Studies on Selection of Fire Resistance Tree Species for Sub-tropical Area of China

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Abstract Fire-resistance forest belts can effectively prevent large area's fire damage. In this paper the components and flammability of the leaves, twigs and bark of 12 tree species in the mountain area of Daguishan, Guangxi-Zhuang autonomous region have been tested and analyzed in the laboratory. The test and analysis indicate the results as following: (1) For all the tree species, the leaf's fire-resistance is much weaker that that of twigs and bark, and the broad leaves are stronger than those of conifers in fire-resistance. (2) Heat value, moisture, ignition point and ash content are main indexes to affect fire-resistance. Heat value relates to lignin content and benzene-ethanol extractive content linearly. (3)Of all the 12 tree species, *Schima superba, Castanopsis hystrix, Myria rubru* have strongest resistance to fire; *Machiluis pauhoi, Mytilaria laosensis, Michelia Macclurei, schima sp.* are relatively strong in fire-resistance, and *Cunninghamia lancedata* and *Pinus massniana* the least strong in fire-resistance.

Key words biological fire-resistance, fire-resistant tree species, fire-resistant forest belts

Introduction

Fire is a primary factor of deforestation. Although in recent years the level of forest management and the technique of fire suppression have been improving and fire fighting forces have been strengthened, the area of fire damage is not decreased. Fire-resistant forest belts can prevent forest fire effectively. The study on the fire-resistance of tree species is the basis for forest belts to prevent fire and to decrease the flammability of trees. To study the fire-resistance of different tree species, samples including those of leaves, twigs and bark of 12 tree species have been taken from the local forest. Some indexes of samples have been tested such as moister content, ignition point, heat value in burning, rough grease content, benzene-ethanol extract and ash content etc. At last the fine fire-resistant trees are found out.

1. Materials

The samples of 12 different tree species were taken from the Daguishan forestry center. The trees include *Michelia macclurei, Myria rubru, Machilus pauhooi, Tsoogiodendron Oadorum, Mytilaria laosensis, Lithocapus thalassica, Schima sp, schima superba, ,Manglietia tenuipes, Castanopsis hystrix, Pinus massniana, Cunningghamia lanceolata* . For each kind of tree, 2-3 trees were taken as samples. Leaf and twig samples (diameter less than 0.5 cm) were taken from the middle of the trees in positive side, and bark samples were taken at breast height. Some samples of each kind were taken back to the laboratory in the sealed plastic bags; some others were used for the tests on moisture immediately after being taken off. In the laboratory, some sealed samples were taken out and dried at 80℃ for 16 hours till invariable weight, then smashed by a muller. The smashed samples are bottled for later use.

2. Methods

2.1 Test on ignition point

Ignition point was obtained by using DW-2 ignition point meter and heat value in burning w by YDQ-3 calorimeter The test was dealt with under the conditions required by the instrument . the same time, the quantity of the pure substance in materials was measured out and then the h value of one unit's pure substance was figured out. The measurement of the time needed for fresh leaves of each tree species to be ignited was dealt with in the following way firstly, the fr leaf samples (weighing 54g of each tree species) were taken from the top, middle and bottom of crown; secondly, the samples were put into a electric stove of 2000 W to be ignited (3 times in way).

2.2 Test on the organic or inorganic matter

Both the benzene-ethanol extract and rough grease content were measured in the method remains-testing, ash content in that of ash drying and lignin content in that of hydrolyzing.

3. Results, analysis and discussion

3.1 Flammability analysis and component analysis

Table1, table 2 and table 3 show the results of all the tests on the components and flammabi of leaf and twig and bark samples of each tree species. Between leaf and twig and bark samp there is no significant difference of moisture, ash content and ignition point (table 4, table 5 table 6 show the results of variance analysis of moisture, ash content and ignition point); but the a significant difference of flammability (table 7 shows the results of variance analysis flammability).

The heat value of leaf in burning is the highest and that of bark is the lowest. The heat value twig is higher than that of bark and lower than that of leaf. It is concluded through multi-comparison that there is a great discrepancy between the heat value of leaf and that of b and that leaf sends out more heat.

Table 8 is the variance analysis of rough grease content, which indicates that there is significant difference of rough grease content between leaf, twig and bark. On the basis multi-comparison, it is concluded that the rough grease content of leaf is remarkably different fro that of twig and that of bark, and the Q-value between leaf and twig and that between leaf and b are 4.1777 and 5.1718 respectively. Both the values are above the critical point Q (3, 33) = 3. Leaf has the highest value of rough grease content. That means that its grease content is the high and most liable to be flamed.

