pine wilt infected trees, economic loss due to wildfire, and psychological studies on the inhabitants at the damaged areas such as emotional loss, depression, despair, and so on from post-traumatic stress.

References

A. It is a nematode that is parasitic in pine trees, nut pine trees, and so on. It is parasitic in the mediators such as Japanese pine sawyer, Bukbangsuyeom-haneulso, and so on to infect the trees.
B. Law 7549 enacted on May 31, 2005 and enforced on Sept 1, 2005
C. Press release by Green Korea United in 2015
D. It means to cause new wildfire from sparks due to gale, and so on.
E. It is a type of fire from solid inflammables such as timber or textiles, and it is a fire inside the inflammables. (Definition of NFSC 106)
F. Jung YJ (2002) Status of damages and spread of pine wilt disease in Korea, Forest Protection, 7, 1-9
G. An SH, Jun MJ, Um YG, Oh SC, Lee ML "Anatomical characteristics of pine trees infected by pine wilt disease" Journal of the Korean Wood Science and Technology. 39, no.1 (2011): 15-20.

H. Yoon SR, Park JH, Park HM, Kim JG, Byun HS. "A study on the density of pine wilt and compression capacity by precipitation and fumigation of damaged pine trees" Journal of the Korean Wood Science and Technology. 37, no.3 (2009): 200-207.

I. Lee SY, Lee MW, Lee HP. "Comparisons of wildfire risks by the types of piling up the products of forest making project" Korean Journal of Fire Science and Engineering 22, no 1 (2008) pp.45-53

J. Kim DH, Go JS, Choi SH, Kim KI "A study on the investigation of Gosung wildfire and calorie analysis of major trees" Korean Journal of Fire Science and Engineering 13, no 1 (1999) pp.31-36

K. Park YJ, Lee HP "A study on the application of combustion products to identify the wildfire" International Journal of Safety. 26, no 4 (2011): 111-119.

L. Lee SY, Lee HP "Analysis of Korean wildfire" Korean Journal of Fire Science and Engineering 20, no 2 (2006) pp.54-63

M. Park WH, Ko DW, Kwon TS, Nam YW, Kwon YD. "Analysis of pine wilt damages in Gyunggi Province: based on projection data in 2008 ~ 2015" Journal of Korean Forestry Society 107, no.4 (2018): 486-496.

N. Kim JW. "Eco-forum issue: Korean pine trees and pine wilt reviewed from the East Sea wildfire, what are the problems?" Journal of Ecology and Environment 28, no.2 (2005): 113-120.

O. Jung YJ. "Special lecture 2: Status of pine wilt damages and countermeasures" Proceeding of the spring congress in the Korean Society of Soil Zoology. 2002, no.0 (2002): 7-9.

P. Park HS, Lee SY, Yeon CH, Sung NM. "Developments of firefighting technologies and scenarios for the East Sea wildfire based on the 4th industrial revolution technologies" Proceeding of the autumn congress in 2019, Graduate School of Firefighting in Gangwon National University, KETI

Q. Lee SY, Lee HP "Analysis of Korean wildfire" Korean Journal of Fire Science and Engineering 20, no 2 (2006) pp.54-63

R. Kim YG. "Status and issues of air firefighting system to cope with large-scale wildfire" Proceeding of the annual congress of the Korean Association for Public Administration. 2019, no.0 (2019): 445-468.

S. Lee SY, Bae TH "Analysis of the Helicopter Fire Attack Pattern on Forest Fire Behavior." Korean Journal of Fire Science and Engineering 23, no 2, 2009 pp.96-100

T. Lee BD, Ku KS, Lee MB. "Forest Fire Direction and Spread Characteristics by Field Investigations" Korean Journal of Fire Science and Engineering 23, no 5, 2009 pp.96-102

U. Song JC (National Forensic Service) Practical investigations of fire causes – causes and phenomena of wildfire. No 86, 2000, pp.48 - 51

V. Lee SY (Forestry Research Institute) "Cases of recent wildfires in the world" Fire Prevention and Insurance. no.76-no.76, 1998, pp.55 - 58

W. Bae TH, Lee SY "Study of Aerial Fire Line Construction and Suppression Method on Forest Fire. Korean Journal of Fire Science and Engineering 24, no 5, 2010 pp.26-31

X. Strong wind between Yangyang and Gosung in Ganwon Province in the spring

Y. Wind between Yangyang and Gangrung

Z. Kim DH, Ko JS, Choi SH, Kim GI "A study on the calorie analysis of major trees and fire investigation in Gosung wildfire" Korean Journal of Fire Science and Engineering, 13, no 1 (1999) 35page

AA. Pine resin or colophony means the solid resin, heating liquid resin from coniferous trees such as pine trees and evaporating terpene which is a volatile liquid. Pine resin is semi-transparent and its colors are various from yellow to black. At the room temperature, pine resin can be crushed but it is dissolved after heating.

BB. Newsis 2016.10.09 14:21

CC. The lowest calorific value is the value to deduct the remaining heat after water evaporation that cannot be used as a heat, representing the calorific values of the fuels called as net calorific value.

DD. The highest calorific value is the value to include the remaining heat of water vapor by combustion, called as total calorific value.

EE. Public hearing on the energy utilization plans with wooden biomass. Korea Energy Economics Institute. 2007.3.20

FF. Interview with Lee SY. 2019-04-06 MBC Gangwon Youngdong News

GG. Press release on 2019-10 MBC News, comparative combustion tests for water contents of pine trees in dry season

HH. Jeong HM, Timber and water content, how much do they contain water content? Wood Culture. 2018. 1.26