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USABLE AND NON-USABLE BIOMASS OF POTATOES GROWN UNDER TWO CROP PRODUCTION SYSTEMS AND TWO DIFFERENT ENVIRONMENTAL CONDITIONS

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ABSTRACT

A field study was conducted in years 2011–2013 in two different places in Poland. Four potato cultivars (Flaming – very early, Viviana – very early, Vineta – early, Gustaw – mid early) were grown under organic and integrated systems. During the full development stage, i.e. end of June (for the early varieties) and 2 weeks later (for later ones) total above-ground biomass was assessed. The tuber yield and share of tuber in total plant biomass was calculated during the harvest. It was stated that the highest influence on assimilates distribution to usable and non-usable part of plant had the site of growing and the cultivar. The farming system and the weather conditions during growing season did not significantly influence the share of tuber in total plant biomass. There was significant interaction between the farming system and the site of growing regard to total biomass and tuber yield. Under organic system on lighter soil the total biomass and the yield was slightly lower than on heavier soil, but under integrated system the relation was diverse. Relatively small diversity of cultivars regarding the share of tubers in the total biomass was noticed.

Key words: above-ground biomass, integrated system, organic system, potato, share of tubers.

INTRODUCTION

In agriculture, particularly important is the part of cultivated plants biomass called agricultural crop, which is used for feeding people and animals. In potato plant only one part of biomass is usable-tubers, the rest is non-usable.

Management of plant growth to maximize yield and economic return while minimizing water, fertilizer, pesticides, and other inputs is a primary goal in commercial crop production. Attention must be given to the partitioning of assimilates between canopy and tubers, as too much to one or the other can lead to an imbalance and a reduction in tuber yield. Maximizing the interception of solar radiation by the potato canopy during key growth stages, and in turn the efficiency of conversion of intercepted light to photosynthesic assimilates, is essential for maximizing yield and or agronomic return [4–8] provided the plant is healthy and has unlimited access to nutrients, water and moderate temperature.

The ideal canopy size and duration varies by cultivar and season length.

Parameter which characterizes the participation of agricultural crop in the total plant biomass is harvest index (share of tubers in total plant biomass) [2, 9, 13, 16].

This indicator depends on many factors, the main ones are: varietal characteristics, growing season conditions such as: photoperiod, air temperature, water, nitrogen fertilization [1, 2, 10, 12, 13, 16]. The potato crop is characterized by one of the highest harvest index.. Modern varieties of potatoes grown in temperate climates in favorable agrometeorological conditions can achieve harvest index in the range from 0.70 to 0.85 [2, 5, 9]. Some research reports the value of the coefficient of 0.90 [1, 11] which means that 90% of the biomass is accumulated in the tubers. For comparison, this ratio for grains ranges from 0.3 to 0.6 [9].

The share of usable biomass in total plant biomass can depend also on crop production system.

It is connected mainly with fertilization and plant protection.

Not many research is available to get some information about distribution of assimilates to usable and non–usable parts of potato plants depending on farming system. The aim of the study was to asses of four potato varieties grown in the two crop production systems i.e. organic and integrated in different climate and soil conditions with regards to distribution of assimilates to different part of plant.

MATERIALS AND METHODS

Material for the research comes from field experiments conducted in years 2011–2013 on two type of soils: experimental station of the Institute of Soil Science – Osiny (south-eastern Poland) on the heavier soil (plow soil with elements of black degradated soil), and the Institute of Plant Breeding and Acclimatization – Jadwisin (central Poland) on lighter soil: pseudopodsolic formed from light loamy sands.

In both places potatoes were grown in 2 crop production systems: organic and integrated. In each system different rotations and various production technologies were used.

Crop rotation in organic system, heavier soil – Osiny: potato → barley with undersown red clover → red clover with grasses → red clover with grasses + catch crop winter wheat. Rotation in the integrated system – Osiny: potato →barley → field bean for seed → wheat + catch crop.

In the organic system, lighter soil, Jadwisin: potatoes → field peas → oat → rye with under sown serradella → phacelia + white mustard as catch crops.

