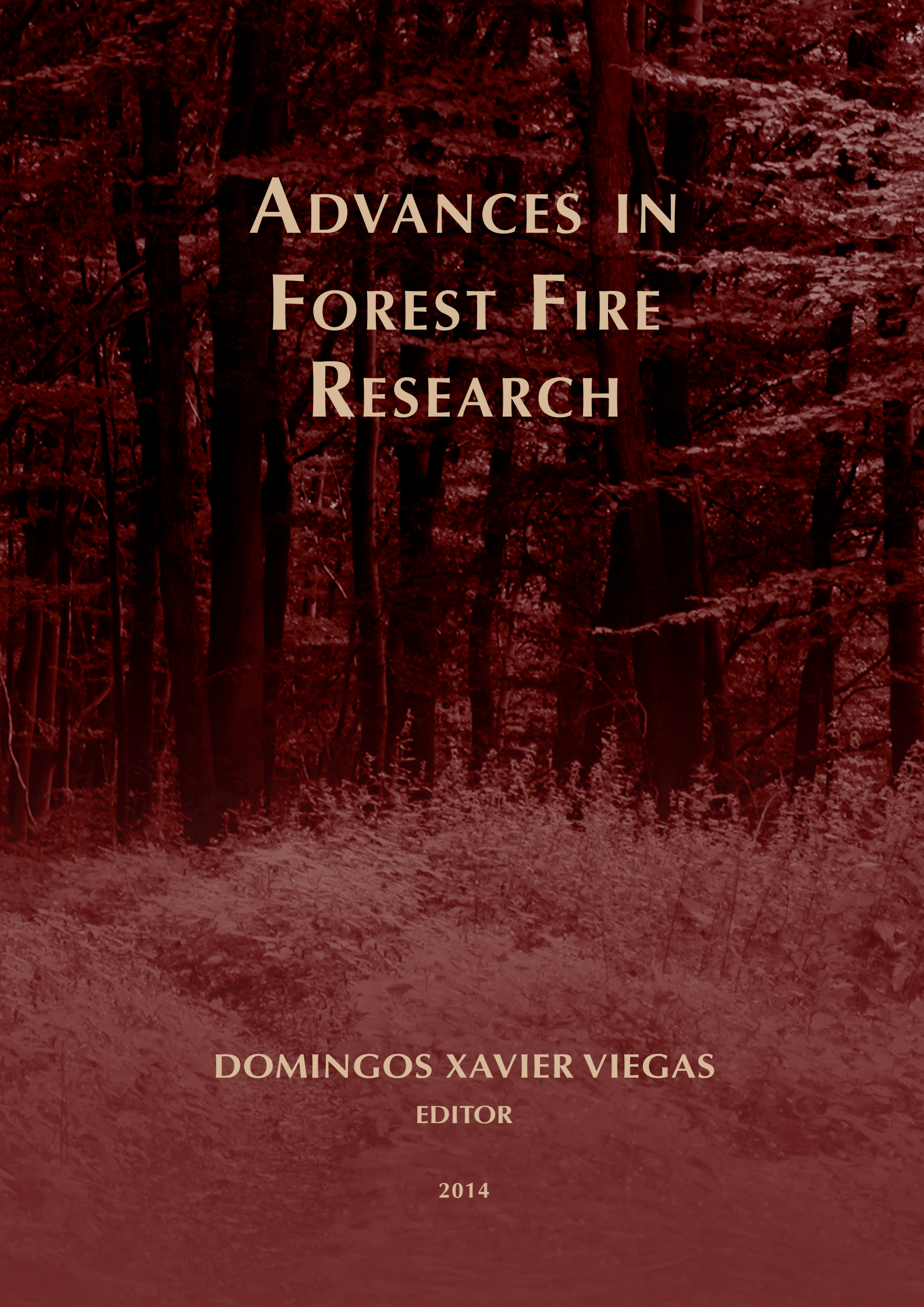

Advances in Forest Fire Research

DOMINGOS XAVIER VIEGAS

EDITOR

2014

Wettability and extinguishing power of different wetting composition for wildland fire fighting

