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The first three-year development of ALASIA poplar clones AF2, AF6, AF7, AF8 in biomass short rotation coppice experimental cultures in Latvia

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Abstract. Hybrid aspen and willows are the fastest growing tree species used for biomass production in short rotation coppice (SRC) cultures in Latvia. Poplars are suitable for cultivation in Latvia, however, their potential for this purpose as SRC in Latvia and North Eastern Europe has not yet been investigated. There is an increasing interest in using poplar clones to establish short rotation plantations. The aim of this study is to analyse the productivity of the Italian poplar clones AF2, AF6, AF7, AF8 and their potential use for biomass production, as well as the effect of fertilization on the development and survival of trees.

The experimental plot consisted of drained mineral soil with the initial spacing of trees ranging from 9,000 to 10,000 trees ha^{-1} (1.5 m x 0.7–0.5 m). Weed management has been carried out on the plantation once per season every year. Four management methods were tested – control (no fertilization), fertilization with waste water sludge 10 t DM ha^{-1}, wood ash 6 t ha^{-1}, mineral fertilizer NPK (12:5:14) 100 kg ha^{-1}.

In the second year, the height of the trees ranged from 0.2 to 2.64 m, on average 1.12 ± 0.005 m. The annual increments during the third year ranged from 0.01–2.14 m, on average 0.787 ± 0.004 m. At the end of the third season, the tree diameters at breast height of all clones varied greatly from 0.36 cm to 4.4 cm. The trees reached average diameters of 1.48 ± 0.007 cm; the tree heights ranged from 0.36 m to 4.24 m and were 1.99 ± 0.01 m, on average at the end of the third season. Depending on the clone and treatment, the amount of fresh biomass was 1.57–10.67 t ha^{-1}(planting density 10,000 trees), and one fifth of the biomass, on average, was located in branches.

Sewage sludge fertilizer contributed to the development of the micropatogen *Venturia sp.*, resulting in lower initial retention and delayed development. Mineral fertilizers were the most effective. No animal and frost damages were observed. Overall, the results indicate a significant potential for us for using poplar for bioenergy production, with the optimal rotation age for bioenergy production being more than 3 years.

Key words: *Populus*, fertilization, growth, increment.

INTRODUCTION

During the period from 2009 to 2013, the cultivation of *Populus sp.* and *Salix sp.* in short rotation coppices (SRC) gradually developed into an energy wood production business in Latvia. This resulted in the need for a supply of appropriate planting material, the availability of specialised contractors for planting and harvesting measures, as well as the practical 'know how' to establish and maintain *Salicaceae,* including *Populus sp.,* plantations. The knowledge of how to develop *Populus* plantations in their calculated stand time and with the predictability of the expected growth and biomass yields related to a certain site type is still lacking. In addition, there is a demand for productive poplar and willow clones in Latvia.

Bioenergy plantations are expected to become the most important source of biomass for energy purposes on a global scale (Mizey & Racz, 2010), while in Latvia, it is just expected to be an additional source of woody biomass (Būmanis, 2007; Būmanis, 2012). In Latvia, no more than 100 ha of poplars are planted. Investors from Scandinavia and 'Old Europe' are mostly interested in establishing SRC.

Several projects were supported with experimental plantations by the Fachagentur Nachwachsende Rohstoffe (Agency for Renewable Resources) and other institutions with a view to answer questions about the practical cultivation, profitability and selection of suitable species and varieties in Germany. The total area of short-rotation coppices in Germany has increased to 4,000–5,000 ha since 2012 and continues to increase significantly (Wühlisch, 2012).

Italy's interest to increase the contribution of agro-energy towards national energy demand is increasing and new incentive-providing instruments have been approved. For example, the so-called Renewable Energy Certificates (Gasol et al., 2010), specifically focussed on electricity and thermal energy generation (González-García et al., 2012), like in Latvia (LME, 2013). Recent changes in the Common Agricultural Policy of Europe incentivize farmers to grow energy crops and rapid development of the bioenergy sector. During last year's short rotation, coppices were established on about 6,500 ha, mainly in the Po Valley area (Spinelli et al., 2008; Fiala et al., 2010). In Italy, the woody species suitable for SRC are poplars, willows, black locust and eucalyptus; however, most plantations consist of specific poplar clones (Fiala et al., 2010).

