Response Reaction of Scots Pine *Pinus sylvestris* L. After Forest Fire in Forest Site Type *Vacciniosa turf. mel.* in Klīve Forest District

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Abstract

It is important to conduct studies on the fire impact in different forest site types in order to obtain information for the planning of forestry activities, financial gain or loss prediction after the forest fire. The topic is current because in the scale of Latvia there is no significant research about the fire impact on radial growth of trees.

The study analyzes impact of fire occurred nine years ago in middle-aged Scots pine stand growing in forest site type *Vacciniosa turf.mel.* During the research mortality of trees were compared and sanitary conditions in areas affected by the forest fire and in unaffected areas were evaluated as well as the analysis of forest fire impact on the dynamics of radial growth of the stand was carried out.

For the collection of empirical data five sample plots in the affected part by fire and five in unaffected part of the stand were established each 500 m^2 large. The diameter and height of trees and height of the scorch were measured, Kraft class were established, cores were taken for measuring the width of annual rings, and sanitary conditions were estimated listing cracked barks caused by fire, insect damages, bark openings at the root collar and exposed roots.

Analysis of the data shows that forest fire does not significantly affect the amount of tree mortality as evidenced by analysis of variance ($p<0.05$). In assessing the sanitary conditions it was found that between all tree damages after fire cracked bark have the greatest proportion (14%), followed by insect damaged trees (7%), trees with bark opening at the root collar (4%) and trees with exposed roots (3%). There is a significant difference between the number of cracked bark in different diameter groups and in the groups of the maximum height of scorching, most of them are found in diameter group up to 20 cm and in the maximum scorching group from 1.51 m to 2.00 m. The effect of fire impact on growth dynamics of tree stand is negative creating a volume reduction in average of 2 m^3 ha^{-1} per year. Overall volume reduction of stand since 2004 is 18.7±0.21 m^3 ha^{-1}, potential loss reach 704.14 LVL i.e. 950.25 EUR.

Key words: forest fire, Pinus sylvestris L., dynamics of radial growth, sanitary condition, forest site type Vacciniosa turf. mel.

Introduction

Scots pine *Pinus sylvestris* L. is one of the three economically significant tree species in Latvia occupying 35% (1,003,625 ha) of the Latvian forests (State Forest Service, 2013). One of the treats to successful forest stand development is forest fire. The statistics of forest fire in Latvia over last twenty years show that occasionally extreme of fire are observed. In 2006 when the last extreme of fire was observed 3.8 thousand ha or 0.13% of Latvian forests suffered from fire (State Forest Service, 2013). It is expected that within the next 100 years air temperature in Latvia in spring and summer - the most inflammable period - will increase on average by 3 °C and 2 °C respectively (Jansons, 2012) so it is necessary to pay more attention to forest fires and to analyze their impact on forest stand. In Latvia studies have been conducted on the tree including Scots pine, insects-dendrophages damage and vitality after forest fire but so far there are no major studies on dynamics of radial growth of pine after forest fire. Forest fire impact is among the actual themes where fire impact on ecosystems, soil and ash characteristics is researched (Pereira *et al*, 2012). The aim of the study is to evaluate the impact of forest fire on the growth of middle-aged Scots pine growing in forest site type *Vacciniosa turf.mel.* It was reached caring out tree scientific tasks: comparison of the proportion of tree mortality in the area affected by fire and unaffected area of the stand, analysis of the impact of forest fire on the radial growth of trees as well as assessment of stand sanitary conditions affected by fire and unaffected area of the stand. Researched forest stand covers an area are 4 ha. Nine years ago in 2004 there detected a forest fire. A fire type – creeping groun fire combined with shallow subsurface fire (Bušs, Vanags, 1987, Kronītis, 1972, Roga, 1979, Rokjānis, 2003), burnt area – 2 ha. The thickness of peat layer there was of an average of 22 cm.