In the integrated system, lighter soil, Jadwisin: potatoes → spring wheat → winter wheat → lupines.

The two systems also differed in fertilization, weed control and insect control practices (Tab. 1).

Table 1. Agronomic inputs in organic and integrated systems

Crop production practice	Organic system Jadwisin	Integrated system Jadwisin	Organic system Osiny	Integrated system Osiny
Fertilization	Cow composted manure applied in spring: 28 t·ha^{-1} + mustard as a catch crop	4–5 t plowed rye straw + 1 kg mineral nitrogen per 100 kg straw + mustard as a catch crop N: 100 kg·ha^{-1} P: 53 kg·ha^{-1} K: 150 kg·ha^{-1}	Compost – 30 kg·ha^{-1} + catch crop	Manure – 25 t·ha^{-1} N: 75 kg·ha^{-1} P: 60 kg·ha^{-1} K:105 kg·ha^{-1}
Weed control	Only mechanical tillage	Mechanical tillage + herbicides: 2011: Afalon 1.9 l·ha^{-1} + Titus + Trend (60 g·ha + 0.5 l·ha^{-1}) 2012: Afalon 1.9 l·ha^{-1} Titus + Trend (60 g·ha^{-1} + 0.5 l·ha^{-1}) 2013: Linurex – 1.8 l·ha^{-1} Titus + Trend (60 g·ha^{-1} + 0.5 l·ha^{-1})	Only mechanical tillage	Mechanical tillage + herbicides: 2011: Afalon 2 l·ha^{-1}, Econom – 2 kg·ha^{-1} 2012: Afalon 2 l·ha^{-1}, Econom – 2 kg·ha^{-1} 2013: Afalon 2 l·ha^{-1}, Ekonom: 2 kg·ha^{-1}
Colorado potato beetle control	Biological insecticide (*Bacillus thuringiensis*) – Novodor 2012, 2013: 2 times per season: 4 l·ha^{-1}	Chemical insecticides: 2011: Actara 2 times per season – 60 g·ha^{-1} 2012: Actara – 60 g·ha^{-1} 2013: Actara 2 times per season – 60 g·ha^{-1} Apacz – 40 g·ha^{-1}	Biological insecticide (*Bacillus thuringensis*) 2–3 times per season: 4 l·ha^{-1}	Chemical insecticides: 2011: Infinito 1.5 l·ha^{-1}, Actara – 60 g·ha^{-1} 2012: Decis Mega 0.1 l·ha^{-1}, Mospilan 0.2 l·ha^{-1}, Infinito 1.5 l·ha^{-1}
Late blight control	Copper fungicides 2012: Miedzian 50 – 2 times per season – 3 l·ha^{-1} 2013: Miedzian 50 – 3 l·ha^{-1}	Chemical fungicides: 2011: Ridomil – 2 l·ha^{-1}, Revus – 0.6 l·ha^{-1}, Ranman – 0.2 l·ha^{-1}, Altima – 0.4 l·ha^{-1} 2012: Ridomil – 2 l·ha^{-1}, Revus – 0.6 l·ha^{-1}, Ranman – 0.2 l·ha^{-1}, Altima –	Copper fungicides 2012: Miedzian 50 – 2 times per season – 3 l·ha^{-1} 2013: Miedzian 50 – 3 l·ha^{-1}	Chemical fungicides 2011: Ranman 0.2 l·ha^{-1} Revus – 0.6 l·ha^{-1} Altima – 0.4 l·ha^{-1} 2012: Ridomil 2 l·ha^{-1} Revus – 0.6 l·ha^{-1} Ranman – 0.2 l·ha^{-1} Altima – 0.4 l·ha^{-1}

		0.4 l·ha^{-1}, Ranman – 0.2 l·ha^{-1} 2013: Revus – 0.6 l·ha^{-1}		Ranman – 0.2 l·ha^{-1} 2013: Ranman – 0.2 l·ha^{-1}

Four potato Polish table cultivars were chosen for this experiment based on maturity class and resistance to late blight. All cultivars were planted at the same time i.e. about 20th of April. Plot size was 84 m^2 for each cultivar in three replications. Plants were grown with spacing 75 × 33.3 cm. Characteristics of tested cultivars is given in Table 2.