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Abstract
Extinguishing fires of forests is a serious problem for fire services since vast areas can be involved in a relatively short time. For extinguishing fire of forests and peat-bogs is indispensable employment of wetting agents, which by its specificity multiplies speed of penetration burning material. Water is the most frequently used extinguishing agent, but when it is used to extinguish the fires of forests, shrubs, peat-bogs or wildland its efficiency is poor because of its weak capacity to wet and penetrate the cracks of the hydrophobic forest floor. The extinguishing efficiency can be enhanced by adding extinguishing concentrates which reduce the water surface tension. The optimum solution is to use wetting extinguishing agents which hamper the development of a fire by reducing the rate of the fire spread and the combustion intensity.
Wetting agent are mixtures of many components inclusive of surfactants, which are well soluble in water and which lower surface tension value of aqueous solutions and boost ability of solution to wetting of surface hydrophobic material. When added to water, those compounds improve its fire extinguishing properties, and thus improve efficiency of rescue actions. Wetting agents are assigned for extinguishing fire of wood (forest) and peat-bogs, cotton, coal and other smoldering and glowing fires.
This study presents the results of laboratory tests of wetting compositions. The purpose of this study was to determine the wetting power, adsorbing power and extinguishing tests for the wetting agents intended to fight forest fires.

Keywords*: wetting agent, wildland fire-fighting, forest fire*

1. Introduction

Extinguishing fires of forests is a serious problem for fire brigades since vast areas can be involved in a relatively short time. For extinguishing fire of forests and peat-bogs is indispensable employment of wetting agents, which by its specificity multiplies speed of penetration burning material. Wetting agent are mixtures of many components inclusive of surfactants, which are well soluble in water and which lower surface tension value of aqueous solutions and boost ability of solution to wetting of surface hydrophobic material. Wetting agents are used to extinguish both the flaming and glowing phases of combustion by application on the burning fuel. Their effectiveness relies also on their ability to retain moisture and absorb heat by cooling. They remain effective until all water has been removed from the fuel by evaporation [1].
When added to water, those compounds improve its fire extinguishing properties, and thus improve efficiency of rescue actions. Wetting agents are assigned for extinguishing fire of wood (forest) and peat-bogs, cotton, coal and other smoldering and glowing fires. Surfactants in this type of compounds are selected under their abilities to reduce surface tension value in water solutions and increase wetting. The purpose of tests and search for new agents is certainly development and implementation of the best and most effective arrangements. Efficiency of wetting agent is a function of the concentrations and types of the active ingredients that are delivered into the solution. The foam generation, more or less important depending on additive quality and concentration, gives a better insulation of the fire by

flame covering. Additionally, the water coming from drainage helps to cool down the fire and so enhances the extinction.
The wettability is an advantage for forest fire-fighting as it makes better the penetration and spreading of the liquid over a thick vegetal cover.
The foam achieved from solutions of commercial wetting agent and in a concentration 1.0% (v/v), prepared by using municipal water were also compared.

2. Materials and Methods

2.1. Materials

In our studies five commercial extinguishing and wetting agents were used. Characteristic of tested compositions is showed in Table 1.