Table 9 shows the variance analysis of lignin content of leaf, twig and bark. Through the Q- t it is acquired that the difference of lignin content between leaf, twig and bark is significant. The value of lignin content between leaf and bark is 9.7574 and that between twig and bark is 7.63 (the critical point is 3.47). The lowest point of lignin content belongs to leaf and the highest poi belongs to bark. Lignin is a kind of matter difficult to decompose and burn. On the whole, lig content highest in bark means that bark is more difficult to burn than leaf and twig.

There is a significant difference of benzene-ethanol extract in leaf, twig and bark, which is t result of variance analysis shown by table 10. Q- test indicates that the differences benzene-ethanol extract between leaf and that between leaf and bark reach the most significant lev Q- values are 12.2157 and 11.7188 (critical point is 3.88). Benzene-ethanol extract in leaf is t highest.

Table 1 The experiment result of twelve tree species leaves

Number	Tree species	Value of burning (kJ/kg)	Moisture content (%)	Ignition point (□)	Ash content (%)	Rough grease content(%)	Benzene-ethanol extract (%)	Lignin content (%)	Ignition time (s)
1	*Michelia macclurei*	21700	56.16	248	4.78	2.91	12.06	32.26	37
2	*Myrica rubru*	20720	55.37	254	3.75	3.45	12.57	28.18	76
3	*Machilus pauhoi*	20691	54.69	250	4.01	4.61	15.64	28.02	59
4	*Tsoogiodendron Odorum*	21001	57.84	210	7.55	4.17	15.05	29.44	82
5	*Mytilaria laosensis*	21479	66.43	246	4.03	4.56	16.31	31.59	105
6	*Lithocapus thalassica*	21131	44.01	242	2.70	4.26	14.49	30.56	51
7	*Schima sp.*	21520	46.82	253	5.42	3.70	13.75	32.67	96
8	*Schima superba*	19728	56.65	253	3.99	2.55	13.11	25.38	69
9	*Manglietia tenuipes*	20762	59.76	226	6.27	3.81	14.21	28.03	45
10	*Castanopsis hystrix*	20419	66.11	243	4.30	2.52	13.86	27.88	86
11	*Pinus massniana*	22889	47.35	238	2.93	8.89	21.11	33.73	2.85
12	*Cunninghamia lanceolata*	21712	59.35	228	3.88	5.16	18.53	25.24	2.28

Table 2 The experiment result of twelve tree species twig

Number	Tree species	Value of burning (kJ/kg)	Moisture content (%)	Ignition point (□)	Ash content (%)	Rough grease content (%)	Benzene-ethanol extract (%)	Lignin content (%)
1	*Michelia macclurei*	20532	56.14	236	3.62	0.78	4.18	30.27
2	*Myrica rubru*	19816	55.38	240	3.82	1.63	3.73	29.35
3	*Machilus pauhoi*	20331	48.06	232	2.05	1.80	2.87	30.47
4	*Tsoogiodendron Odorum*	20134	56.94	228	3.03	2.05	8.40	29.02
5	*Mytilaria laosensis*	21217	60.55	236	2.23	3.73	7.59	31.73
6	*Lithocapus thalassica*	20067	44.50	236	5.12	1.67	2.26	29.42
7	*Schima sp.*	20485	48.85	240	3.76	2.10	3.75	30.74
8	*Schima superba*	20494	55.85	241	3.46	1.07	3.73	30.42
9	*Manglietia tenuipes*	20180	54.68	237	6.31	1.84	4.31	29.85
10	*Castanopsis hystrix*	20227	51.77	229	2.59	1.04	4.93	30.50
11	*Pinus massniana*	20808	42.15	244	1.61	6.13	11.17	32.94
12	*Cunninghamia lanceolata*	20988	49.62	238	2.16	4.73	7.26	33.14