Research methods

Empirical data material was collected in five circular plots in the forest stand part affected by fire and five in unaffected part of the stand, area of one sample plot was 500 m^2. For all of the trees in each plot diameter 1.3 m above root collar was measured, Kraft class (Kraft, 1884, Miezite, 2013) was determined, measuring of peat layer was done, for 25 trees drilling towards to the centre of the plot at the height of 1.3 m above the root collar using Pressler borer was made. Tree height of all bored trees was measured (Liepa *et al*, 2013). Maximum height of scorching was measured; trees with insect damage, bark openings at the root collar caused by fire, trees with exposed roots and cracked barks were listed. Cracked bark is opened, by bark unprotected wood which is bounded by wood lumps and formed in the result of mechanical abrasion of bark, as well as in the result of fire (Вакин *et al*, 1980). Height at the root collar, length and width of the cracked barks were measured. For measuring of width of tree-rings Lin TAB system microscope was used. Data processing was made using computer software T-Tools Pro, Microsoft Office Excel and VidesFIV (Vides Faktoru Ietekmes Vērtēšana) computer software developed in Latvia University of Agriculture (Liepa *et al*, 2013). Mathematical calculations of the software are based on the algorithms given by professor I. Liepa.

Proportion of damaged or dead trees (P, %) is calculated using the following formula -

$$P = \frac{n}{N} \cdot 100 \,, \tag{1}$$

where

n – number of damaged or dead trees, pieces ha^{-1};

N – total number of trees, pieces ha^{-1};

Results and discussion

Comparison of the amount of tree mortality in fire affected part and unaffected part of the stand

The proportion of deadwood in fire affected part and in unaffected part of the stand is not high (Table 1), it consists of IV and V Kraft class trees, so those who are already doomed – stunted, depressed by other trees, with small dimensions.

Table. 1. **Proportion of tree mortality in fire affected and unaffected area**

Sample plots (SP)	Total number of trees measured in SP pcs.	Number or healthy trees in SP, pcs.	Number of dried trees		Amount of dead trees, %	Volume of mean tree, m^3	Deadwood volume, m^3 ha^{-1}
			SP, pcs.	pcs. ha^{-1}			
Fire affected part of the stand	219	212	7	28	3.2	0.4629	13.0
Fire unaffected part of the stand	196	191	5	20	2.6	0.4584	9.2

Tree mortality depending on their dimensions is also confirmed by research of J. Donis (2010). The results confirm that the smaller dimension trees have higher risk of mortality. In plots located in the part of stand affected by fire 7 trees were perished but in the unaffected part – five, respectively 28 and 20 trees ha^{-1} (3.2% and 2.6% of all trees). Deadwood volume in the area affected by fire is 13.0 m^3ha^{-1} and in unaffected area - 9 m^3ha^{-1}.

Small difference of the amount of mortality between fire affected and unaffected part of the stand can be explained by the fact that pine has reached middle age and thicker bark has developed (Zviedre, Mangalis, 2003), crowns are significantly higher than the crowns of young trees, so resistance to fire is higher. This is confirmed by the research carried out in Finland, the results show that with the increase of the intensity of fire, scorches significantly increase in 15 to 45 year old pine stands but in 40 to 60 year old stands such effect has not been observed (Tanskanen, 2007). The results of Sidroff (2007) research indicate that the amount of tree mortality of *Pinus sylvestris* L. stands decreases with age. Hypothesis that fire impact on the mortality of trees in forest stand is not significant in this object is confirmed by analysis of variance ($F_{stat.} = 0.29 < F_{crit.} = 5.32$, $p = 0.607 > \alpha = 0.05$).

Graphical representation of comparison of deadwood volume (Figure 1) shows that there is no significant difference between tree mortality in fire affected and fire unaffected area ($\alpha = 0.05$).

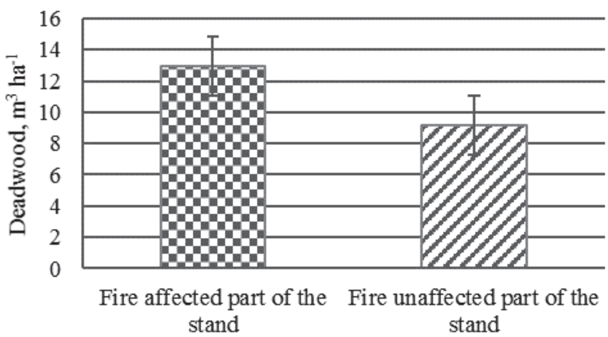

Figure 1. **Comparison of deadwood volume (M±$s_{\bar{x}}$) in fire affected and fire unaffected area.**

