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Development and yielding of Virginia fanpetals depending on some elements of agricultural practices

Rozwój i plonowanie ślazowca pensylwańskiego w zależności od niektórych elementów agrotechniki

Summary. In the years 2016–2018, two field experiments with species *Sida hermaphrodita* L. Rusby named Virginia fanpetals (syn. Virginia mallow) later in the manuscript as Sida, were carried out in the Świętokrzyskie province. They were located on light soil prone to drought. The experiments were established in a set of randomized blocks in triplicate. The results were statistically analyzed and significance of differences was assessed by Tukey's test. In the first experiment, the influence of sowing dates (beginning, half, end of May) and fertilization before sowing (NPK: 20, 20, 40 kg·ha^{-1} and control without fertilization) on the development of plants in the first growing year, were examined. In the second experiment, development and yielding of Sida after using three different propagation materials (seedling, root cuttings and seed sowing) in the first three years of cultivation, were compared. The test results clearly showed beneficial effect of pre-sowing fertilization compared to the control (without fertilization). From three May sowing dates, in three years on average, sowing in the middle of this month turned out to be the best. On the light soil prone to drought, the best conditions for growth and yield were provided by seedling and root cuttings, the least favorable – sowing seeds. The average heat of combustion was determined as 18.515 MJ·kg^{-1}.

Key words: Virginia fanpetals, light soil, sowing date, fertilization before sowing, propagating material

INTRODUCTION

Growing economic development and growth of urbanization increase the demand for electricity and transport fuels. Production of energy from minerals contributes to the constant pollution of the natural environment. Reduction of this unfavorable phenomenon is possible due to the increasing substitution of fossil sources with renewable energy ones. Among the renewable sources, there is also a biomass from agricultural crops. To avoid competition with food production, energy crops are located on inefficient soils [Jadczyszyn et al. 2008]. In such conditions, the yields of energy-biomass will decrease from 10–12 t·ha^{-1} to 3–10 t·ha^{-1} [Roszkowski 2013].

Perennial species of crops for bio-energy (e.g. Miscanthus, Switchgrass, Sida etc.) in the first three-five years, usually produce lower yields than in subsequent years of cultivation [Chołuj et al. 2008]. Especially, the first year is distinguished, in which the biomass yield is abnormally low, often below one ton, and rarely reaches 3 t·ha^{-1} [Elbersen 2001, Borkowska et al. 2009, Borkowska and Molas 2013]. Despite such low yields, that do not matter in the energy use, their size and values of basic elements of yield structure indicate the degree of plant development. The yield of the species in subsequent years of cultivation depends to a large extent on the scale of development. Yields can be reduced by some pathogens, especially by *Sclerotinia scleriotiorum*. Among the whole range of factors, weather conditions (mainly rainfall and temperatures) and soil fertility have large impact on the yields obtained [Jadczyszyn et al. 2008, Roszkowski 2013]. In the case of Sida cultivated on medium soil, mineral fertilization is not recommended in the first year of cultivation [Borkowska and Styk 2007]. On light soil with low content of nutrients, this treatment can bring positive results.

In various regions of the country, crop plants have more or less different sowing dates. The situation is similar for Sida. Introduction of industrial production of Sida as a source of energy biomass or high-protein fodder, in the Świętokrzyskie province requires establishment of an optimal date for sowing in this region.

Light, permeable soil and frequent lack of rainfall are not conducive to seed germination and the growth of delicate, small Sida' seedlings. This leads to the search for other propagating material that is more resistant to difficult conditions. According to Wardzińska [2000a], sprouting and emergence of Sida in difficult conditions (sewage sludge) were limited, while development of root cuttings was normal [Wardzińska 2000b]. Following this path, it was worth checking whether this tendency would be confirmed on the light soil that is susceptible to drought.

The aim of the study was to assess the impact of the sowing date and pre-sowing mineral fertilization on the development of plants in the first year of cultivation, as well as various propagation material on Sida yield.

Research hypothesis: it was assumed that determination of the optimal sowing date, fertilization before sowing, as well as selection of the appropriate propagating material will improve the development and yield of Sida plants in the area of research.