In Sweden, substantial areas of willow coppice were established between1980 and 1990 when the Swedish government subsidized land conversion, with the aim of decreasing the farmland area by 0.5 million hectares. As a result, 15,000 ha of commercial SRF willow plantations, along with 500 ha of poplar plantations, existed by the end of 1990 (Johansson & Karacic, 2011). Over the long-term, the mean annual yield of hybrid poplars of the Swedish experiment was 6.7 ton ha^{-1} $year^{-1}$, in a 24 year rotation period. After 6–12 years of growth (1,100–5,000 trees ha^{-1}), high yields were recorded in Southern and Central Sweden (Telenius, 1999; Karasisc et al., 2013).

The Department of Forest Tree Genetics and Breeding Institute of Forestry of the Lithuanian Research Centre for Agriculture and Forestry has collected approximately 74 poplar clones; however, in practice, willows and hybrid poplars are mainly planted on agriculture land (personal communication with Dr. Habil. Alfas Pliura Senior Research Scientist).

Poplar research activities in Estonia were active in the 1960s (Tamm, 1967). Like in Latvia (Saliņš & Smilga, 1960), it was planned at the time to use poplars for greening and as 'fast wood' for pulp and timber production. Nowadays, research activities are mainly related to hybrid aspen investigations (Tullus et al., 2012).

The interest among Latvian scientists and practitioners to increase the contribution of the agro-energy system based on short rotation crops to the national energy demand has increased in recent years and, nowadays, direct payments are granted directly to farmers under a support scheme – the Single Area Payment Scheme (SAPS) for cultivating fast growing ligneous plants, such as *Populus sp., Salix sp. and Alnus incana* (Rural Support Service, 2014), specifically focussed on electricity and thermal energy generation.

Poplar, like hybrid aspen, is desirable for longer period cultivation, because it has high quality timber, which can be used as sawn timber, panels, pulpwood production, and veneer (Spinelli et al., 2008; Johansson & Karacic 2011; González-García et al., 2012).

MATERIALS AND METHODS

An experimental plot was established on agricultural land in the central part of Latvia (56°41 N and 25°08 E) in the spring of 2011. The experimental plot (16 ha) is divided into compartments of different species establishing agroforestry systems to investigate the growth of herbaceous energy plants together with trees as a multifunctional plantation of short rotation energy crops and deciduous trees. Poplars were planted on 2 ha in total.

The ALASIA poplar hybrid clones AF2 (*P. deltoides 145-86 x P. nigra 40*), AF6 (*P. x generosa 103-86 x P. nigra 12*), AF7 (no information), AF8 (*P.xgenerosa 103-86 x P.trichocarpa PEE*) (www.http://www.alasiafranco.it) were planted using 20 cm long cuttings with the density of 15 cm x 70–50 cm. Cutting producers and suppliers were performed by an Italian company, ALASIA NEW CLONES. Weed management was performed once per season.

The soil type is *Phaeozems/ Stagnosols* with the dominant loam (at 0–20 cm depth) and sandy loam (at 20–80 cm depth) soil texture. The soil chemical content and nutrients added in the course of initial fertilization have been described in earlier articles (Rancane et al., 2012; Bārdule et al., 2013), first class (according to the Regulation of the Cabinet of Ministers of the Republic of Latvia No. 362) waste water sludge (wws) (dose 10 t DM ha^{-1}) from Ltd. 'Aizkraukles ūdens' (Aizkraukle Water) and stabilised wood ash from a boiler house in Sigulda (dose 6 t DM ha^{-1}) were spread mechanically before the planting (Table 1).

