HYBRID ASPEN AND PERENNIAL GRASS AGROFORESTRY SYSTEM INTERACTIONS

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Abstract

This research´s aim is to determine productivity of hybrid aspen (*Populus tremula* L. *x Populus tremuloides* Michx.) at the fifth year rotation period after managing it as agroforestry system together with perennial crops–reed canary grass (*Phalaris arundinacea* L.), festulolium (*Festulolium pabulare*) and fodder galega (*Galega orientalis* Lam.) as intercrop and fertilized by digestate waste water sludge and wood ash. It is recognized that best effect on tree growth for both clones is by fertilizing with digestate and waste water sludge, on average 30–31% better tree height compared to control. The best effect on tree growth is obtained with red canary grass and fodder galega intercrop, comparing to control the average tree height is 16% higher. Hybrid aspen clone No 4 is significantly (+33%) more productive than clone No 28. The clone selection has the most important impact on plantation productivity. All kinds of fertilizers significantly increased seed yield of festulolium by 30%, but fodder galega showed positive response just to wood ash fertilization resulted to +15% of seeds yield.

Keywords: aspen hybrid; perennial grass; agroforestry; galega; festolium; reed canary grass; inter copping

Introduction

In order to diminish usage of fosil fuel and to increase usage of local renewable energy sources there is a need for alternative energy sources (AES). Biomass is considered as one of the most perspective in Latvia. Hybrid aspen is one of the fastest tree growing species used for biomass production in short rotation coppice cultures in Latvia and *Populus spp*. is one of three SRC which are financially supported by government within direct support scheme. As a solution for the need of AES are agroforestry systems, which balancing economical and ecological needs provides sustainable land management.

Since 2011 aspen is an eligible agriculture energy crop with a rotation period up to five years in Latvia. In previous studies we found that inter-crop system allows to make positive cash flow already at 2-3 year after establishing these systems, if grasses are used as seed producers. The research´s aim is to determine productivity of hybrid aspen (*Populus tremula* L. *x Populus* [illegible] forestry system together with perennial crops seed producers and biomass plants as intercrop and fertilized by biogas fermentation residues, waste water sludge and wood ash.

Material and methods

The study area is located in central Latvia, region of Skrīveri (56°41 N 25°08 E). The experimental plot is established in 2011 on drained mineral soil. Average carbon (C) content in soil plough layer 21.3–25.4 g kg^{-1}, K_2O 136.8 mg kg^{-1}; P_2O_5 277.1 mg kg^{-1} and average pH_{KCl} of soil is 6.1 (Rancane et al. 2014). In the current study, system with trees of high growth rate hybrid aspen, by choosing clones with significantly different productivity were used (No 4 high yield and No 28 low yield, both were used as reference clones for breeding of hybrid aspen).

The trees were planted in the 2.5×5 m planting design with ~3 m wide intercrop stripes between tree rows (Figure 1).

Figure 1: Small scale demo agroforestry system Hybrid aspen and Festolium (foto D. Lazdina).

Plantation of hybrid aspen (*Populus tremula* L. x *Populus tremuloides* Michx.) was established within 4 replicates for each fertilizer, (waste water sludge 10 t_{DM} ha^{-1}, wood ash 6 t_{DM} ha^{-1} and digestate 30 t ha^{-1}). Intercrops Galega (*Galega orientalis* Lam.), Reed canary grass (*Phalaris arundinacea* L.), Blue lupin (*Lupinus polyphyllus* Lindl.), Festolium (*Festulolium pabulare*) were sown between rows of trees for seed production and biomass (Figure 2). Intercrops sown in strips which are double of harvesting width of experimental seed harvesting machine owned by Institute of Agriculture.

control	ash	sludge	digestate	control	sludge	digestate	ash	control	digestate	ash	sludge	control	digestate	sludge	ash
Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen
Galega	Galega	Galega	Galega	RCG	RCG	RCG	RCG	Lupin	Lupin	Lupin	Lupin	Festolium	Festolium	Festolium	Festolium
Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen
Galega	Galega	Galega	Galega	RCG	RCG	RCG	RCG	Lupin	Lupin	Lupin	Lupin	Festolium	Festolium	Festolium	Festolium
Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen	Hybrid aspen

Figure 2: Design of experimental plantation agroforestry system intercropping (tree rows 5 to 2.5 m intercrop 3m wide strips).

During the work were measured heights, diameters at breast height (DBH) and biomass to aspen clones No 4 and No 28 (*Populus tremula x tremuloides*) with three different perennial intercrops reed canary grass (*Phalaris arundinacea* L.), festulolium (*Festulolium pabulare*) and fodder galega (*Galega orientalis* Lam.), each divided into four replicates with different fertilisers biogas fermentation residues (digestate) 30 t ha^{-1}, waste water sludge 10 t ha^{-1}, stabilized wood ash 6 t ha^{-1} and one replicate with no fertiliser control. Planting density was 800 trees ha^{-1}. Biomass equations were estimated using six representative trees per clone, sample trees were selected by considering average tree height. The moisture was determined weighing naturally wet biomass of wood samples and again after drying samples till constant weight in 105^0C. Carbon amount in biomass was determined using established quotients for hybrid aspen trunk and branches (Muiznieks and Liepins 2006). In order to determine average carbon amount in tree the quotients were recalculated using trunk and branches proportion. Estimated quotient is 511.33 g C kg^{-1}. From amount of carbon in absolutely dry wood biomass using IPCC Guidelines for National Greenhouse Gas Inventories (2006), the amount of stocked CO_2 in plantation was calculated. The experimental data were statistically processed by using two-way analysis of variance, the differences among means was detected by LSD at the 0.05 probability level.