Table 2. Characteristics of four potato cultivars evaluated in organic and integrated production systems during the years 2011–2013

Cultivar	Maturity	Resistance to Phytophthora infestans*
Flaming	very early	2
Viviana	very early	2
Vineta	early	2
Gustaw	mid late	5

At the full development stage, i.e. end of June (for the early varieties) and 2 weeks later (for later ones) total above ground biomass was assessed. Plants were removed, main stems were calculated, all biomass were divided on stems and leaves and weighted. The measurements were conducted on four plants from each of the three replicates.

At harvest time, 5th of September for early cultivars and 2 weeks later for later one tuber yield were assessed. Tuber yield was analyzed from all plots in 3 replications. Data were analyzed using the ANOVA program, with means separated by Student's t-test.

Weather conditions during growing season for both places are given in Table 3.

Table 3. Total monthly rainfall (P) and mean monthly temperatures (T) during the vegetative growth period in the years 2011–2013 for Jadwisin and Osiny

Year	Place	April		May		June		July		August		September	
		P [mm]	T [ºC]	P [mm]	T [ºC]	P [mm]	T [ºC]	P [mm]	T [ºC]	P [mm]	T [ºC]	P [mm]	T [ºC]
2011	Jadwisin	21.8	9.7	33.1	13.2	44.8	17.5	278.1	17.0	57.1	17.5	18.5	13.7
	Osiny	32.5	10.2	60.5	14.8	54.4	19.4	250.1	18.5	36.2	18.7	3.1	14.4
2012	Jadwisin	54.3	7.9	52.4	13.9	96.6	15.6	92.2	18.8	87.2	17.4	26.9	12.8
	Osiny	49.3	8.4	35.3	15.6	68.9	17.7	114.3	21.4	93.9	19.0	19.4	15.0
2013	Jadwisin	51.1	6.3	130.0	15.7	105.4	17.2	17.1	18.7	97.7	18.2	94.0	10.9
	Osiny	54.4	7.2	85.4	15.6	37.4	19.7	30.3	19.8	7.1	19.8	47.6	12.1

RESULTS

Statistical analysis

There were significant differences in most of the examined parameters characterizing the usable and non-usable biomass of potatoes associated with production system, place, cultivar and year (Tab. 4). The only exceptions were for yield and total biomass, which were not affected by place, and share of tuber yield in total biomass, which was not affected by production system and year. There were a few significant interactions between tested factors. For tuber yield and total biomass there was significant interaction between farming system and place of growing.

Table 4. Significance of differences in parameter means

Tested parameter	Cultivar	Farming system	Site	Year
Above-ground mass of 1 plant	*	**	**	**
Yield of 1 plant	**	**	–	**
Total biomass of 1 plant	*	**	–	**
Share of tubers in total biomass	*	–	**	–
** = *significant at* $\alpha \leq 0.05$				
* = *significant at* $\alpha \leq 0.01$				
– = *non significant*				
Significant interactions:				
Yield: system × site				

Influence of crop production system on usable and non-usable biomass of potatoes

Production system significantly differentiated the values for all studied parameters. Higher values were obtained for the integrated system. The biggest difference concerned the tuber yield per one plant, the smallest-the share of tubers in the total biomass (Tab. 5).

Table 5. Value of tested parameters depending on farming system (mean for 2 places and 3 years)

Farming system	Above-ground biomass [g]	Tuber yield per plant [g]	Total biomass [g]	Share of tubers in total biomass [%]
Organic	305a	554a	859a	65.5a
Integrated	427b	972b	1399b	70.2b
Difference in relation to integrated system [%]	+28.6	+43.0	+38.6	+6.7
a, b – statistically different groups				

Influence of growing site on usable and non-usable biomass of potatoes

The site of growing (environmental conditions) significantly differed only such parameter as above-ground biomass, and share of tubers in total biomass. There was no significant difference in tuber yield and total biomass. The above-ground biomass was significantly greater in Osiny (heavier soil) than in Jadwisin (lighter soil). There was a big difference in distribution of assimilates depending on growing site i.e. better results were obtained in Jadwisin (Tab. 6).