Table 1. Chemical composition (content of elements, g kg^{-1}) of wastewater sludge and wood ash

Fertiliser	N	P	K	Ca	Mg	Mn	Fe	Na
Wood ash	0.40	10.9	31.6	224.8	30.9	3.1	4.6	1.6
Wastewater sludge	25.9	16.3	2.2	10.9	11.3	0.3	23.4	0.2
Minerals NPK	12	5	14		*			

The growth parameters of poplar clones - diameter of stem, length and annual increment, fresh biomass of shoots were statistically analysed by applying the OpenOfficeCalc, Gnumeric T-test and analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Short rotation coppice can be subdivided into SRF – plantation with short cutting frequency (1 or 2 years) and MRF – plantation with medium cutting frequency (> 5 years). Pant densities vary highly: 10,000–14,000 plants ha^{-1} (annual plantation with twin rows), 5,000–6,000 plants ha^{-1} (biennial plantation with single rows) and 1,000–1,800 plants ha^{-1} (in MRF) are used in Italy (Fiala et al., 2010). Nowadays, the larger part of Italian short rotation crops are based on 2-year cuts (VSRC), the best quality of biomass comes from 5-year plantations (SRC), and it is possible that in the near future SRC plantations will be more widespread due to the lower ash content in the bark (Guidi et al., 2008) and the longer the rotation, the better the result in both biomass yields and cellulose content under the same conditions (Guidi et al., 2009). According to the Latvian law, the maximum rotation for SRC in agriculture is 5 years. The current plantation will be cultivated till this age and then harvested; now, data of the third year potential yield are presented.

Single-factor ANOVA comparison shows that height differences between all clones are only significant at end of the second season (Table 2). The heights and diameters of all poplars grown on the sample plots with initial treatments with waste water sludge (wws), wood ash and control are not different at a significant level. After using mineral fertilizers, the differences became significant for all parameters of current year increment, height and diameter.

Table 2. Anova one-factor comparison (P-values) between the means of parameters

Factors compared	Second season	Third season		
	height	increment	height	diameter at breast height (1.3 m)
Clones	0.001	0.660	0.154	0.218
Initial fertilization treatment	0.573	0.297	0.348	0.129
All treatments including minerals		0.000	0.011	0.007

After the second season, under all initial fertilization treatments, the stems of clone AF6 were higher, in spite of the negative effect on growth by giving of initial fertilizers, because of the sensitivity to ground vegetation concurrence. In Italian conditions, AF6 has a 15 days shorter vegetation period compared to others (http://www.alasiafranco.it), but in Latvia, in the first three seasons, AF6 was faster-growing and had significantly better height results compared to the other three clones (Table 3, Fig. 1). In the ENERWOODS project, poplar fertilization with the mineral fertilizer NPK 12:5:14 100 kg ha^{-1} was performed in the third season.

Table 3. P-values of the differences between poplar clone height at end of the second vegetation season

Cone	AF 2	AF7	AF8
AF6	0.003	0.002	0.007
AF2		0.186	0.563
AF7			0.556

All clones show different reaction to initial fertilization. The amounts of fertilizer applied on the field where poplar experiment is conducted are 2 ha of 16 ha, in some cases, it was not the main factor impacting on the height growth of the trees (Rancane et al., 2012), for example, in the first two seasons on both unfertilized parts of the field, one later used for testing of the effect of mineral fertilization, the height of the shoots varied (Fig. 1). During the first two seasons, a statistically non-significant but positive effect on the growth of poplars was observed under treatment with wood ash. Additional N, taken into the soil by WWS, caused decreasing of resistance to *Venturia sp.,* which affected the plants in the first season, and was the reason of the more vigorous vascular plants development – ground vegetation competed for nutrients in the second season.

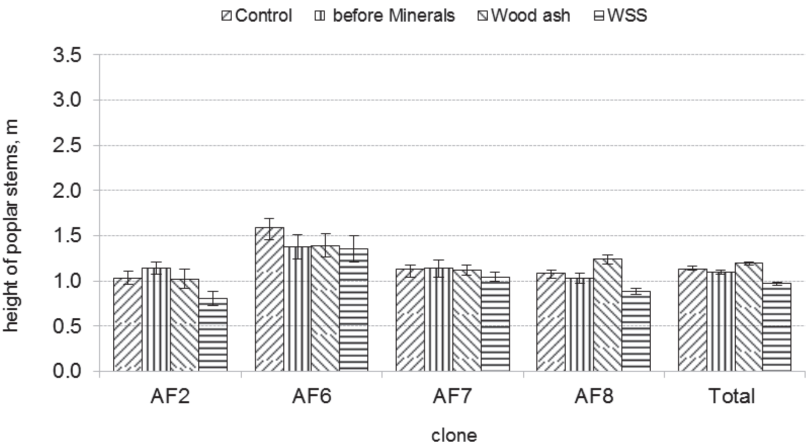

Figure 1. Height of poplar clone stems in the end of the second vegetation season after different initial fertilization treatments.