Results and discussion

During the work it was recognized that the best effect on the tree growth and only relevant difference among control to the aspen hybrid No 4 gives the fodder galega and reed canary grass. Average tree height ranges from 661 cm with reed canary grass intercrop and waste water sludge fertilizer and 615 cm with fodder galega intercrop and digestate fertilizer while in control with no intercrop only 387 cm. Aspen clone No 4 is significantly more productive than No 28, even the most productive 28th clone stand does not reach the average tree height of 4th clone, therefore in future analysis is considered only the 4th clone. All of researched fertilizers give positive impact on the hybrid aspen tree growth. The best effect is observed with digestate fertilizer, comparing to control averagely for 31% higher results and waste water sludge fertilizer averagely for 30% (Table 1).

Table 1: Hybrid aspen 4th clone biomass harvest comparison

	Intercrop	Survival	Naturally wet wood biomass at real survival t ha-1	Absolutely dry wood biomass at real survival t ha-1
Digestate	Festulolium	96	6*	3.2
	Fodder galega	85	12.7**	6.9
	Control	89	6.5	3.5
	Reed canary grass	96	15.7**	8.5
Sludge	Festulolium	81	6.6*	3.5
	Fodder galega	81	7.4*	4
	Control	93	6.4	3.4
	Reed canary grass	96	15.7**	8.4
Ash	Festulolium	81	3.1*	1.6
	Fodder galega	89	7.1**	3.7
	Control	81	2.7	1.4
	Reed canary grass	96	10.7**	5.6
Control	Festulolium	89	2.3**	1.2
	Fodder galega	74	5**	2.6
	Control	81	2.5	1.3
	Reed canary grass	82	5.2**	2.7

* = P>0.05 ** = P<0.05

There were estimated the possibility of growing herbaceous plants between rows of tree plantations with the aim to harvest seed production in first years after establishment, and thus at least partially compensate invested funds. The average seed yield in first two years of use for all species was estimated as good. *Festulolium* produced from 688 kg ha^{-1} without use of any fertilizers (control) to 908 kg ha^{-1} in variant of mineral fertilizers; galega produced from 285 kg ha^{-1} (control) to 470 kg ha^{-1} (wood ash) on average, what is good result also taking into account the meteorological conditions and the characteristics of this species. Numerous rainy days during the vegetation period in the 1st year of use adversely affected the pollination of galega flowers and thereby made a negative effect on the seed yield formation (Figure 3).

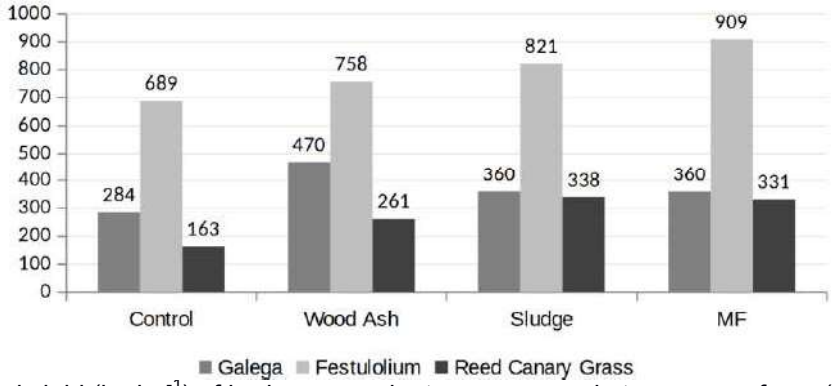

Figure 3: Seed yield (kg ha^{-1}) of herbaceous plants on average in two years of use (2012-2013).

However, in the second year of use weather condition was more favorable for galega flower pollination and seed development, hence the average seed yield of two years of use can be evaluated as satisfactory. Relatively lower seed yields on average in 1st and 2nd year of use obtained from RCG sowings from 163 kg ha^{-1} without use of any fertilizer to 338 kg ha^{-1} using sewage sludge. However, the seed production of RCG in general is complicated due to the fact that seed often shatter from the upper branches while seed at the base is still immature (Baltensperger and Kalton 1959). For this reason the average seed yield of RCG usually fluctuates around 200 kg ha^{-1} and hence we can conclude that harvested yields in fertilized variants between tree rows are sufficiently high (Figure 3).

The results of two years indicate that the use of different bio-energy and municipal waste products as fertilizers in general contributed the formation of higher seed yields for all three species. However the influence of fertilizers under research on the species was different. The greatest increase in seed yield on average in two years provided applying of sewage sludge for RCG; mineral fertilizers for festulolium; and wood ash for galega.

Conclusion

It is recognized that best effect on tree growth for both clones was achieved by fertilizing with biogas fermentation residue and waste water sludge, on average giving 30–31% better tree height compared to control. The best effect on tree growth is achieved with a Reed canary grass and fodder galega intercrop, compared to control the average tree height is 16% higher. It is recognized that hybrid aspen clone No 4 is significantly (+33%) more productive than clone No 28. The most important impact on plantation productivity is achieved by clone selection, although there was relevant impact on the tree growth from fertilizer and intercrop as well. All kinds of fertilizer significantly increased seed yield of festulolium by 30%, but fodder galega showed positive response just to wood ash fertilization resulted with a 15% increase in seed yield.

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