Table 1. Commercial fire-fighting agents

Commercial fire-fighting agent	Field of application	Recommended concentration [%]	Basic surfactants
Biofor C	forest fires and urban fires plastics, tyres, cotton hydrocarbon fuel	0,1-1,0	salts of fatty alcohol ether sulfates C_{12}-C_{14} - anionic surfactant
Prosintex A	structures and buildings hydrocarbon fuel rubber, plastic, tyres paper, wood, forest fires	0,1-1,0	salts of fatty alcohol ether sulfates C_{10}-C_{14} - anionic surfactant
Forexpan S	forestry and wildland fire structural fires tyres and rubber fires hydrocarbon spill fires	0,1-1,0	salts of fatty alcohol ether sulfates C_{10}-C_{16} - anionic surfactant
Sthamex cl. A	cotton, peat, pulverised coal fires forest and bush fires	0,1 – 1,0	polyoxyethylene glycol dodecyl ether- nonionic
Amber One	forest fires, bush fires and peat bog fires, cotton, wood, paper, pulverised coal fires	0,1 – 1,0	fatty alcohol C12-C15 ethoxy sodium sulphates

2.2. Surface tension

Equilibrium surface tension was measured using the du Noüy ring technique with a Krüss K9 ET tensiometer (Germany) with platinum ring [2]. The surface of each solution was cleaned immediately prior to measurement.
Aqueous solutions were prepared in a wide range of concentrations immediately prior to measurements. All measurements were carried out at 294 K. The average standard deviation of these determinations was equal to 0.2 $mN \cdot m^{-1}$. In all the systems, re-distilled water with conductivity equal to 3 μS was used as the aqueous phase.

2.3. Foaming power

The foam was generated according to standard EN 1568-3 [3] from an aqueous solution of the wetting agent at a concentration of 1.0 %. This method consists of measuring the foam volume in a 1 L cylinder.

The expansion ratio (E), given in Eq. (1), is the proportion of the volume of foam (V_{foam}) to the volume of solution ($V_{solution}$) from which it was made.

$$E = \frac{V_{foam}}{V_{solution}} \quad (1)$$

All measurements were carried out at 294±2 K. The average standard deviation of expansion ratio determinations was equal to 1.5 %.

2.4. **Wettability**

100 g of wetted material (peat or wood bark) was dried in order to achieve moisture content of approximately 8–10 % . Next the wetted material was placed in steel mesh baskets, weighed, and spayed by studied solutions of wetting mixtures. Then, the bottom of the basket was dried with absorbent paper and the basket with wetted material was weighed. For estimating wettability W (%) the following equation was used:

$$W = \frac{m_1 + m_0}{m_0} \cdot 100\% \quad (2)$$

where m_1 is the mass of wetted material after spaying by tested solution and m_0 is the mass of dry peat or wood bark which is equal to 100 g.

Measurements were conducted at 294±2 K. The average standard deviation of these determinations was equal to 3 %.

2.5. **Extinguishing test**

Tests of the effectiveness of extinguishing fires of solid materials were performed in accordance to method described in standard EN 3-7 [4] using portable fire extinguishers of 2 L volume filled with 1% solutions of the wetting mixtures analysed. After extinction no burnback was observed for any studied compositions.

Measurements were carried out at 294±5 K. The average standard deviation of extinction time determinations was up to 2s.

2.6. **Retardancy**

The peat was soaked by 1% solutions of wetting compositions and dried to obtain moisture below 13%. Next the 100 g of peat was put in basket and ignited by propan (propan-butan) pilot burner. Measurements were conducted from the start of ignition of pilot burner till the smoldering of fuel was observed.

Measurements were carried out at 294±5 K. The average standard deviation of extinction time determinations was up to 2s.

3. **Results**

3.1. **Surface tension**

In the Figure 1 values of surface tension of studied agents were showed. The surface tension of the analysed wetting compositions varies between 26 mN/m (for Sthamex A) to almost 30 mN/m (for Amber One). Typical values of surface tension for solutions of extinguishing agents is below 35 $mN \cdot m^{-1}$.