Table 3 The result experiment of twelve tree species bark

Number	Tree species	Value of burning (kJ/kg)	Moisture content (%)	Ignition point (□)	Ash content (%)	rough grease content (%)	Benzene-ethanol extract (%)	Lignin content (%)
1	*Michelia macclurei*	19866	55.58	226	4.32	1.12	4.98	33.36
2	*Myrica rubra*	18493	46.78	242	2.02	1.25	9.47	32.78
3	*Machilus pauhoi*	19611	50.48	235	3.48	1.66	4.87	34.36
4	*Tsoogiodendron Odorum*	19485	51.66	232	5.31	1.86	6.01	33.93
5	*Mytilaria laosensis*	21480	63.43	249	2.51	2.67	12.80	35.84
6	*Lithocapus thalassica*	20926	49.25	252	5.11	1.50	1.38	37.25
7	*Schima sp.*	20888	57.64	248	2.69	5.17	9.08	35.81
8	*Schima superba*	20277	54.87	222	3.07	1.16	5.22	35.01
9	*Manglietia tenuipes*	19699	61.26	226	4.11	1.98	9.89	33.96
10	*Castanopsis hystrix*	20005	43.20	249	3.84	0.90	2.41	34.19
11	*Pinus massniana*	21039	34.87	258	1.61	2.91	4.12	38.57
12	*Cunninghamia lanceolata*	21235	37.58	214	1.41	1.15	11.69	36.12

Table 4 Analysis of variance of moisture content

Variance	Total square	Free of freedom	Average square	F	Critical value
Between the groups	181.3605	2	90.680	1.72	3.28
Inter group	1737.548	33	52.652		
Total	1918.908	35			

Table 5 Analysis of variance of ignition point

Variance	Total square	Free of freedom	Average square	F	Critical value
Between the groups	128.222	2	64.111	0.49	3.28
Inter group	4352.083	33	131.881		
Total	4480.306	35			

Table 6 Analysis of variance of ash content

Variance	Total square	Free of freedom	Average square	F	Critical value
Between the groups	10.877	2	5.4383	3.01	3.28
Inter group	59.632	33	1.807		
Total	70.509	35			

Table 7 Analysis of variance of burning value

Variance	Total square	Free of freedom	Average square	F	Critical value
Between the groups	5346857	2	2673429	5.08	3.28
Inter group	17374470	33	526499.1		
Total	22721327	35			

Table 8 Analysis of variance of rough grease content

Variance	Total square	Free of freedom	Average square	F	Critical value
Between the groups	34.873	2	17.437	7.53	3.28
Inter group	76.401	33	2.315		
Total	111.274	35			

Table 9 Analysis of variance of lignin content

Variance	Total square	Free of freedom	Average square	F	Critical value
Between the groups	214.346	2	107.173	26.121	3.28
Inter group	135.396	33	4.103		
Total	349.742	35			

Table 10 Analysis of variance of benzene-ethanol extract

variance	Total square	Free of freedom	Average square	F	Critical value
Between the groups	656.800	2	328.421	36.185	3.28
Inter group	299.491	33	9.078		
Total	956.291	35			

Benzene-ethanol extract can decompose at a relatively low temperature. In burning, it sends out a great amount of heat and boosts other substances burning. So it plays a key role in causing and spreading the forest fire. Compared with twig and bark, leaf is significantly higher in rough grease content and lower in lignin content while it is not significantly different from the other two organs in moisture content and in ash content. This fact indicates that leaf is the most liable to burn among the three tree organs, for its ignition requires lower temperature. So flammability of leaf is intended to be the focus of this study, as the basis to determine the best tree species to resist forest fire.

3.2 comparison of flammability between conifer and broadleaf

The results of t-test are as follows:

There is a significant difference of heat value and ignition time between conifer and broadleaf. The T-value of conifer is 2.90 and that of broadleaf is 4.13 (critical point is 2.23). Conifer has a higher heat value and shorter ignition time, so it is easier to burn than broadleaf.

Benzene-ethanol extract of conifer averages 19.82% which is higher than that of broadleaf (14.11%) by 5.71%. The difference is significant (t-value =5.31). The above figures show that conifer sends out more volatile matter at lower temperature and much easier to burn.

The rough grease content of conifer is 3.37% higher than that of broadleaf (t-value=3.90) so conifer is much easier to burn that broadleaf.

According to the above test results, it can be concluded that broadleaf species has stronger resistance to fire.