The third season increments, after fertilizing with fertilizers, using an experiment design similar to the ENERWOODS project, poplar fertilization in Denmark and Sweden (mineral fertilizer NPK 12:5:14 100 kg ha^{-1}) were impressive and significantly better than another treatments (Fig. 2, Fig. 3). Clone AF2 started to grow faster.

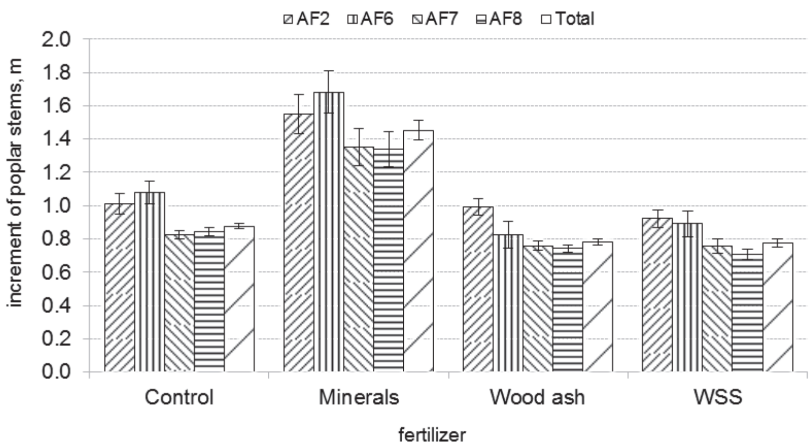

Figure 2. Third season annual increments of poplar clone stems after different initial fertilization treatments.

As in the second season, the clone AF6 had larger increments and higher stems in the third season as well (Fig. 3).

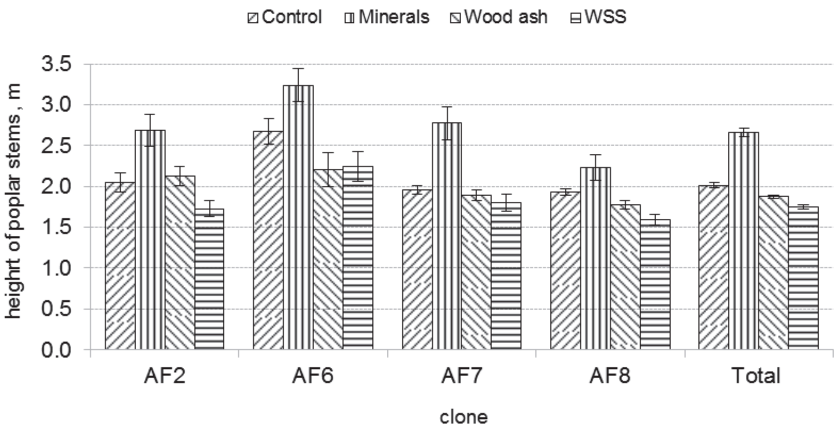

Figure 3. Height of poplar clone stems in the end of the third vegetation season after different initial fertilization treatments.

The trees of clones AF2 and AF8 had relatively higher increments in the third growing season compared to others (Fig. 4), which means that their growth strategy is different and it is necessary to follow the growth rate for a longer period before making conclusions regarding which clones to choose and recommend for cultivation in Latvia.

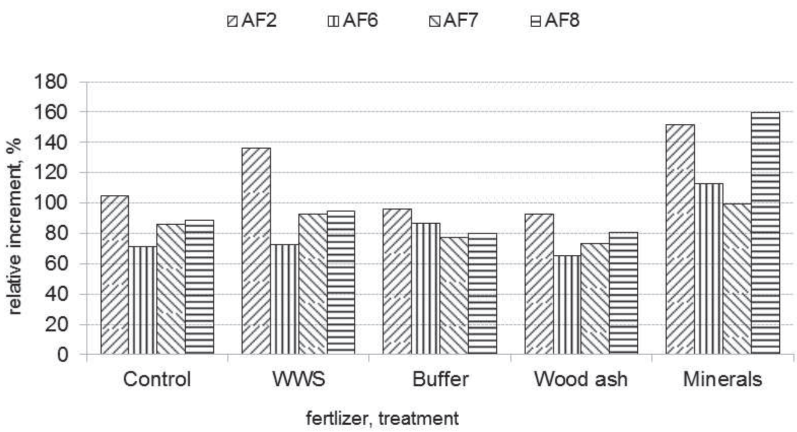

Figure 4. Relative third season increment (%) to initial height in the spring.