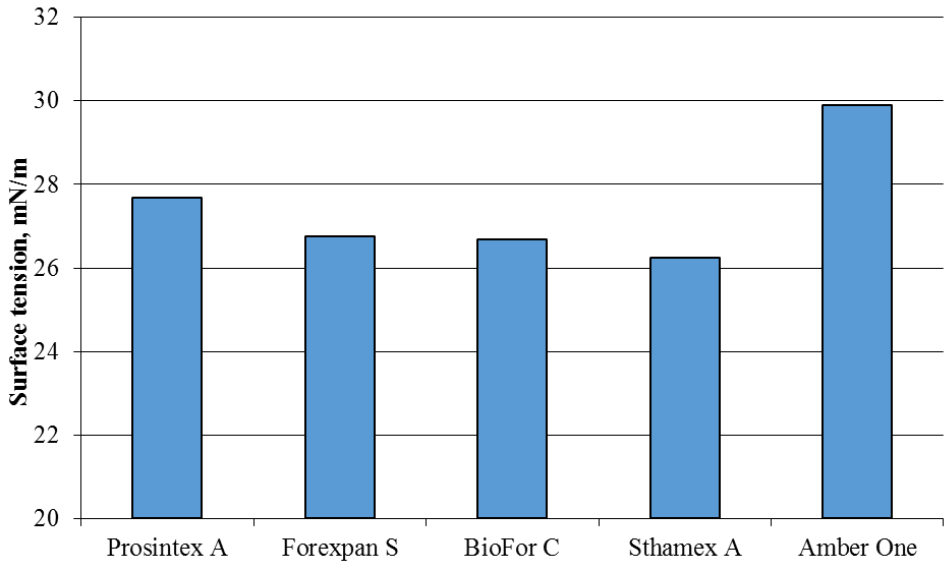

Figure 1. Surface tension of the analysed wetting compositions

3.2. **Foaming power**

The results of foaming properties were presented in the Figure 2. The foaming power of analysed wetting compositions varies between 5 (for Prosintex A) to 8 (for Sthamex). For good properties of wetting and extinguishing fire of natural hydrophobic material a low foamability (between 4-6) is required.

In the Fig 3 time to drainage of 25% and 50% of foam volume were showed. Short time of draining is demanded for quick speeding of wetting agent on the flammable surface.