Forest fire impact on the dynamics of radial growth of tree stand

Forest fire impact on Scots pine radial growth is given in the graphs of changes of the width of annual rings in the fire affected plots and unaffected (control) plots (Figure 2) where thinline shows the width of annual rings of control stand (KONT), black line – widths of annual rings of trees affected by fire (VIV) but dash line – predicted widths of annual rings in the absence of fire impact. On the X-axis interval of years when annual rings were measured is given - the first six years is the period of retrospection but the next nine years is the period of the assessment of fire impact. On the Y-axis the widths of annual rings are given.

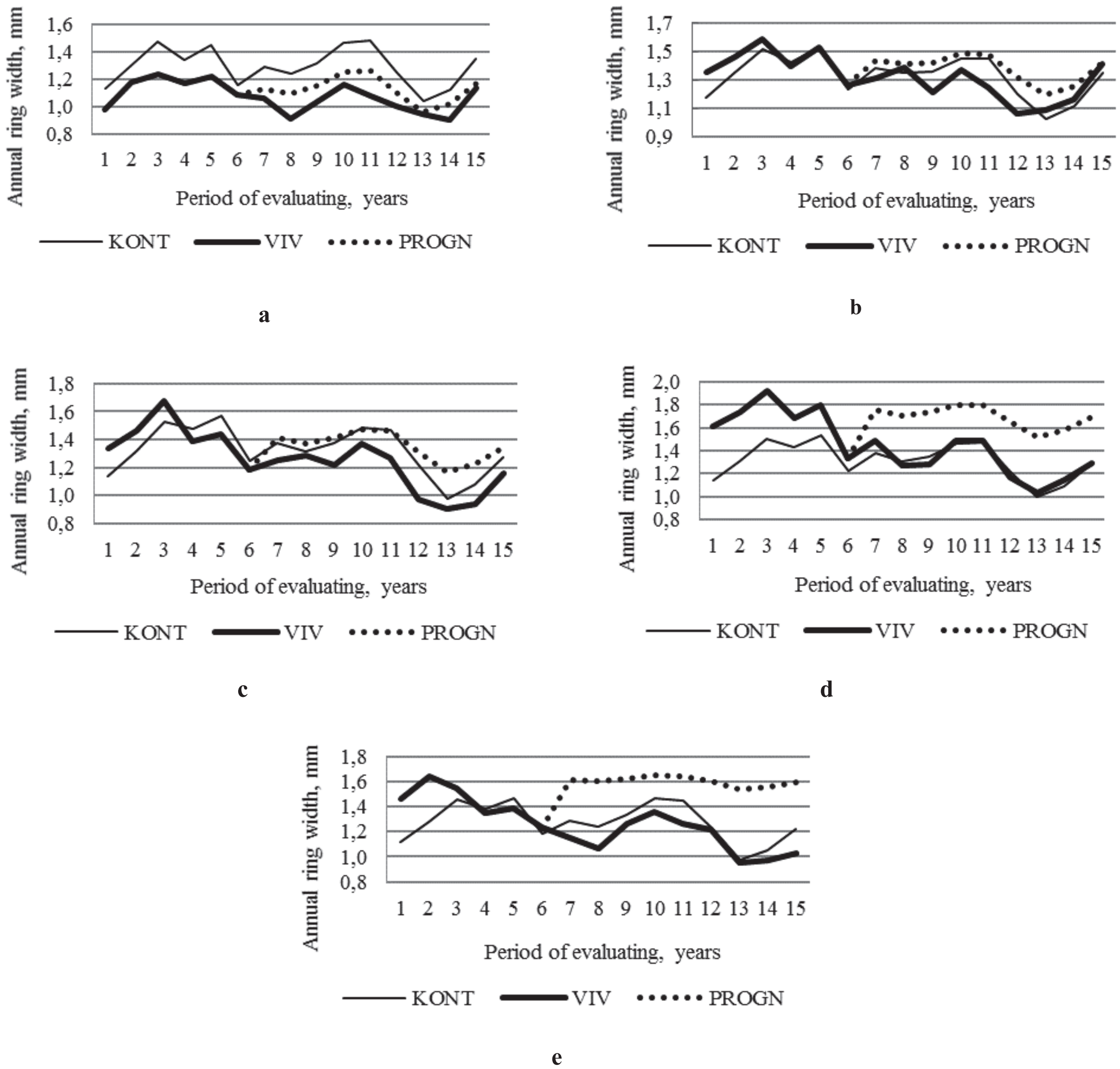

Figure 2. **Changes of the widths of annual rings in the fire affected plot and in control plots**: a – first fire affected plot, b – second, c – third, d – fourth, e – fifth.

Dynamics of the Scots pine radial growth after forest fire in all fire affected plots is similar – with a negative trend in growth dynamics contrary to the results of K. Cirse (2013) where the results show a positive growth trend. The difference between both studies is due to the different forest site types included in research (forest stand on mineral soils and forest stand on peat soil) and fire type which in the case of K. Cirse is creeping ground forest fire but in current research - creeping ground forest fire combined with shallow subsurface fire.

Looking at the graph of changes of the overall width of annual rings in the fire affected plots and unaffected plots (Fig. 3) it can be concluded that forest fire has negative effect on radial growth of the stand. This potential result of forest fire is also noted by I. Liepa (1991).

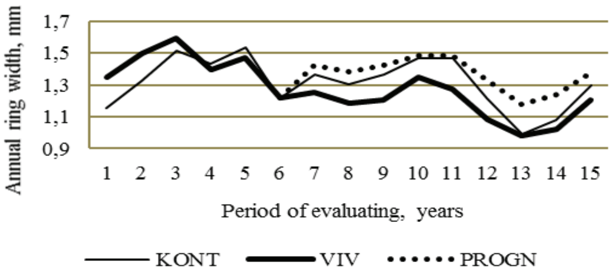