MATERIAL AND METHODS

Field experiments were carried out in 2016–2018 in Brzeziny (20°57'E, 50°37'N) belonging to the Szydłów commune in Świętokrzyskie province. The experiments were established in a randomized block pattern in triplicate. In the first experiment, the factors were three dates of seed sowing (beginning, half and end of May) and two levels of fertilization (NPK before sowing in the amount of 20 N, 20 P and 40 K in kg·ha^{-1} and control – without fertilization). Every year, the sowing rate was applied, providing a density of 70,000 seeds·ha^{-1}, and a row spacing of 65 cm. The surface of plots was 110 m^2. In the second one, three types of propagating material were used: seed sowing, root cuttings and seedlings grown in 2015 in the field without covers. In the second and third year of cultivation, mineral fertilization was applied in the following quantities: 110 N, 50 P and 100 K in kg·ha^{-1}, and in the first year – half of that dose. The density was 50,000 seeds ha^{-1}, row spacing – 65 cm, and the area of plots 25 m^2. In both experiments, the harvest was carried out after the vegetation of Sida was completed – in the second half of November. The biomass yield, number and weight of plants per 1 m^2 were assessed. The shoot-height of 10 plants was also measured. A sample of plant material was taken to determine the water content, and on this basis, the yield of dry biomass and dry mass of one shoot were calculated. Results were analyzed statistically according to the Anova model, and Tukey's test at the level of $\alpha = 0.05$. Assessment of the soil sample (taken before the start of the study) and biomass moisture was ordered to the District Chemical and Agricultural Station in Kielce. The combustion heat was determined at the Institute of Power Engineering in Warsaw.

The soil, on which the experiments were carried out, contained small quantities of basic nutrients: 1.4 P, 4.2 K, 2.2 Mg in mg·100 g^{-1} soil, and pH (in KCl) was determined for 5.1. The percentage content of earthy fractions (<2 mm) was as follows: sand (2.00–2.050) – 76.55, dust (0.050–0.002) – 21.45, clay (<0.002) – 2.00, alluvial (<0.020) – 13.45. Presented data show that it is a sandy, light soil, prone to drought.

The average air temperatures and sums of rainfall were obtained from the climate station in Staszów belonging to the Institute of Meteorology and Water Management of the National Research Institute in Warsaw. On the basis of these data, according to Skowera and Puła [2004] Sielianinov hydrothermal coefficients (K) were calculated for vegetation periods (April–September) in the years of research (Tab. 1) as follow: K ≤0.4 – extremely dry, 0.4 – ≤0.7 – very dry, 0.7 – ≤1.0 – dry, 1.0 – ≤1.3 – fairly dry, 1.3 – ≤1.6 – optimal, 1.6 – ≤2.0 – fairly wet, 2.0 – ≤2.5 – wet, 2.5 – ≤3.0 – very wet, >3.0 – extremely wet.

The sum of rainfall and average temperatures in the growing seasons (April–September) and years (January–December) was also presented (Tab. 2). From these data, it results that during the vegetation of Sida, there were long-lasting, even three-month, periods of drought.

RESULTS

Indication of the optimal date of sowing is of great importance in obtaining satisfactory values of the yield structure elements. Value of these elements shapes the size of the crops. As results presented in Table 3 show, the differences in density depending on the sowing date changed in the years of research. On average, from three years, significantly the most plants were found from sowing in the second term – mid-May. There were no differences between density of plants from other dates. From three years of research in 2016 and 2017, dates of sowing did not affect the diversity of the number of plants. Probably, extremely dry or dry periods in the following months after sowing had a large influence on this situation. In 2016, they were 3 months from May to July, and in 2017 in June and July (Tab. 1). Other dependencies occurred in 2018, in which the best sowing was in the middle of May (term II).

Table 1. Values of Sielianinov' hydrothermal coefficients (K) during the growing seasons (01.04–30.09); Staszów Climate Station, IMGW PIB Warsaw

Months	Years			
	2016	2017	2018	2008–2018
April	1.81	5.10	0.18	1.33
May	0.54	1.32	1.09	1.93
June	0.22	0.25	0.79	1.02
July	0.93	0.79	1.85	1.78
August	1.04	1.29	0.74	0.85
September	1.21	2.41	2.03	1.60
Mean	0.81	1.44	1.13	1.40

Hydrothermal coefficients were calculated for months with an average temperature above 8°C, which corresponds to the vegetation period of Sida

Table 2. Sums of precipitation (mm) and mean and sums of average temperatures (°C) for vegetation periods (1.04–30.09) and years of research (1.01–31.12) on the background of multi-annual averages; Staszów Climate Station, IMGW PIB Warsaw