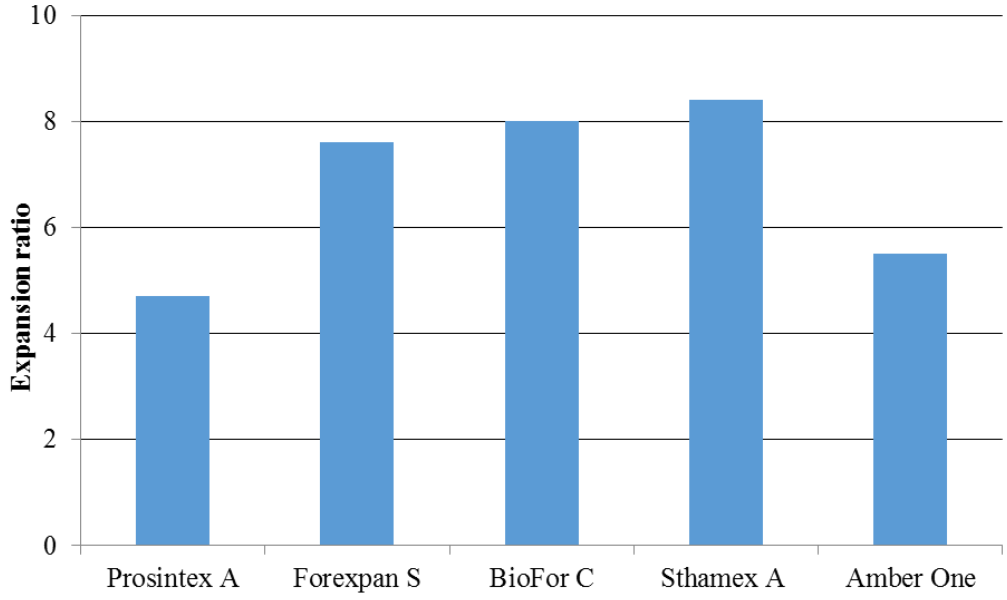

Figure 2. Foaming power of analysed wetting compositions

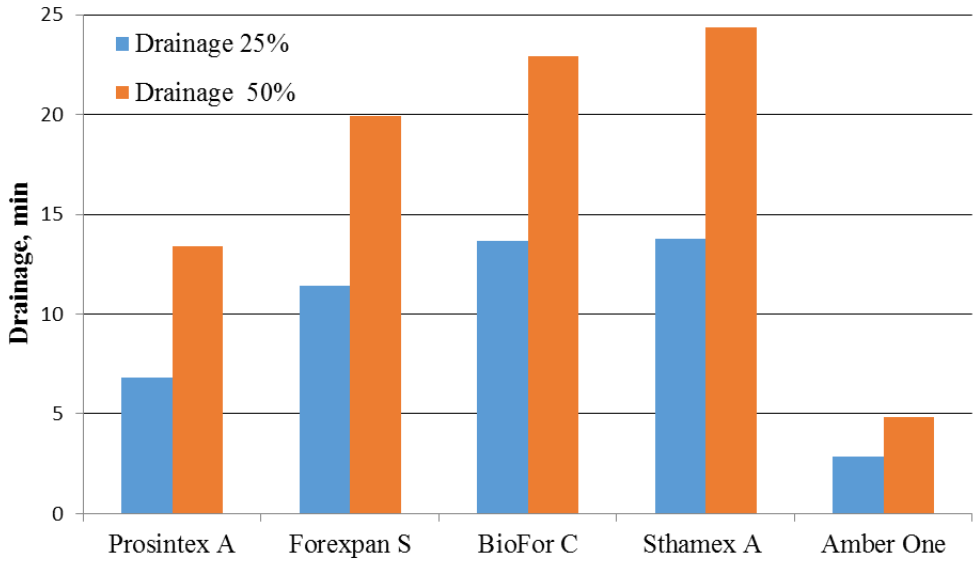

Figure 3. Drainage time of the produced foam for analysed wetting compositions

3.3. **Wettability**

In the Fig 4 and Figure 5 the wetting power of studied wetting agents were showed. At the concentration of 0,10% all of the analysed wetting compositions have comparable wettability of peat. The highest wettability was recorded for Amber One and Forexpan S. Wettability for this two wetting compositions was comparable at concentration 0,5% and 1,0%.

The highest wettability of bark was recorded at the concentration of 1,0%. In this respect the best was BioFor C and next Sthamex A, Forexpan S and Amber One.