3.3 analysis of factors that affect ignition time

The components of leaf affect the process of burning and ignition time is closely related to the occurrence and spreading of forest fire. In experiment, ignition time directly reflects the fire resistance. Using three variables: moisture content (x_1), rough grease content (x_2), and lignin content (x_3) to analyze ignition time, the following regression equation is obtained.

$$Y=-107.4092+1.1389x_1-13.5680x_2+5.4465x_3$$

Multiple correlation coefficient $r= 0.7076$

The multiple correlation coefficient test shows that the correlation is significant. The ignition time has a negative relation with rough grease content but has a positive relation with both the moisture content and lignin content. In other words, the moisture higher, water volatilizing need more heat and the ignition time longer; lignin content higher, leaf burns more difficult. The rough grease is easy to decompose and burn and the content of it negatively related to ignition time.

3.4 analysis of factors that affects heat value in burning

Fuel's heat value affects fire's spreading. The analysis of the factors that affect burning value contributes to the study on the flammability of fuel. After this analysis the following regression equation of heat value (y) and benzene-ethanol extract (x_1) and lignin content (x_2) is achieved.

$$Y=13373.7500+177.8047x_1+ 173.2031x_2$$

Multiple correlation coefficient $r = 0.9047$

The partial correlation coefficient of x_1 to Y is 0.7998 and that of x_2 to Y is 0.8121. The correlation is remarkable. Lignin content is closely related to heat value: the higher lignin content, the higher heat value. Benzene-ethanol extract is quite a

flammable matter and its combustion sends out a large amount of heat. Its content has a positive correlation with heat value: the higher benzene-ethanol content, the higher heat value.

3.5 main component analysis on leaf indexes

Each factor's contribution rate can be obtained through the main component analysis. All the leaf's factors' contribution rates are as follows: heat value 41.35%, moisture 23.73%, ignition point 19.39%, ash content 9.33%, rough grease content 4.12%, benzene-ethanol extract 1.61%, lignin content 0.43%, ignition time 0.04%. The contribution rates of the first four factors get to 93.80%, but that of benzene-ethanol extract and lignin content is very little. Therefore the first four factors should be taken as main indexes. The first four factors are heat value, moisture content, ignition point and ash content respectively. The rest of the elements such as rough grease content, benzene-ethanol extract and lignin content should be taken as assistant indexes in selecting the best fire-resistance tree species.

3.6 multipurpose determination of fire resistance trees

Principle:

Multipurpose determination was done in the one-dimensional comparison method of Pareto optimizing set.

Firstly, all the indexes were turned in to the same dimension. The data were turned into the same unit through equation 1 and 2.

$$U=1-0.9(V_{max}-V)/(V_{max}-V_{min}) \quad (1)$$

$$U=1-0.9(V-V_{min})/(V_{max}-V_{min}) \quad (2)$$

Equation 1 indicates increasing by degrees while equation 2 indicates decreasing by degrees.

Secondly, the weight of the indexes was decided according to their contribution rates. $\lambda_j, \sum_{j=1}^{n} \lambda_j = 1$, (j=1,2···n). The weight of the indexes was determined through the comparison of them with each other. Based on the equation $\varpi_i = \sum_{j=1}^{n} \lambda_j U_{ij}$, the comprehensive value ϖ_i of each tree species was worked out.

Finally, the order of tree species in fire resistance was given by the value of ϖ_i.

Analysis process:

In addition to the effects of the flammability of leaf, twig and bark, the ecological and biological characteristics of a tree species should be taken into consideration concerning its fire resistance on the ecological community level. As a tree of fire -resistant forest belts, all its following factors will effect on the functions of fire-resistant forest fire belts: the crown figure, the training attribute, the flammability and decomposing speed of the ground cover, the adaptability to the site, the budding ability and the growth speed at early period. The trees of the belts need strong fire resistance and are liable to rehabilitation after a fire. The ecological and biological characteristics of the trees can be classified into three grades: grade I is flammable, grade II relatively flammable, grade III hardly combustible. The ecological and biological indexes affecting a tree's fire resistance are mainly the following: (1) the crown figure and training attribute (x_1)-- sparse crown and worse training belongs to class I, dense crown and well training belongs to class III, class II lies between class II and class III, (2) the flammability of the ground cover and its decomposing speed (x_2)-- class I covers that the ground cover contains volatile lipid and is difficult to decompose, class III covers that the ground cover contains a great deal of moisture and has a high speed of decomposition, class II stands in between. (3) The adaptability to the site (x_3)-- not being able to adapt to aridity and barren is classified in to class I, adapting to aridity and barren is class III, the class II lies in between; (4) the budding ability and the growth speed at early period (x_4)-- no budding ability and slow growth is class I, strong budding ability and fast growth is class III, the between is class II.