Periods	Years			
	2016	2017	2018	2008–2018
Average temperature totals				
1.04.–30.09	2886	2785	3157	2826
1.01.–31.12.	3281	3517	3422	3109
Average temperatures				
1.04.–30.09.	16	15	17	15
01.01.–31.12.	9	10	9	9
Sum of rainfall				
1.04.–30.09.	234	400	355	395
1.01.–31.12.	533	614	512	616

On soil with low content of basic nutrients, it was possible to expect a beneficial effect on the growth and development of Sida, even at a small dose of NPK brought before sowing. Results presented in Table 3 indicate significant increase in density in combination with pre-sowing fertilization compared to the control. The interaction of years with fertilization was visible only in 2018, in which fertilization before sowing increased the plant density by more than 5 plants per 1 m^2 compared to the combination without fertilization.

Similar dependencies as in plant density occurred in plant heights (Tab. 4). Sida fed with fertilizers was on average more than 30 cm higher than in the control combination. Interactions of years with fertilization were not found only in 2017. During the growing season of this year, the most rainfall was recorded (Tab. 2), but the sum of average temperatures was lower than in other years, as well as in many years (2008–2018). From sowing seeds in mid-May (the second date), the highest Sida plants were obtained. The influence of weather conditions in the years of research conducting was dominant. In 2017, with the lowest sum of average temperatures during the growing season (Tab. 2), the plants were more than three times lower than in 2018. That year (2018), Sida sprouts reached an average of over 120 cm in height; the highest (160 cm) were plants from the II sowing date (mid-May).

Table 3. Plant density (pcs·m^{-2}) of Sida in the first year of cultivation depending on the experimental factors

Factors	Years			Mean
	2016	2017	2018	
Fertilization				
0 NPK	2.6^{a}	6.0^{b}	12.1^{c}	6.9^{A}
80 NPK	3.0^{a}	7.3^{b}	17.6^{d}	9.3^{B}
Sowing dates				
I	3.3^{e}	7.0^{e}	10.7^{f}	7.0^{C}
II	2.7^{e}	7.0^{e}	20.0^{g}	9.9^{D}
III	2.3^{e}	6.0^{e}	13.8^{f}	7.4^{C}
Mean	2.8^{X}	6,7^{Y}	14.8^{Z}	8.1

Values not significantly different at the level of $\alpha = 0.05$ are marked with the same letters; the capital letter distinguishes average values

Table 4. Plant height (cm) of Sida in the first year of cultivation, depending on the experimental factors

Factors	Years			Mean
	2016	2017	2018	
Fertilization				
0 NPK	49.4^{a}	33.1^{a}	103.8^{b}	62.1^{A}
80 NPK	91.7^{b}	45.7^{a}	148.4^{c}	95.3^{B}
Sowing dates				
I	91.7^{f}	22.8^{d}	108.8^{g}	74.4^{C}
II	74.5^{ef}	42.7^{d}	163.3^{h}	93.5^{D}
III	45.5^{de}	52.7^{de}	106.2^{fg}	68.1^{C}
Mean	70.6^{Y}	39.4^{X}	126.1^{Z}	78.7

Values not significantly different at the level of $\alpha = 0.05$ are marked with the same letters; the capital letter distinguishes average values

Table 5. Dry mass (g) of Sida plants in the first year of cultivation, depending on the experimental factors

Factors	Years			Mean
	2016	2017	2018	
Fertilization				
0 NPK	16.76^{c}	2.03^{a}	$5,85^{b}$	8.21^{A}
80 NPK	26.54^{d}	2.66^{a}	$7,53^{b}$	12.25^{B}
Sowing dates				
I	25.67^{i}	1.48^{f}	5.33^{fg}	10.83^{D}
II	25.56^{i}	2.27^{f}	9.61^{gh}	12.48^{E}
III	13.73^{h}	3.28^{f}	5.13^{f}	7.38^{C}
Mean	21.65^{Z}	2.34^{X}	6.69^{X}	10.23

Values not significantly different at the level of $\alpha = 0.05$ are marked with the same letters; the capital letter distinguishes average values

Table 6. Yields of dry biomass ($t \cdot ha^{-1}$) of Sida in the first year of cultivation depending on the experimental factors