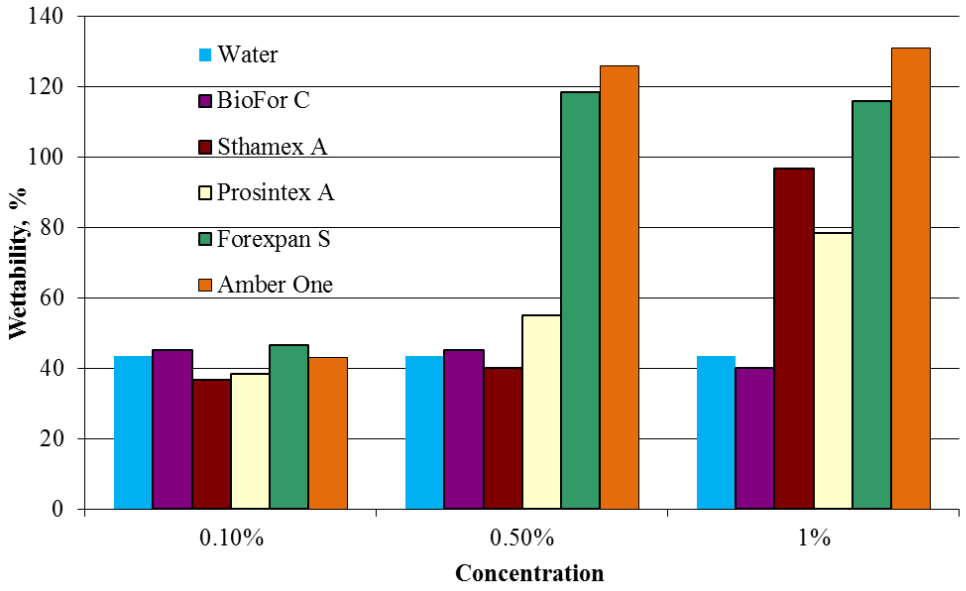

Figure 4. Wettability of peat with the analysed wetting compositions versus to concentration

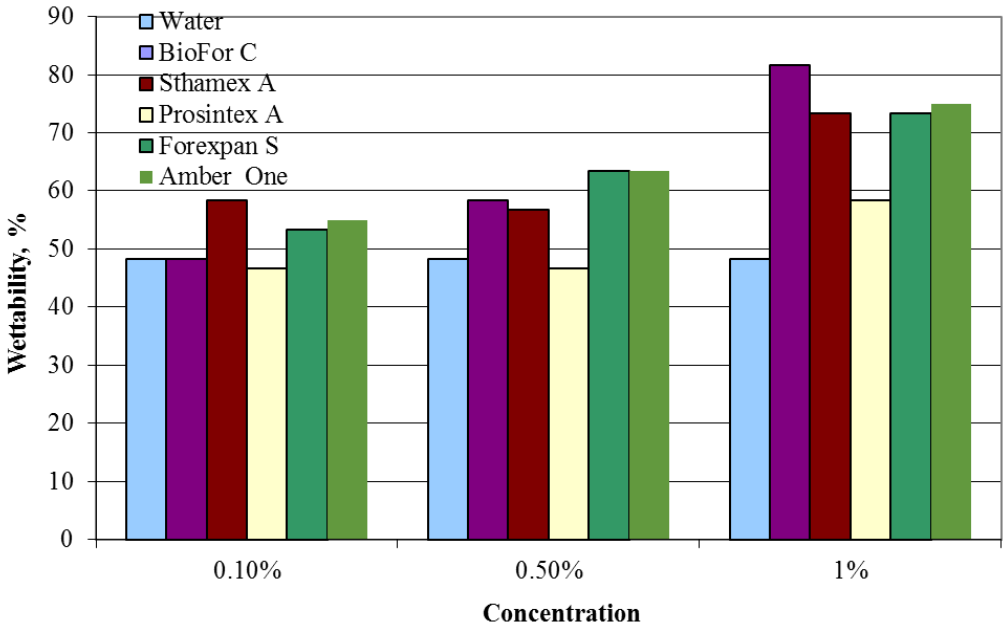

Figure 5. Wettability of bark with dispersed stream of the analysed wetting compositions.

3.4. **Extinguishing test**

The results of extinguishing tests were presented in the Figure 6. The times required for the wetting agents used to extinguish fires proved to be up to two times shorter than the time required for synthetic extinguishing agents typically applied in fighting fires of solid porous materials. Once the flames were extinguished by applying each of the solutions investigated, no return of fire was observed.