Table 11 Classify biological and ecological characters of tree species

Number	Tree species	X_1	X_2	X_3	x_4
1	*Michelia macclurei*	3	2	2	3
2	*Myrica rubru*	3	3	3	1
3	*Machilus pauhoi*	3	2	2	2
4	*Tsoogiodendron Odorum*	2	3	1	2
5	*Mytilaria laosensis*	2	3	1	3
6	*Lithocapus thalassica*	3	2	3	3
7	*Schima sp.*	3	2	3	3
8	*Schima superba*	3	2	3	3
9	*Manglietia tenuipes*	2	3	1	2
10	*Castanopsis hystrix*	3	2	2	3
11	*Pinus massniana*	3	1	3	1
12	*Cunninghamia lanceolata*	1	1	1	3

Table 12 The weight of indexes

	Weight of main index	Ratio of indexes weight	Indexes weight
Definite indexes	0.7	0.4223	0.2956
		0.2423	0.1696
		0.1980	0.1386
		0.0953	0.0667
		0.0421	0.0295
Qualitative indexes	0.3	0.5534	0.1660
		0.1148	0.0345
		0.1118	0.0335
		0.2200	0.0660

Table 13 is the order of tree species in fire-resistance. It can be concluded that *Schima superba*, *Castanopsis hystrix* and *Myrica rubru* have strong fire resistance which value are above 0.70. The fire resistance of *Machilus pauhoi, Mytilaria laosensis,Michelia macclurei Schima sp., Manglietia tenuipes* is commonly, which value range from 0.60 to 0.70. *Lithocapus thalassica, Tsoogiodendron Odorum, Cunninghamia lanceolata, Pinus massniana* are not fire resistance tree species, which value are below 0.6.

Table 13 The synthetical evaluated result of tree species

Tree species	Value of burning	Moisture content	Ignition point	Ash content	Rough grease	x_1	x_2	x_3	x_4	Value	Order
...helia macclurei	0.1296	0.0997	0.1216	0.0324	0.0279	0.1660	0.0190	0.0184	0.0660	0.6806	5
...yrica rubru	0.2121	0.0943	0.1386	0.0197	0.0256	0.1660	0.0345	0.0335	0.0066	0.7309	3
...chilus pauhoi	0.2146	0.0897	0.1273	0.0229	0.0208	0.1660	0.0190	0.0184	0.0363	0.7150	4
...ogiodendron Odorum	0.1885	0.1111	0.0139	0.0667	0.0226	0.0913	0.0345	0.0034	0.0363	0.5683	10
...tilaria laosensis	0.1482	0.1696	0.1159	0.0231	0.0210	0.0913	0.0345	0.0034	0.0660	0.6730	6
Lithocapus thalassica	0.1775	0.0170	0.1046	0.0067	0.0222	0.1660	0.0190	0.0335	0.0660	0.6125	9
Schima sp.	0.1448	0.0361	0.1358	0.0403	0.0246	0.1660	0.0190	0.0335	0.0660	0.6661	7
...hima superba	0.2956	0.1030	0.1358	0.0226	0.0294	0.1660	0.0190	0.0335	0.0660	0.8709	1
...nglietia tenuipes	0.2086	0.1242	0.0592	0.0509	0.0241	0.0913	0.0190	0.0034	0.0363	0.6170	8
...stanopsis hystrix	0.2374	0.1674	0.1074	0.0265	0.0295	0.1660	0.0190	0.0184	0.0660	0.8376	2
Pinus massniana	0.0296	0.0397	0.0932	0.0095	0.0030	0.1660	0.0035	0.0335	0.0066	0.3846	12
Cunninghamia lanceolata	0.1286	0.1214	0.0649	0.0213	0.0185	0.0166	0.0035	0.0034	0.0660	0.4442	11

3.7 cluster analysis on the flammability of tree species

The cluster analysis was done according to the qualitative factors such as crown figure, training contribute, flammability of the ground cover and its decomposing speed, the adaptability to the site, budding ability and the growth speed at early period, and the quantificational indexes such as moisture content, ignition point, heat value, rough grease content, benzene-ethanol extract and ash content. In the analysis, the samples are classified according to the standard Oushi distance. The result shows that *Cunninghamia lanceolata*(12) and *Pinus massniana* (11) belong to the same sort and their ability to resist fire is very low, *Manglietia tenuipes* (9) and *Tsoogiodendron Odorum* (4) are the same sort and they have relatively low fire resistance, and the others are the sort of having strong fire resistance.

