MULTI-CROP BIOMASS PRODUCTION FOR ENERGY PURPOSES

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Abstract
The research was conducted in 2020–2021 at Vytautas Magnus University, Academy of Agriculture, Research Station. The soil of the experimental field is light loam Planosol. The aim of the study was to determine the impact of multi-crops grown for energy purposes on the development and productivity of crops. Crops with different biodiversity were studied:
1. Single maize crop (MA);
2. Single hemp crop (HE);
3. Single faba bean crop (FB);
4. Binary maize and hemp crop (MA + HE);
5. Binary maize and faba bean crop (MA + FB);
6. Binary hemp and faba bean crop (HE + FB);
7. Ternary crop of maize, hemp and faba beans (MA + HE + FB).
The highest total fresh biomass of crops was established in single and multi-cropped maize; however, as expected, the highest total dry biomass was found in the ternary crop. The highest dried biomass of individual species (maize, hemp or beans) was observed of singly grown species, except faba bean in ternary crop. In this crop, the dried biomass of faba bean was the highest, and it replace ternary crop to the first place according to the dried biomass.

Key words: *Cannabis sativa; Zea mays; Vicia faba; multi-crops; productivity.*

INTRODUCTION

The faba bean (Vicia faba L.) is an important legume crop of the Fabaceae family; it is widely grown in the world for its economic and ecological value in sustainable agriculture (*Zong et al., 2019*). Faba bean are well able to adapt to different climatic conditions, as evidenced by their worldwide distribution (*Duc et al., 2015*). Technical hemp belongs to the family of magnolias (Cannabaceae) and has been used for medicine, fibre and food for more than six thousand years (*Pain, 2015*). Hemp is most commonly grown for seed or fibre. Its seeds are rich in starch, protein, and oil (*Galasso et al., 2016*). Hemp is also a promising crop for biofuel production. The amount of biomass obtained per unit area does not lag behind other energy crops (*Hodsonetal, 2011*). Maize (Zea mays L.) is an annual crop belonging to the mistletoe family (*Jakienė et al., 2013*). It is one of the most widely grown cereals in the world and is a major food source in many developing countries (*Kumawat et al., 2020*). Maize is also widely grown for animal feed, in the form of fresh biomass, grain or fermented and preserved in the form of silage, which could be used during colder periods of the year. In addition, one of the important targets for maize cultivation, mainly associated with developed countries, is ethanol production (*Barnes et al., 2016*).
Crop functionality is enhanced by sowing fast-growing other species of crops into the main crop. With increasing biodiversity, hemp and maize protect each other from the spread of pests, weeds and diseases, as well as increase productivity of total biomass per unit area. The nutritional and energetic value of the main products is also improving. However, the physical, biological and chemical properties of the soil are rapidly deteriorating, with a reduction in nutrients and humus, an increase in soil hardness and a deterioration of the soil structure (*Brussaard et al., 2007*).

Until now, the cultivation technologies of multifunctional multi–crops of hemp, faba bean or maize have been little studied abroad and in Lithuania. Future research results are a perspective for developing productive energy agrocenoses rotations and producing high quality biofuels. Hypothesis of investigation states that diversification of crops is likely to improve productivity per unit area. The aim of investigations was to evaluate the productivity of single and multi-cropped agrocenoses.

MATERIALS AND METHODS

A stationary field experiment was started in 2020 at the Research Station (54°52′ N, 23°49′ E) of Vytautas Magnus University, Agriculture Academy. Research data from 2021 is presented in this study. Soil of experimental field is light loam Planosol (Endohypogleyic-Eutric Planosol – Ple-gln-w). Soil pH_{HCl} is from 7.0 to 7.5, total nitrogen content – from 0.103 to 0.153%, available phosphorus – from 179 to 310 mg kg^{-1}, available potassium – from 95 to 172 mg kg^{-1}, available sulphur – from 1.5 to 2.5 mg kg^{-1}, magnesium – 488 to 820 mg kg^{-1}. The water regime is regulated by closed drainage, the micro relief is levelled. The arable layer of the soil is 23–27 cm thick.

Three crops are grown in the experiment: maize (Zea mays L.) (Pioneer breeding hybrid P8105), technical hemp (Cannabis sativa L.) (variety Austa SK) and field bean (Vicia faba L.) (variety Vertigo).