Table 6. Value of tested parameters depending on place of growing (mean for 2 systems and 3 years)

Place of growing	Above-ground biomass [g]	Tuber yield per plant [g]	Total biomass [g]	Share of tubers in total biomass [%]
Jadwisin	312a	789a	1101a	71.7b
Osiny	419b	735a	1154a	63.7a
Differences in relation to Osiny [%]	+25.5	-6.8	+4.6	-11.2

Influence of cultivar on usable and non-usable biomass of potatoes

Cultivars significantly differed depends on all tested parameters. The biggest difference for above-ground biomass and total biomass concerned early cultivar Viviana and mid late cultivar Gustaw, for tuber yield – very early cultivar Viviana and early cultivar Vineta. The best distribution of assimilates had cultivar Vineta, the worse – cultivar Gustaw (Tab. 7).

Table 7. Value of tested parameters depending on cultivar (mean for 2 systems and 3 years)

Cultivar	Above-ground biomass [g]	Tuber yield per plant [g]	Total biomass [g]	Share of tubers in total biomass [%]
Flaming	389ab	746ab	1135ab	66.8ab
Gustaw	425b	795ab	1220b	65.7a
Vineta	335ab	827b	1162ab	71.0b
Viviana	315a	681a	996a	67.8ab

Influence of years on usable and non-usable biomass of potatoes

The weather conditions in the years of investigations had significant influence on all tested parameters apart from share of tubers in total biomass. The best parameters were achieved in favorable for growing potatoes 2012 and the worse in 2013 – when weather conditions were unfavorable (Tab. 8). The above-ground biomass in 2013 was of 47.8% lower than in 2012, tuber yield of 37.5% and total biomass of 40.5%. The distribution of assimilates to above-ground part of plant and to tubers was the same in all years.

Table 8. Value of tested parameters depending on years (mean for 2 systems and 4 cultivars)

Year	Above-ground biomass [g]	Differences in relation to 2012 [%]	Tuber yieldper plant [g]	Differences in relation to 2012 [%]	Total biomass [g]	Differences in relation to 2012 [%]	Share of tubers in total biomass [%]	Differences in relation to 2012 [%]
2011	400b	-12.9	808b	-11.3	1208b	-11.0	66.3a	-1.5
2012	459b	–	911c	–	1357c	–	67.3a	–
2013	239a	-47.9	569a	-37.5	808a	-40.5	69.8a	+3.6

Interactions between tested parameters

There was significant interaction between farming system and site of growing in regard to tuber yield and total biomass. Under organic system on lighter soil the yield was slightly lower than on heavier soil but under integrated system the relation was diverse. There were similar relationships to total biomass. Under organic system the total biomass was higher in Osiny (heavier soil) but under integrated system, higher biomass was noticed in Jadwisin (Fig. 1).