Factors	Years			Mean
	2016	2017	2018	
Fertilization				
0 NPK	0.343^{b}	0.115^{a}	0.534^{c}	0.331^{A}
80 NPK	0.724^{d}	0.167^{a}	1.442^{e}	0.778^{B}
Sowing dates				
I	0.782^{f}	0.093^{f}	0.384^{f}	0.420^{C}
II	0.613^{f}	0.134^{f}	1.842^{g}	0.863^{D}
III	0.207^{f}	0.197^{f}	0.738^{f}	0.381^{C}
Mean	0.534^{Y}	0.141^{X}	0.988^{Z}	0.554

Values not significantly different at the level of $\alpha = 0.05$ are marked with the same letters; the capital letter distinguishes average values

Dry mass of a single plant changed under the influence of experimental factors, but the greatest variation occurred between years (Tab. 5). Attention should be paid to the high mass of plant in 2016, which was several times higher than in subsequent years. This is probably due to low planting density (less than 3 per square meter – Tab. 3) facilitating access to light and nutrients. With a small density, even the high mass of a single plant does not affect the release of a high biomass yield (Table 6). In 2018, the highest yield of dry biomass (about 1 $t \cdot ha^{-1}$) was obtained, despite the small mass of a plant, but at the highest density. The application of pre-sowing fertilization in 2016 and 2018 resulted in a significant increase in yield as compared to the control. The effect of years with sowing dates cooperation was visible only in 2018. The biomass yield from the second sowing date was significantly higher (1.8 $t \cdot ha^{-1}$) than from the 1st and 3rd dates (0.3 and 0.7 $t \cdot ha^{-1}$, respectively). Despite two dry months (June and August), 2018 was the most beneficial for the growth, development and yielding of Sida. In contrast to previous years (2016 and 2017), dry months (Tab. 1) did not occur consecutively, but were preceded by humid months (May – fairly dry and July – fairly humid).

Table 7. Density (pcs·m^{-2}) and height (cm) of Sida shoots depending on the propagating material in the first three years of cultivation

Propagating material	2016 – first year of cultivation	2017 – second year of cultivation	2018 – third year of cultivation	Mean
Shoot density				
Seedling	5.7^{a}	23.0^{c}	24.7^{c}	17.8^{B}
Root cutting	5.7^{a}	26.0^{c}	24.7^{c}	18.8^{B}
Sowing	4.7^{a}	18.3^{b}	20.3^{b}	14.4^{A}
Mean	5.3^{X}	22.4^{Y}	23.2^{Y}	17.0
Plant height				
Seedling	142.3^{a}	165.7^{a}	200.7^{a}	169.6^{B}
Root cutting	131.0^{a}	152.3^{a}	177.0^{a}	153.4^{AB}
Sowing	122.7^{a}	145.3^{a}	164.0^{a}	144.0^{A}
Mean	132.0^{X}	154.4^{X}	180.6^{Y}	155.7

Values not significantly different at the level of α = 0.05 are marked with the same letters; the capital letter distinguishes average values

Table 8. Dry mass (g) of a single shoot and yield of dry biomass (t·ha^{-1}) of Sida in the first three years of cultivation, depending on the propagating material

Propagating material	2016 – first year of cultivation	2017 – second year of cultivation	2018 – third year of cultivation	Mean
Shoot mass				
Seedling	28.6^{e}	14.7^{b}	26.8^{de}	23.4^{A}
Root cutting	24.6^{d}	10.8^{a}	19.2^{c}	18.2^{B}
Sowing	18.7^{c}	11.2^{a}	13.8^{a}	14.5^{C}
Mean	23.9^{Z}	12.2^{X}	19.9^{Y}	18.7
Biomass yield				
Seedling	1.49^{ab}	3.33^{e}	6.49^{g}	3.77^{C}
Root cutting	1.11^{a}	2.76^{de}	4.46^{f}	2.78^{B}
Sowing	0.85^{a}	1.73^{ac}	2.40^{bcd}	1.66^{A}
Mean	1.15^{X}	2.61^{Y}	4.45^{Z}	2.74

Values not significantly different at the level of α = 0.05 are marked with the same letters; the capital letter distinguishes average values

In the second experiment, an attempt was made to select propagating material allowing for more effective development and yielding of Sida than sowing seeds in light soil conditions. Data contained in Tab. 7 indicate that, on average, the least sprouting was obtained from seed sowing (14.4 pcs·m^{-2}) over three years, a much higher density was found in combination with seedling and root cuttings (17.8 and 18.8 pcs·m^{-2}, respectively). Presented values seem to be high if we take into account the original planting of 5 pieces per 1 m^{2}. Already in the first year of cultivation, plants produced more than one shoot (an average of 5.3 pcs·m^{-2}). Significantly more than 20 shoots were obtained in the second and third year of cultivation. Interaction of years and propagating material indicated the smallest values of this feature obtained in the combination of seed sowing.