The clones with better growth rates also developed thinner shoots. Fertilizers mainly influenced shoot growth in height (Fig. 5).

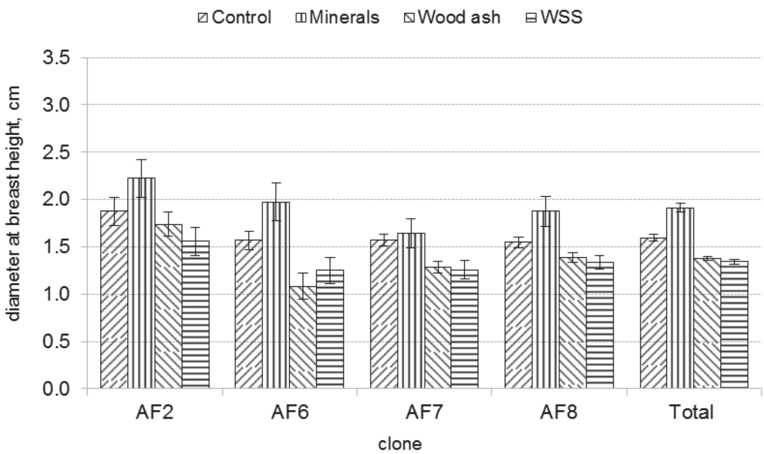

Figure 5. Breast height diameter value differences of poplar clone stems in the end of the third vegetation season after different initial fertilization treatments.

The maximum measured values are promising and show that poplars are quite promising forest plantation tree in the case of better growth conditions and appropriate management systems (Table 4), because of the easy vegetative propagation and establishment by cuttings or rods. The highest values of each parameter under each treatment are highlighted in bold in Table 4, for example, in 2012, the clone AF2 showed the best results under all treatments, but in 2013, the height of the clone AF2 in control was higher and AF 7 had very positive response to the use of minerals. Initially, it has been considered on the basis of the data on a poplar plantation growth in the Po Valley area in Italy that mainly10 years cutting time 5 years (biomass yield 40 $t_{wet\ biomass}$ $ha^{-1}\cdot$year (at 55% of moisture content wet biomass)) is optimal. In these conditions, a ratio between the output and input energy of 30 and between GHG absorption and GHG emission of 56 with the production cost of € 60 t DM were pointed out. In addition to the positive energy and environmental balances, even the economical sustainability of medium rotation forests (MRF) with the gain of € 820 ha^{-1} per year appears interesting (Fiala et al., 2010). It seems that in Latvian conditions, poplars could be cultivated as MRF plantations as a forest plantation culture or as the maximum duration agricultural SRC, because poplars are slower 'starters' that willows, where the optimal harvesting is 2–3 year rotation (Lazdina, 2010).

Table 4. Maximum measured values of poplar clones in the autumn of the third vegetation season

Data	Height 2012, cm				Increment				Height 2013, cm				DBH 2013,cm			
Clone	AF2	AF6	AF7	AF8	AF2	AF6	AF7	AF8	AF2	AF6	AF7	AF8	AF2	AF6	AF7	AF8
Control	2.22	**2.51**	2.12	1.95	**1.95**	1.81	1.51	1.94	**3.93**	3.91	3.02	3	**4.4**	2.5	3	3.2
WWS	1.52	**2.43**	2.16	1.76	1.37	1.31	**1.59**	1.43	2.58	**3.74**	3.02	3.04	**3.1**	2.1	2.9	2.9
Wood ash	2.11	**2.3**	2	2.08	1.5	1.5	1.26	**1.92**	3.33	**3.56**	3.2	3.01	**3**	1.8	2.4	**3**
Minerals *					2.1	**2.14**	2.02	**2.14**	4.09	4.14	**4.24**	3.62	**3.9**	3.3	3.1	3.6

*treatment in 2013 NPK

The biomass of fresh shoots was determined by cutting down of shoots and weighting stems and branches separately. The cut shoots were measured and an equation for the average biomass grown on experimental fields was created using shoot height as an argument (Fig. 6). The biomass of the branches of clone AF2 was 29% of total the above-ground biomass, the biomass of clone AF6 – 22% and the biomasses of clones AF7 and AF8 21 % of the total above-ground biomass.