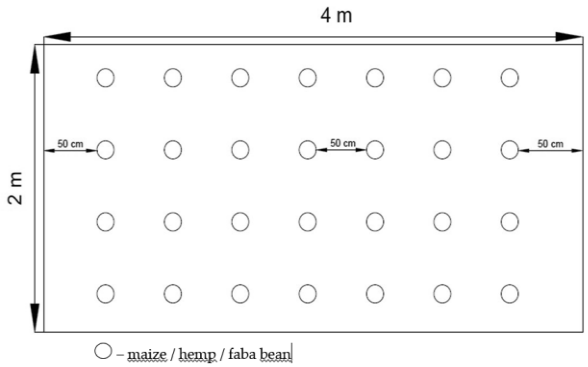
A total of seven treatments were tested (Tab. 1) (*Romaneckas et al., 2022*).

Tab. 1 Crop biodiversity

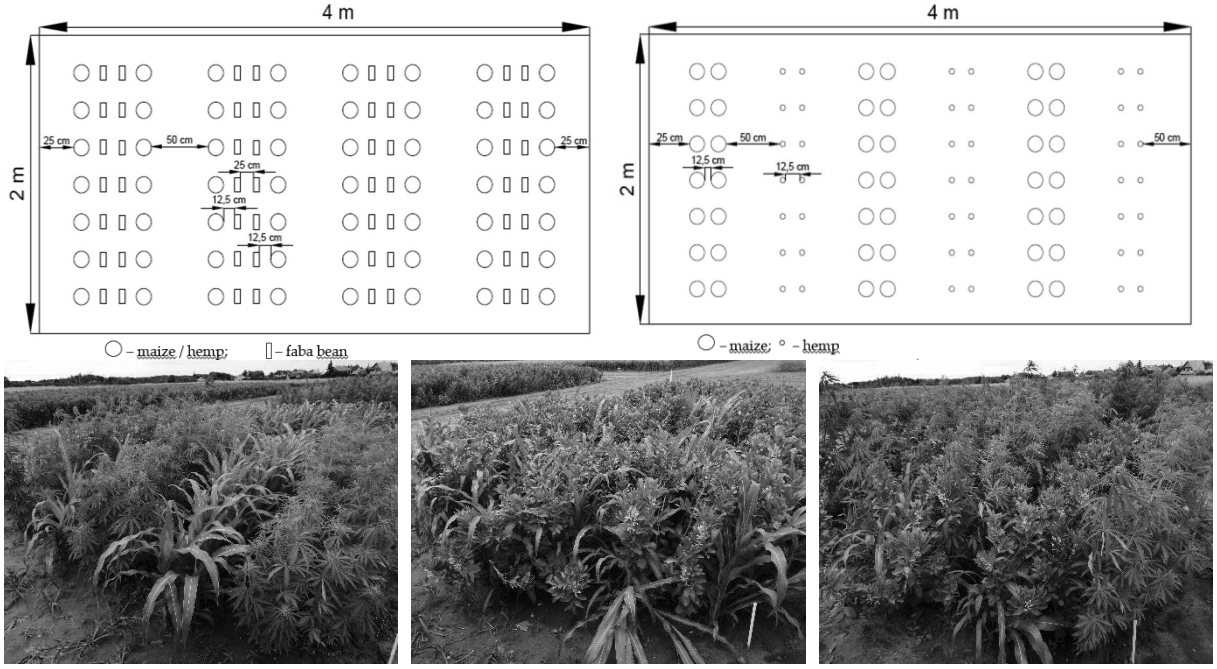
Level of crop biodiversity	Cultivation	Abbreviation
single crop	maize	MA
	hemp	HE
	faba bean	FB
binary crop	maize + hemp	MA+HE
	maize + faba bean	MA+FB
	hemp + faba bean	HE+FB
ternary crop	maize + hemp + faba bean	MA+HE+FB

The experimental plots were distributed in a random order. The initial size of each plot is 8 m^2. The experiment was performed in 3 replications. The buffer strip of the experiment field is 1 m wide, and between the repetitions and treatments– 2 m wide.