Table 9. Energy value (MJ·ha^{-1}) of dry Sida biomass in the third year of cultivation, depending on propagating material

Propagating material	Yield (t·ha^{-1})	Combustion heat (MJ·kg^{-1})	Energy yield GJ·ha^{-1}
Seedling	6.49	18.515	120.14
Root cutting	4.46		82.65
Sowing	2.40		44.45
Mean	4.45	–	82.41

Heat of combustion – the average of three samples was adopted: 18749, 18592, 18204 kJ·kg^{-1}

Also from seed sowing, plants produced lower shoots than from seedlings (Tab. 7), but their height did not differ from the height of shoots from root cuttings. Differences in the plant heights between the years of cultivation are the result of the development of Sida, which in the first year, produces one fairly short shoot. In subsequent years (perennial development cycle), there are taller shoots. Statistically proven differences were found between the second and third year of cultivation. Plants in the third year were over 180 cm tall (Tab. 7). An important feature of the yield structure, which is the mass of a single shoot, has changed under the influence of propagating material and growing years (Tab. 8). The largest mass was distinguished by shoots from seedlings, the smallest – from seed sowing. Attention should be drawn to high value of this feature in the first year of cultivation. This is the result of a small density – plants have produced 1–2 shoots. In the second year of cultivation, Sida shoots were of little weight. In that year, exceptionally low mass of the shoot was found in combinations with sowing and root cuttings (respectively 11.17 and 10.75 g). A similar tendency as in the mass of a single shoot was found for the yields of dry biomass (Tab. 8). The least mass was obtained from seed sowing, and the most from seedlings. Between subsequent years of cultivation, a systematic increase in the biomass yields is visible, which is natural phenomenon for perennial plants. The effects of interaction of years with propagating material are particularly pronounced in the third year of cultivation (2018). That year, there were significant differences between all types of propagating materials tested. The largest yield of energy biomass was obtained from seedlings (6.4 t·ha^{-1}), while the lowest from seed sowing (2.4 t·ha^{-1}). The yield of Sida biomass in the third year of cultivation obtained from seedling may provide 120 GJ of renewable energy (Tab. 9).

DISCUSSION

Among many species providing a biomass for energy purposes, the most important are perennial species, such as giant miscanthus, *Miscanthus sacchariflorus*, *Silphium perfoliatum*, switchgrass, Sida, basket willow etc. [Clifton-Brown et al. 2004, Chołuj et al. 2008, Roszkowski 2013, Payne et al. 2017]. Roszkowski [2013] reports that 40% of energy is used for heating the buildings. This number also includes households and public utility buildings using coal-fired boilers. In such locations, coal should be replaced with fuel from agricultural biomass. In the production of fuel from biomass (briquettes, pellets), the species that have low humidity at the harvest time become particularly important. They do not require additional energy-consuming drying. Such species include Sida [Chołuj et al. 2008, Borkowska and Molas 2013, Gehren et al. 2019]. In Poland, the trend of "pushing" the energy crops to areas with limited food production is dominating [Roszkowski 2013]. Among them, there are light minerals that are poor in minerals and organic matter, which are most often susceptible to drought. Yields on such soils will be much lower than commonly presented [Chołuj et al. 2008, Borkowska and Molas 2013, Roszkowski 2013]. To increase the chances of obtaining satisfactory crops, basic agrotechnical measures should be adapted to these areas. One of them is the optimal sowing date. In the conditions of Lublin region, the end of April – the beginning of May – was adopted for the optimal sowing date [Borkowska and Styk 2006]. In the area of our research (Kielce region), the best sowing from three sowing dates, on average over three years, was in the middle of May. Although two weeks after sowing, the months of June (2018) and July (2016 and 2017) were dry or extremely dry periods [Skowera and Puła 2004], Sida survived unfavorable conditions. Values of the examined crop structure elements were significantly higher than those obtained in other dates. From sowing at the beginning and end of May, more than twice lower yields of dry biomass were obtained (respectively: 0.42 and 0.38 $t{\cdot}ha^{-1}$) than from sowing in the middle of this month (0.86 $t{\cdot}ha^{-1}$). Low yields of biomass in the first year of cultivation concern not only Sida, but also other long-term energy species. Most often, they amount to 0.5–3 $t{\cdot}ha^{-1}$ [Elbersen 2001, Stolarski et al. 2005, Chołuj et al. 2008, Borkowska and Molas 2013]. In conditions of soils poor in nutrients, these crops are particularly small [Roszkowski 2013]. The results of our own research confirm this statement; average biomass yields amounted to only 0.554 $t{\cdot}ha^{-1}$. Enriching the soil with nutrients with a small dose of mineral fertilizers resulted in a two-fold increase in the yield as compared to the control (0.778 and 0.331 t ha^{-1}, respectively). This increase in yield does not affect the possibility of energy use. However, it causes better plant development in the first year, which will increase the yield potential in the following years (development of the root system).