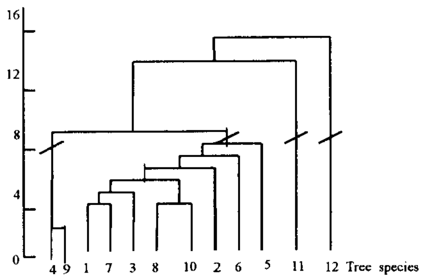

Figure1 Cluster analysis of tree species fire resistance

4. Conclusion

It is indicated that leaf is flammable organic, through analyzing fire resistant ability and component of 12 tree species and the difference of leaf, twig and bark. We know burning value, moister content, ignition point and ash content as main indexes and rough grease content, benzene-ethanol extract and lignin content as assistant indexes on selection fire-resistance tree species, according to the main component analysis. Ignition time have positive correlation with water content and lignin content, and have negative correlation with rough grease content. Heat value relates to lignin content and benzene-ethanol extractive content linearly, it will increase with lignin content and benzene-ethanol extractive content growth.

By means of the fuzzy mathematics method, the fire-resistance of 12 tree species is put in order. That is *Schima superba, Castanopsis hystrix, Myria rubru Machilus pauhoi, Mytilaria laosensis, Michelia macclurei, schima sp., Cunninghamia lancedata* and *Pinus massniana.*

The result of cluster analysis also indicated that *Cunninghamia lancedata* and *Pinus massniana* have weak fire resistance, and *Schima superba, Castanopsis hystrix, Myria rubru* ,etc. have strong fire-resistance.

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Reference

1 陈存及等 fire-resistant forest belts 树种选择的研究.福建林学院学报.1988,8(1):1-12

2 李振问等.火力楠防火性的初步研究. 福建林学院学报.1991,11(4):369-373

3 段向阁.兴安落叶松抗火性研究.森林防火. 1991,(4):7-10

4 Peter P. ect. Effective heat content of green forest fuels. Forest Science. 1977,1:81-92

5 Gavrill X. & Ronald W. A time to ignition-temperature-moisture relationship for branches of three western conifers. Canada Journal of Forest Research. 1993,23:253-258

6 Ronald A. Thermal behavior of conifer needle extractives. Forest Science. 1980,26(3):347-360

7 中国土壤学会农业化学专业委员会编. 土壤农业化学常规分析方法.科学出版社.1984.

8 阮传成等.木荷生物工程防火机理及应用.成都:电子科技大学出版社.1995.

9 袁嘉祖, 冯晋臣.模糊数学及其在林业中的应用.中国林业出版社.1988,147-169

10 王莲芬.层次分析法中排序权数的计算方法.系统工程原理与实践.1987,(4):31-37

11 郑郁善等.造林模式效益综合评价和决策研究. 福建林学院学报.1993,13(4):394-400

12 周玉丽. 层次分析法在制定农业生态经济发展规划中的应用. 生态学杂志.1988,7(2)54-57

Forest Fires in Boreal Forest – FROSTFIRE in Alaska Taiga

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ABSTRACT

This paper describes results of FROSTFIRE, a forest fire experiment carried out in July 1999 and also surveys results of the Donnelly Flats forest fire in June 1999. An investigation of the Donnelly Flats forest fire site found that the main burnt matter were branches with needles of black spruce and mosses and lichen which cover the ground. On the basis of these results, a vegetation investigation was carried out before the FROSTFIRE experiment. The following items were measured : weight of branches with needles of two black spruce trees and the thickness of mosses which covered the surface around the trees. Thunder storm observations by video camera from the Poker Flat mountain top recorded multiple lightning strikes. After the storm, three plumes from forest fires were observed in different directions and the probability of ignition of forest fires by the lightning is discussed. Finally, the combustion calculations using mean tree densities of black spruce and mean thickness of mosses estimate the quantity of CO_2 released in forest fires in Alaska.

KEYWORDS : Forest Fire, Boreal Forest, Taiga, Carbon Dioxide, FROSTFIRE, Lightning, Black Spruce, Moss

INTRODUCTION

The taiga is the common term for coniferous forest zones, and this kind of forest covers over one third of all woodland on the Earth. The Eurasian Continent has 55% of the taiga and North