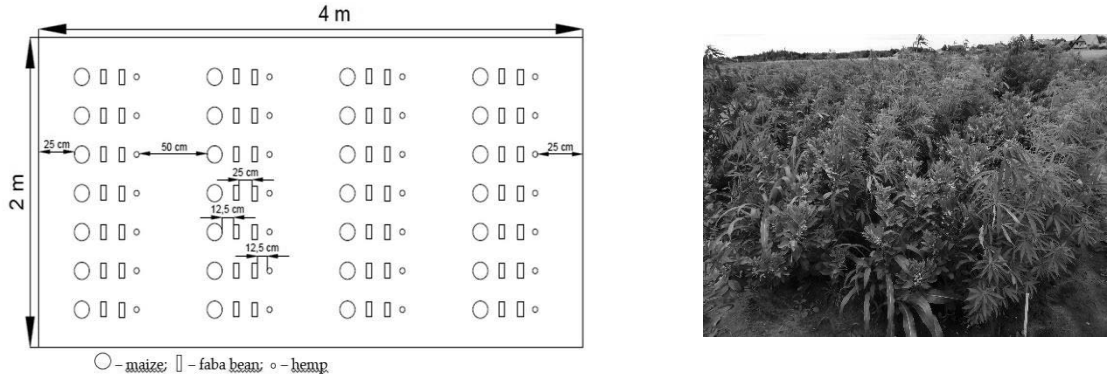
In autumn, the soil was ploughed up to 22–25 cm depth. In spring, the soil was cultivated twice with a complex cultivator. Depth of the last cultivation was 3–4 cm. The experimental plots were measured and the complex fertilizer NPK 5:15:30 was scattered on the soil before sowing. Fertilizer rate – 200 kg ha^{-1} (170 g per plot). The experimental plots were then seeded according to the intended sowing schemes (Fig. 1). They were sown by hands. When the weeds germinated abundantly, the crop spacing was loosened 2 times.



Single crops (MA, HE, FB)



Binary crops (MA+HE, MA+FB, HE+FB)



Ternary crop (MA+HE+FB)

Fig. 1 The sowing scheme (*Romaneckas et al., 2022*)

According to the amount of precipitation, the territory of Lithuania is in the zone of surplus moisture. The climate is maritime shifting to continental; so, meteorological conditions vary. The average annual rainfall is 600–650 mm and evaporates about 500 mm. The vegetation of agricultural plants lasts 150–170 days. In our experiment, in 2021, faba bean vegetation was lacking for only 103 days (period from germination to BBCH 09–10 to maturity at BBCH 83–86) because June and July were dry and hot. At the beginning of the vegetative season in 2021, the average air temperature was 6.2° C or 0.7° C lower than the long-term average. Precipitation was relatively low, only 33.7 mm or 7.6 mm less than the long-term average. Such conditions for the growth of crops were favourable. There was a lot of rainfall in May, about 121.6 mm; the temperature was only 11.4° C. The month of June was warm; the average temperature was 19.5° C. This month was dry – 40.3 mm of precipitation. July was extremely warm and received on average 2 times less precipitation than the long-term norm (96.6 mm). August was 0.8° C colder than usual. Precipitation was 33.3 mm higher than the usual norm. Such conditions were favourable for faba bean maturation. The crops were harvested at the end of the month.

Crop productivity parameters were carried out at harvest. Samples have been taken in a longitudinal row of 1 m (2 rows of beans) from at least 5 spots per plot. An average sample was formed. A total of 36 samples were prepared for more detailed studies. Biomass of crops were dried in the oven in 105° C

temperature. The experimental data were analysed by programme ANOVA for EXCEL (vers. 4.0, author Pavelas Tarakanovas, PhD. Lithuanian Institute of Agriculture, Akademija, Kedainiu distr., Lithuanija), for SELEKCIJA software was employed.

RESULTS AND DISCUSSION

Crop fresh biomass. Crop biomass is one of the most important indicators of crop development and productivity. Testing of crop fresh biomass at the end of vegetative season revealed that the significantly lowest fresh biomass was by the single faba bean crop (822.2 g m^{-2}), and insignificantly the highest – in the single maize crop (4163.3 g m^{-2}), or about 5 times higher (Fig. 2).