Figure 3. **Changes of the width of annual rings in fire affected and fire unaffected plots and predicted widths of annual rings in the absence of fire impact.**

Numerical comparison of mean values of the widths of annual rings in fire affected and fire unaffected plots before and after fire (Table 2) shows that evaluating the width of annual rings in the borders of sample plots before and after fire the average width is 0.11±0.018 mm narrower and in comparison of control stand - 0.18 ± 0.030 mm.

Table 2. **Difference of mean width of annual rings between control and fire affected plots before and after forest fire**

Time	Difference of widths of annual rings in sample plots, mm					
	Sample plot					Average
	Fire affected_1SP	Fire affected_2SP	Fire affected_3SP	Fire affected_4SP	Fire affected_5SP	
After forest fire	-0.26 ± 0.029	-0.05 ± 0.034	-0.13 ± 0.021	0.01 ± 0.017	-0.11 ± 0.023	-0.11 ± 0.018
Before forest fire	-0.16 ± 0.025	0.06 ± 0.032	0.03 ± 0.060	0.32 ± 0.057	0.12 ± 0.077	0.07 ± 0.050
Difference of widths of annual rings after forest fire	-0.10 ± 0.023	-0.11 ± 0.027	-0.16 ± 0.039	-0.31 ± 0.047	-0.23 ± 0.044	-0.18 ± 0.030

Table shows the average values obtained from the difference of the width of annual rings between plots affected by fire and unaffected plots. Negative numbers indicate that annual rings obtained in the plots affected by fire are narrower than in fire unaffected (control) plots while positive ones – to wider annual rings in the fire affected than the unaffected part of the stand. The table shows that the negative growth increases after the fire.

The effect of fire impact (Fig. 4) illustrates the negative impact of forest fire on trees in the research object. Plots are encrypted under the following names: the first plot in fire affected area - „ Fire affected_1SP", the second – „ Fire affected_2SP" and as follows.