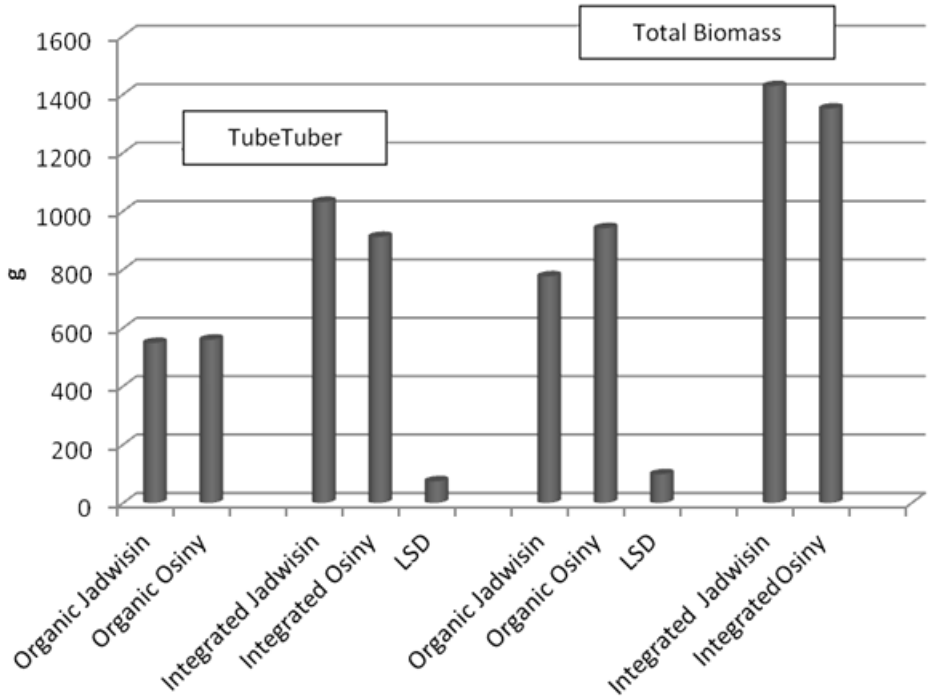

Figure 1. Total biomass and tuber yield depending on crop production system and place of growing (mean for 3 years)

DISCUSSION

An indicator that best describes the share of usable yield in total biomass is harvest index .Harvest index of potato plants or share of tuber yield in total biomass in literature is most often related to conventional plantations, with different levels of fertilization [1, 6, 13, 14, 17]. The value of this index is rather higher than in our study, where the potatoes were grown in the organic and integrated systems. Growing potatoes in these systems generally involves a lower yield of tubers. According to the literature data yielding of organic plantation is about 20–50% lower compared to the conventional one [11, 18, 19] also a weight of aboveground part of plant is less [18, 20]. Literature states that the harvest index decreases with increasing of nitrogen doses fertilization [1, 13, 17]. In our study, there was no such relationship. Also Mazurczyk and others 2009 did not confirm such it. In the present work have not been compared different doses of nitrogen but different crop production systems, although it is known that in the organic system only natural fertilizers was used while in the integrated system additionally mineral fertilization. In addition, to the production system, the distribution of assimilates was also influenced by the quality of the soil. Comparing only the organic system, it is noted that the higher index was achieved on heavier soil [21]. This confirms the well-known relationship that on the fertile soils the yield is higher. In presented study such relationship respected only for organic system. In the integrated system, this dependence did not take place.

Noteworthy is small impact of weather conditions prevailing in the individual years on the distribution of assimilates to different part of plant. In all years the share of tuber in total biomass was very similar. No strict correlations between the value of the harvest index and a Sielianino‘v coefficient was also found in earlier studies [16], however Mazurczyk et al. [13] has found relationship between weather condition and value of harvest index

Among of 4 tested varieties, 3 of them included to very early or early maturity group and only 1 for mid late. Despite this, the distribution of assimilates was different. From the observations and previous studies it is known that the development model of early and late varieties of potatoes is slightly different [3, 15, 18]. Early varieties are generally characterized by lower aboveground mass than the later once, but also produce a lower yield of tubers, hence the share of tubers in total biomass may remain at a similar level. In our study the highest share of tubers in total biomass was obtained for early cultivar Vineta, which produced the highest tuber yield and the lowest for mid early cultivar Gustaw, which produced the highest above ground biomass.

A share tuber in total biomass for all varieties and years of research, ranged from 47.1 to 78.8% with a coefficient of variation ratio of 16.0. Such large range indicates the wide possibilities formation of assimilates distribution by genetic as well as climate and soil factors.

CONCLUSION

The highest influence on assimilates distribution to usable and non-usable part of plant had growing site and cultivar. Farming system and weather conditions during growing season did not significantly influence the share of tuber in total plant biomass.

There was significant interaction between farming system and place of growing regards to total biomass and tuber yield. Under organic system on lighter soil the total biomass and yield was slightly lower than on heavier soil but under integrated system the relation was diverse.

There was relatively small diversity of varieties in regard to the share of tubers in total biomass.

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