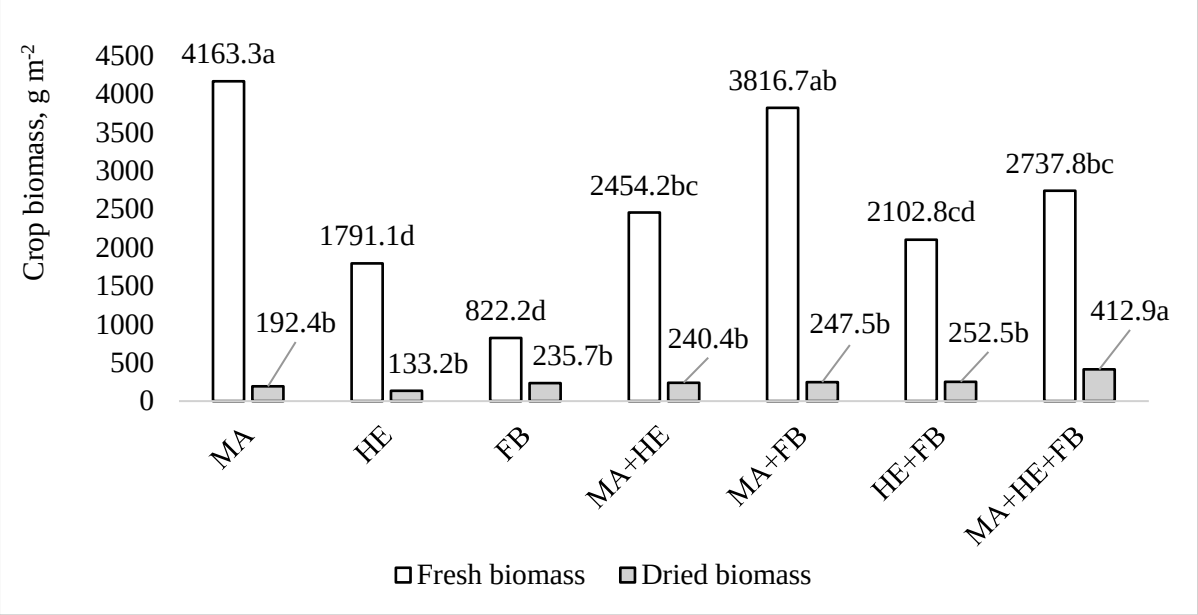


Fig. 2 Effect of diversification on crop biomass
Note: values marked with different letters differ significantly at P<0.05. Treatments: MA – single maize crop, HE – single hemp crop, FB – single faba bean crop, MA + HE – binary maize and hemp crop, MA + FB – binary maize and faba bean crop, HE + FB – binary hemp and faba bean crop, MA + HE + FB – ternary crop of maize, hemp and faba bean.

Out of binary crops, the highest amount of fresh biomass was grown by MA + FB crop, or 8.3% less than in single MA crop. The ternary crop (MA + HE + FB) produced 2737.8 g m^{-2} of fresh biomass, or about 3.3 times more than the single faba bean crop. The results differed significantly. According to *Streit et al. (2019)*, faba bean grows on average of 5% more fresh biomass in mixtures than in single crops. *Li et al. (2014)* reported a positive effect of maize fresh biomass yield when maize and bean roots in the mixture were freely mixed, and interspecies interactions were affected. *Streit (2018)* found that faba bean produces more fresh biomass than spring wheat, but did not show higher amounts of fresh biomass in binary crops (beans with spring wheat) than in single faba bean crop. *Shtaya et al. (2021)* also confirms that beans grown in combination with other plants increase the total fresh biomass. Growing faba bean together with triticale produced the highest fresh biomass of beans. Although a decrease in fresh biomass of beans was observed when growing binary crop with barley.
The highest fresh biomass mainly was observed of singly grown species; however significance of differences varied (Fig. 3).
Crop dried biomass. This indicator is perhaps the most important for determining a crop's productivity and energy potential. At the end of the vegetative season, significantly highest dried biomass was found in the ternary (MA + HE + FB) crop, although the maximum amount of fresh biomass was not found in this treatment (Fig. 2).