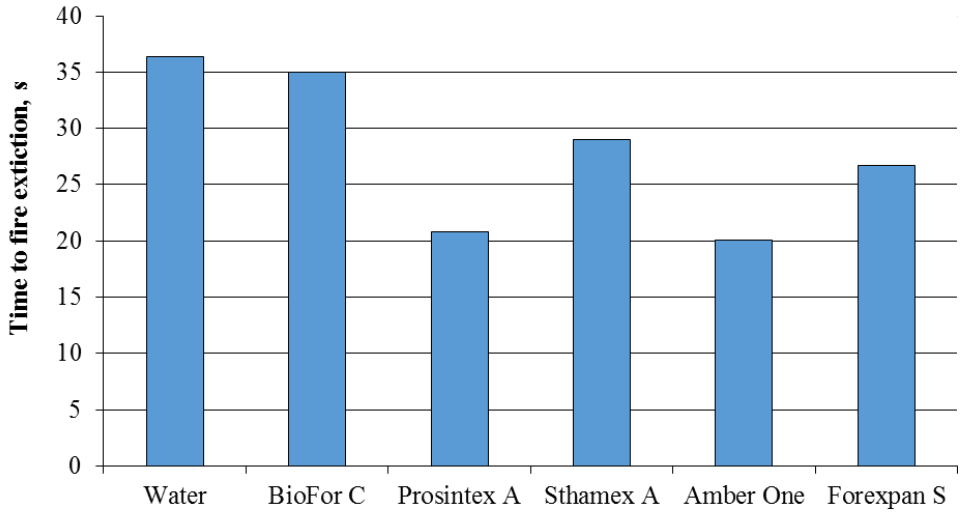

Figure 6. Extinguishing time of test fire 5A [5]

3.5. **Retardancy**

In the Figure 7 a comparison of delaying time to inflammation of dry peat was presented. Unprotected peat sample has an inflammation time of 25s. After wetting composition treatment inflammation time was extended by 5s (for Biofor C) up to 15s (Forexpan S).

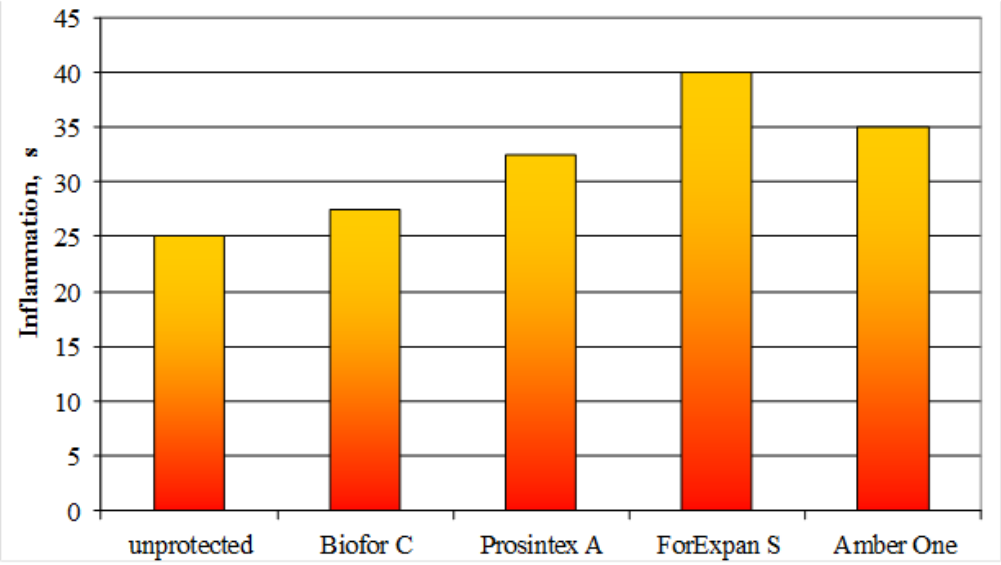

Figure 7. Inflammation time of peat sample

4. Conclusions

- Wetting agents added to water for lowering surface tension and improving wettability. The foaming of extinguishing agent for suppression wildland fire should not be so high like to agent used to extinction for liquid fuel.
- The use of wetting agents reduces the time to extinguish the fire and delaying burnback.
- Wetting agents can be used as a short-term retardants.
- Application of the wetting agent helps to reduce the size of burnt areas of forest and decreases the number of fatalities, as well as material and ecological losses.

5. Aknowledgement

This work was financially supported by MNiSW as project R00-O0046/03 in years 2007-2010 and 016/BC/CNBOP-PIB/2011-2016.

6. References

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