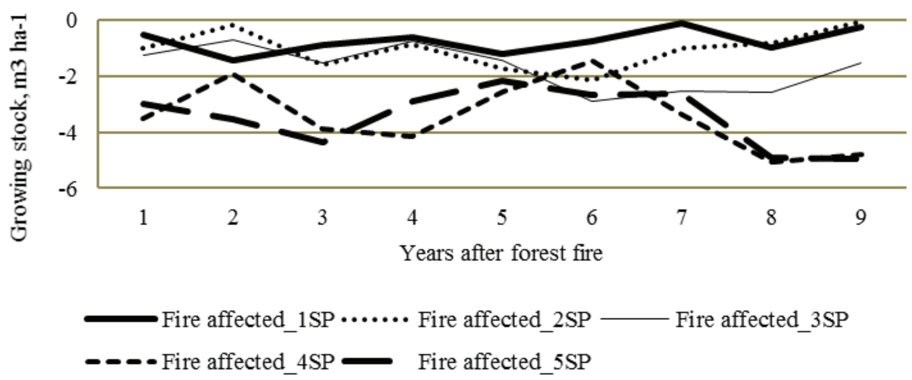

Figure 4. **The effect of forest fire impact in the fire affected plots.**

Significant negative growth was observed in the fourth and fifth plot which can be explained by the relatively large amount of cracked barks caused by fire in these plots. Fluctuations by years hypothetically can be explained by the impact of meteorological factors and the amount of ash formed as result of ground vegetation, litter and undergrowth combustion. Ņesterovs (1954) notes that the ash formed from low intensity forest fire encourages the growth of forest stand. In the second, third and fourth plot growth conditions in the second year although the impact effect is still negative have improved. This can be explained by combustion caused ash disposal and infiltration in the soil. In later years the existing fluctuations between plots can be explained by meteorological factor what accumulates in the result of stand heterogeneity. The third plot line is placed between the first and the last two (4th and 5th) plots so it has features of both the first and the second as well as of the fourth and fifth plot.

As the result of forest fire an average of 2 m^3 ha^{-1} of additional growth are lost every year, in nine years since the forest fire makes a total of 18.7±0.21 m^3 ha^{-1}.

Sanitary conditions in the fire affected part and unaffected part of the stands territory

In the research object sanitary conditions were evaluated in four categories: trees with cracked barks caused by forest fire, insect damaged trees, trees with bark openings at the root collar, trees with exposed roots. As you can see in the graph of damage intensity (Fig. 5) the sanitary conditions in fire unaffected area are good, but in fire affected part of the stands cracked barks can be observed in the 14% of cases, insect damage occur in 7% of cases, bark openings at the root collar and exposed roots can be observed in less than 4% and 3%, respectively.

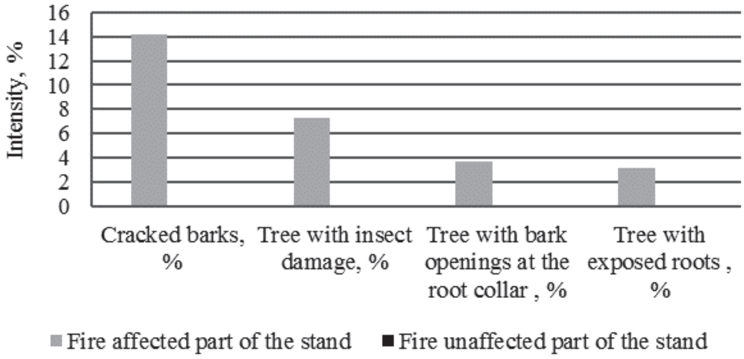

Figure 5. **Damage intensity in fire affected and unaffected part of the stand**

As the most common damage is cracked bark incidence of it in different tree diameter and maximum height of scorching groups was analyzed. Evaluating different diameter groups it should be marked that cracked barks are the most observed in group up to 20 cm and 20-25 cm, 64 pieces ha^{-1} and 48 pieces ha^{-1} respectively (Fig. 6).There is no significant difference between these two groups in the number of cracked barks but between them and the number of cracked barks in diameter rating group > 25 cm a significant difference appears.