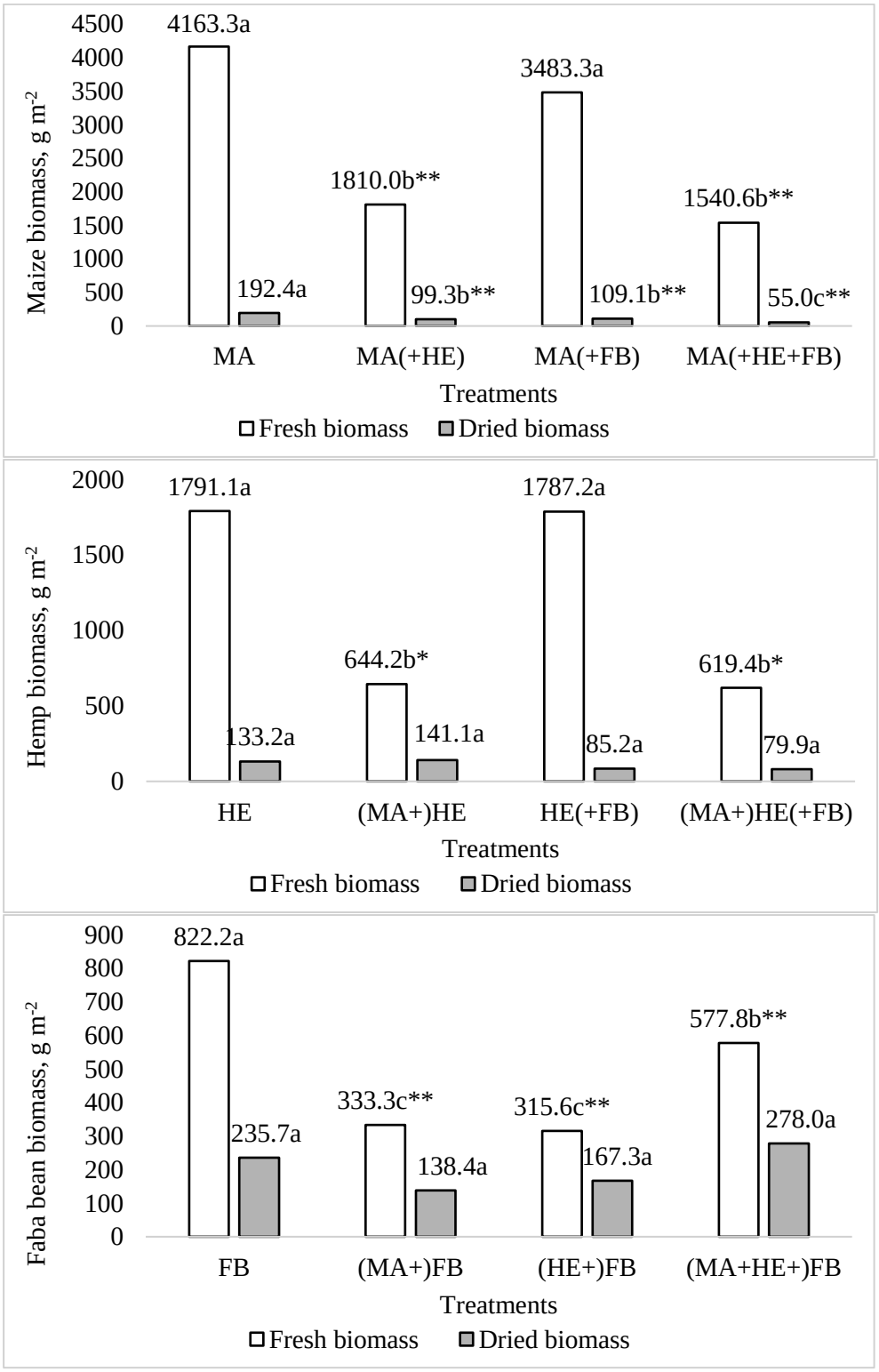


Fig. 3 Effect of crop diversification on species individual biomass
Note: values marked with different letters differ significantly at P<0.05. * – significant difference from control treatment (single crop) at 95% probability level, ** – at 99% probability level. Treatments: MA – single maize crop, HE – single hemp crop, FB – single faba bean crop, MA + HE – binary maize and hemp crop, MA + FB – binary maize and faba bean crop, HE + FB – binary hemp and faba bean crop, MA + HE + FB – ternary crop of maize, hemp and faba bean.

Meanwhile, during the period under review, the insignificant lowest dry biomass was found in the single hemp crop (133.2 g m^{-2}). The content of dry biomass in binary crops was similar, ranging from 240.4 to 252.5 g m^{-2}. Only the MA + FB crop was distinguished; it had a negligible maximum dry biomass content compared to other binary crops.
The highest dried biomass was observed of singly grown species, except faba bean in ternary crop (Fig. 3). In this crop, the dried biomass of faba bean was the highest, but not significantly.

CONCLUSIONS

The highest total fresh biomass of crops was established in single and multi-cropped maize. However, as expected, the highest total dry biomass was found in the ternary crop. The highest dried biomass of individual species (maize, hemp or beans) was observed of singly grown species, except faba bean in ternary crop. In this crop, the dried biomass of faba bean was the highest, and that replace ternary crop to the first place according to the dried biomass.

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