Study of Surface Fuel Loading and Combustion Characteristics of Different Forest stands in Shandong Province

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Abstract: We examine the surface fuels of 11 main stands in Shandong Province, measured their combustion indexes such as load, moisture content, ignition point and calorific value. The results showed that the ignition point of surface litter layer < ignition point of surface humus layer, the calorific value of surface litter layer > calorific value of surface humus layer in the same stand. The lowest ignition point of litter layer in *Pinus tabulaeformis* forest was 265.67℃ and the highest calorific value was 21911.78 J/g. Among different forest stands, *Pinus tabulaeformis* forest has the strongest surface fuel combustion, while poplar forest has the weakest surface fuel combustion.

Keywords: Surface Fuel; Combustion Characteristics; Fuel Loading

Introduction

Forest fuel is the main factor causing forest fires. Based on the spatial distribution characteristics of forest fuels, they can be divided into underground, surface and air fuels from bottom to top (Shan et al., 2004). The combustion characteristics of forest fuels are usually the comprehensive reactions of the difficulty of ignition of forest fuels and the combustion state and velocity after ignition (Wang et al., 2020). Scholars have shown that the combustion characteristics of forest surface fuels are closely related to their physical and chemical properties (moisture content, ignition point, calorific value, etc.) (Plucinski and Anderson, 2008 Curt et al., 2011 Jolly and Johnson, 2018 Li , 2021). In order to better analyze the combustion characteristics of surface fuels of different forest types, the surface fuels of 11 forest types in Shandong Province were taken as the objects in this study. The moisture content, ignition point and calorific value of the fuels were measured, and the combustion characteristics of 11 forest types were evaluated .

1. Study site

Shandong Province is located between 34°22.9′-38°24.01′ N and 114°47.5′-122°42.3′ E. The site has a warm temperate monsoon climate with a frost-free period of 180-220 days. Summer is rainy, spring is less rain, the average annual precipitation is 480 mm. The terrain of the province is mainly mountainous and hilly, and the forest cover rate reaches 22.88%.

2. Study method

2.1 Standard setting and fuel collection

2.1.1 Standard setting

Representative *Pinus thunbergii, Pinus densiflora, Platycladus orientalis, Pinus tabuliformis, Quercus acutissima, Robinia pseudoacacia, Populus and Pinus thunbergii × Robinia pseudoacacia were selected in the whole province. Pinus densiflora × Quercus acutissima forest, Platycladus orientalis × Robinia pseudoacacia forest and Robinia pseudoacacia × Quercus acutissima forest* were set up to 290 standard plots per mu (25.82 m×25.82 m). The stand factor and site factor were determined by conventional methods.

2.1.2 Fuels collection

Shrub layer sampling: Five 2m× 2m quadrats were set in the sample plot to harvest and determine the fresh weight of aboveground dry, branch and leaf. Shrubs mixed in 5 quadrats, not less than 500g, were brought back to the laboratory to determine their dry-fresh ratio.

Herb layer, litter layer, humus layer sampling: 1m× 1m quadrats were set in the shrub sample, respectively, harvested herbs, litter1 (diameter less than 0.6cm twigs, leaves, fruits, weeds), litter2 (diameter in0.6cm- 2.5cm twigs), litter3(diameter in2.5cm- 7.62cm branches and diameter greater than 7.62cm fallen wood) and humus samples. Field mixing makes each sample not less than 300g. Into the sample bag, bring back to the laboratory determination.

2.2 Indoor experiments and calculations

The collected fuels were dried at 80 °C for 48 h until they were absolutely dried. The samples were weighed by an electronic balance, and the fuel load and moisture content were calculated.

2.3 Data processing and analysis

The data was collated using Excel 2010 and SPSS Statistics 25 was used to carry out analysis of surface combustible load and water content.

3. Results and analysis

3.1 Surface fuels moisture content of different stands

According to Table 1, in the moisture content of coniferous forest (*Pinus thunbergii*, *Pinus densiflora*, *Platycladus orientalis*, *Pinus tabuliformis*), *Pinus thunbergii* had the highest moisture content of 28.276%, and *Platycladus orientalis* had the lowest moisture content of 22.20%; in the moisture content of the surface humus layer: *Pinus tabuliformis* had the highest moisture content of 37.73%, and the *Populus* had the lowest moisture content ofis the lowest, 27.66%.

In the moisture content of litter layer under broad-leaved forest (*Quercus acutissima*, *Robinia pseudoacacia* and *Populus*), *Quercus acutissima* had the highest moisture content of 18.61 %, and *Robinia pseudoacacia* had the lowest moisture content of 14.30 %; in the moisture content of the surface humus layer: *Quercus acutissima* had the highest moisture content of 22.68 %, *Populus* had the lowest moisture content of 17.35 %.