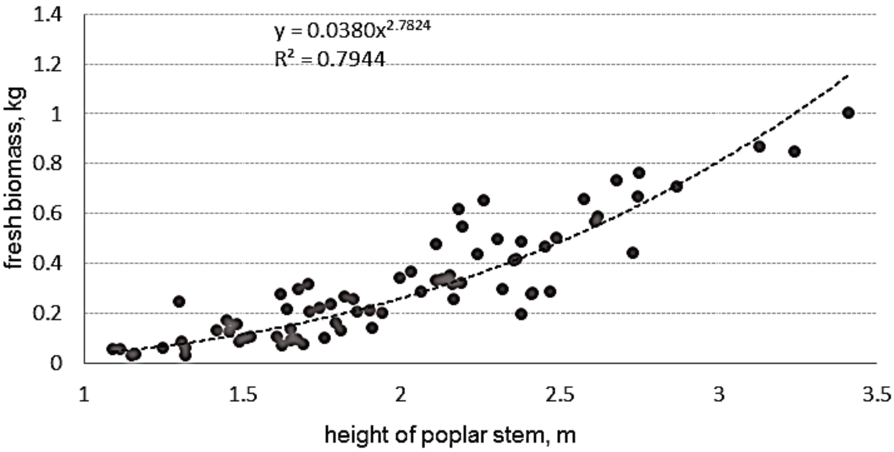

Figure 6. Stem total biomass and height of poplars in the end of the third vegetation season.

From the equation obtained through stem measurements and weighted biomass, the potential yields of the ALASIA clones under various fertilizers in Latvian conditions were calculated for the density of 10,000 plants per ha at a 3-year rotation period (Table 5), the maximum values are in bold.

Table 5. Potential biomass from cultivation of poplars as SRC under a 3-year rotation period

Treatment, year/clone	Control	Sludge, 2011	Wood ash, 2011	Minerals 2013	Buffer zone of minerals	Total average
AF2	3.34	1.90	3.52	6.72	2.90	3.52
AF6	6.62	4.18	3.88	**10.64**	5.54	**6.19**
AF7	2.73	2.31	2.54	**7.37**	2.96	2.96
AF8	2.66	**1.57**	2.19	4.18	3.95	2.82
Total average	3.08	2.11	2.54	**6.76**	3.63	3.19

AF6 had the highest biomass under all treatments. In contrast to willows (Lazdina, 2010), fertilization with waste water sludge does no give positive results and wood as the fertilizer only had a positive impact on the biomass of the clone AF2. On the current field, the three-year rotation cycle is too short for calculations of the economical reasonability of hybrid poplar cultivation.

CONCLUSIONS

The height of poplars in the spring of the third vegetation season ranged from 0.2 to 2.64 m, on average 1.12 ± 0.005 m, the annual increment during the third year ranged from 0.01–2.14 m, on average 0.787 ± 0.004 m, in autumn, tree height ranged from 0.36 m to 4.24 m and was 1.99 ± 0.01 m on average.

The tree diameter at breast height of all clones varied greatly and ranged from 0.36 cm to 4.4 cm; the trees reached the average diameter of 1.48 ± 0.007 cm at the end of the third vegetation season.

Clone AF6 had significantly better growth results and could be recommended for plantation in Latvia, clone AF2 had moderate results. All clones should be tested till reaching at least five years to evaluate the suitability for usage in SRC systems or plantation forests.

Clones AF8 and AF7 are taller and had less biomass of branches than the other two more productive clones AF 2 and AF 6 (AF2 – 29%, AF6 – 22%, AF7, AF8 – 21%).

Depending on the clone and treatment, fresh biomass ranged from 1.57–10.67 tha^{-1} (density 10,000 trees ha^{-1}).

Three-year rotation period is too short in Latvia conditions for obtaining high yield from hybrid poplar short rotation crop fields.

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