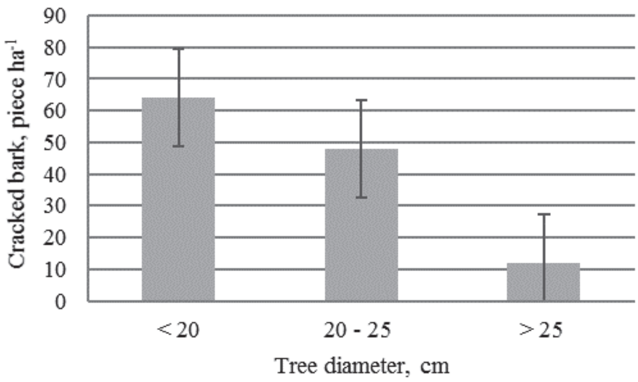

Figure 6. **Number of cracked barks ($N \pm s_{\bar{x}}$) in diameter rating groups**

Analyzing cracked bark by maximum height of scorching (Fig. 7) five groups are distinguished where the first up to 1.50 m, the second - from 1.51 to 2.00 m, the third - from 2.01 to 2.50 m, fourth - from 2.51 to 3.00 m, the fifth – scorched higher than 3.00 m. The most part of cracked barks (48 pieces ha^{-1}) was observed in height group 1.51 to 2.00 m.

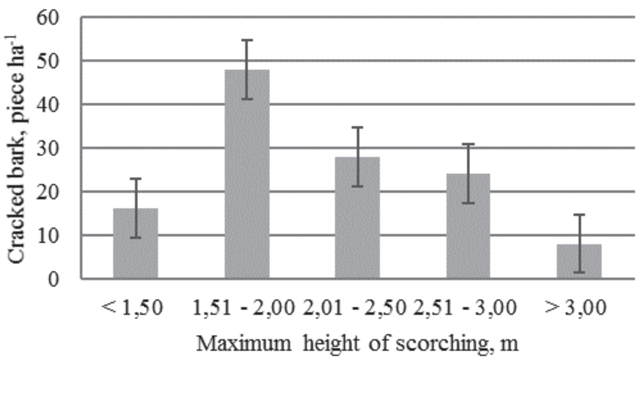

Figure 7. **The number of cracked barks ($N \pm s_{\bar{x}}$) in the groups of maximum height of scorching**

Number of cracked barks is significantly different among scorching height groups while between the first, the third and the fourth group there are not significant differences. Significant difference is between the fifth (8 pieces ha^{-1}) and the other height groups.

Dead wood and lost potential wood increase after forest fire in the evaluated forest stand reach 704.14 LVL i.e. 950.25 EUR (Table 3).

Table 3. **Calculation of dropout and potential timber increase loss after the forest fire**

Lost timber volume, m^3 ha^{-1}		Timber price, m^3, LVL	Timber price, m^3, EUR	Potential loss, LVL	Potential loss, EUR	Total potential loss, LVL	Total potential loss, EUR
Lost potential wood increase after forest fire	18.7±0.21	27.00	38.16	504.90±5.67	713.64±8.01	704.14	950.25
Volume of dead wood	7.4	27.00	38.16	199.24	281.61		

Scots pine round wood purchase parameters from Ltd. „BALTIC TIMBER.LV" (www.baltictimber.lv) and average pulpwood purchase price from www.mezi.lv were used, currency rate from www.swedbank.lv was used (14.06.2013.).

Conclusion

In researched stand forest fire does not significantly affect the amount of tree mortality ($F_{stat.} = 0.29 < F_{crit} = 5.32$, $\alpha = 0.05$).

In the fire affected part the annual tree rings is narrower than in unaffected part of the stand, difference reach 0.18±0.030 mm.

Forest fire has a negative effect on the growth of researched stand. Each year the average wood loss reaches 2 m^3 ha^{-1}. Nine years after the forest fire forest owner has already lost 18.7±0.21 m^3 ha^{-1} or 704.14 LVL i.e. 950.25 EUR from the stand.

Fire exposure in researched stand not only has a negative impact on growth but it also worsens sanitary condition of stand. After forest fire fire caused cracked barks (14%), insect damage (7%), bark openings at the root collar (4%) and exposed roots (3%) are observed.

The number of cracked barks is significantly different in several diameter groups and maximum height of scorching groups.

Most cracked barks are found in diameter groups up to 20 cm and 20-25 cm and the maximum height of scorching group from 1.51 m to 2.00 m.

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