In the moisture content of litter layer under mixed forest(*Pinus thunbergii × Robinia pseudoacacia*, *Pinus densiflora × Quercus acutissima*, *Platycladus orientalis × Robinia* , *Robinia pseudoacacia × Quercus acutissima*), *Pinus thunbergii*×

Robinia pseudoacacia had the highest moisture content of 21.86%, *Robinia pseudoacacia*× *Quercus acutissima* had the lowest moisture content of 15.24 %, in the moisture content of the surface humus layer: *Pinus thunbergii* × *Robinia pseudoacacia* had the highest moisture content of 27.85%, *Robinia pseudoacacia* × *Quercus acutissima* had the lowest moisture content of 18.07%.

The overall moisture content of the surface litter layer shows: coniferous forest > mixed forest > broad-leaved. The overall moisture content of the surface humus layer shows: coniferous forest > mixed forest > broad-leaved.

Table 1 Surface fuel moisture content of different forests

Forest	Fuel moisture content			
	Shrub layer	Herbage layer	Litter	Humus
Pinus thunbergii	122.47	189.15	28.28	33.78
Pinus densiflora	83.59	302.96	26.95	30.87
Pinus tabuliformis	201.98	177.47	24.41	37.73
Platycladus orientalis	107.95	141.14	22.20	27.66
Quercus acutissima	115.03	213.83	18.61	22.68
Robinia pseudoacacia	119.87	305.14	14.30	19.67
Populus	228.93	361.64	15.70	17.35
Pinus thunbergii × *Robinia pseudoacacia*	116.09	197.33	21.86	27.85
Pinus densiflora × *Quercus acutissima*	117.54	231.15	20.80	25.49
Platycladus orientalis × *Robinia pseudoacacia*	133.90	198.80	16.42	22.35
Robinia pseudoacacia × *Quercus acutissima*	129.50	300.85	15.24	18.07

3.2 Surface fuels load of different stands

According to Table 2, in the surface litter layer of different forests, the highest load of *Pinus densiflora* × *Quercus acutissima* is 12.33 t/ha, and the minimum load of *Populus* is 5.55t/ ha. In the surface humusr layer of different forests, the highest load of *Pinus tabuliformis* is 7.53 t/ha, and the minimum load of *Robinia pseudoacacia* × *Quercus acutissima* is 1.37t/ ha.

Table 2 Surface fuel litter layer and humus layer load of different forests

Forest	Litter(t/ha)	Humus(t/ha)
Pinus thunbergii	10.61	6.79
Pinus densiflora	9.67	4.89
Pinus tabuliformis	8.11	7.53
Platycladus orientalis	8.12	4.21
Quercus acutissima	9.15	2.93
Robinia pseudoacacia	7.07	1.93
Populus	5.55	2.28
Pinus thunbergii × *Robinia pseudoacacia*	10.18	5.45
Pinus densiflora × *Quercus acutissima*	12.33	2.27

Platycladus orientalis × *Robinia pseudoacacia*	5.61	2.23
Robinia pseudoacacia × *Quercus acutissima*	7.51	1.37

3.3 Ignition points and calorific value of surface fuel of different different stands

According to Table 3, in the same forest, litter ignition points are< humus ignition points, and litter calorific values> humus calorific values. Therefore, litter is more likely to fire than humus. The lowest ignition point of *Pinus tabulaeformis* was 265.67 °C; the highest ignition point of *Robinia pseudoacacia* × *Quercus acutissima* is 285.25 °C. The highest calorific value of Pinus tabulaeformis forest was 20911.78 J/g, and the lowest calorific value of Populus was 15432.05 J/g.

Table 3 Ignition points and calorific values of surface fuel of different forest

Forest	Litter		Humus	
	Ignition point（℃）	Calorific value（J/g）	Ignition point（℃）	Calorific value（J/g）
Pinus thunbergii	268.81±7.09	19346.17±1564.74	311.42±11.54	9475.00±3218.87
Pinus densiflora	275.33±11.42	19118.80±1366.81	307.71±14.11	10417.00±3208.92
Pinus tabuliformis	265.67±5.01	20911.78±1412.85	302.00±10.46	12831.00±2129.42
Platycladus orientalis	276.71±9.91	18737.67±1998.26	312.47±6.40	8859.00±3294.31
Quercus acutissima	280.24±7.27	18080.78±1625.37	318.86±8.19	7459.00±1939.92
Robinia pseudoacacia	283.15±3.03	17156.00±1462.44	321.75±14.26	7084.00±2710.24
Populus	278.41±5.19	15432.05±1299.25	326.23±4.64	6464.96±1795.25
Pinus thunbergii × *Robinia pseudoacacia*	275.94±7.65	19130.65±2437.46	307.79±11.64	8812.51±3429.18
Pinus densiflora × *Quercus acutissima*	277.27±4.13	18701.23±2661.60	316.82±29.67	8367.73±2484.01
Platycladus orientalis × *Robinia pseudoacacia*	281.25±4.39	17675.66±1031.00	319.38±6.39	7909.23±883.91
Robinia pseudoacacia × *Quercus acutissima*	285.25±4.47	16871.63±1506.51	324.70±10.79	12831.00±2129.42

4. Conclusion

The comprehensive analysis of the two shows that the combustion characteristics of fuel on the surface of *Pinus tabulaeformis* are the strongest, and that of fuel on the surface of *Populus* are the weakest.

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