Determination of the optimal date of sowing and pre-sowing fertilization influenced the better development of plants, but insufficiently. In addition to the listed agrotechnical elements, the propagating material used seems to be important. Light soils with a small amount of alluvial fraction do not provide a good environment for germination and emergence of delicate seedlings. Hence, there is a comparison of the impact on Sida's development, in addition to seed sowing, planting seedlings and root cuttings. According to Wardzińska [2000a, 2000b], better development and higher biomass yields result from planted root cuttings than from seed sowing results. In our research, the yield obtained from root cuttings was almost twice as high as from seed sowing. In the third year of cultivation, much better results than from sowing (2.4 $t{\cdot}ha^{-1}$) were obtained after planting the seedlings (6.5 $t{\cdot}ha^{-1}$). Over 6 t of dry matter from 1 ha allows for Sida growing on light soil to obtain over 120 GJ of energy. Higher biomass yields can be expected in 4–5 years of cultivation. Such forecasting is based on the results of research conducted by Chołuj et al. [2008]. The authors stated that the best LAI index (Leaf Area Index), conditions for photosynthesis and yielding, are obtained by perennial species of energy-crops only in 4–5 years of cultivation. Among those studied by Chołuj et al. [2008], the best indicator of LAI characterized Sida. This indicates the chance of obtaining more energy from the biomass of Sida's biomass [Jablonowski et al. 2017] than given in Table 9.

CONCLUSIONS

1. In light soil conditions with low content of basic nutrients, bringing in even a small amount of mineral fertilizers has a positive effect on the growth and development of Sida plants.

2. In the area of research, the best date for sowing is the middle of May.

3. On light soil, much better propagating material than sowing seeds was seedling cultured in the field without cover as well as root cuttings.

4. In the years of research, there was a significant variation in the value of assessed features under the influence of meteorological elements.

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Streszczenie. W latach 2016–2018 w województwie świętokrzyskim przeprowadzono dwa eksperymenty terenowe z gatunkiem ślazowiec pensylwański (*Sida hermaphrodita* L. Rusby; synonim Virginia fanpetals, Virginia mallow) później w rękopisie Sida, na lekkiej glebie podatnej na suszę. Eksperymenty przeprowadzono w zestawie losowych bloków w trzech powtórzeniach. Wyniki przeanalizowano statystycznie, a istotność różnic oceniono za pomocą testu Tukeya. W pierwszym eksperymencie badano wpływ terminu siewu (początek, połowa, koniec maja) i nawożenia przed siewem (NPK: 20, 20, 40 $kg \cdot ha^{-1}$ i kontrola bez nawożenia) na rozwój roślin w pierwszym roku wzrostu. W drugim eksperymencie porównano rozwój i plonowanie Sida po zastosowaniu trzech różnych materiałów rozmnożeniowych (sadzonka, sadzonki korzeniowe i siew nasion) w pierwszych trzech latach uprawy. Wyniki testu wyraźnie wykazały korzystny wpływ nawożenia przedsiewnego w porównaniu z kontrolą (bez nawożenia). Spośród trzech majowych terminów siewu, średnio z trzech lat, siew w połowie tego miesiąca okazał się najlepszy. Na lekkiej glebie podatnej na suszę najlepsze warunki wzrostu i plonów zapewniały rozsada i sadzonki korzeniowe, najmniej korzystne – nasiona siewne. Średnie ciepło spalania określono na 18.515 $MJ \cdot kg^{-1}$.

Słowa kluczowe: ślazowiec pensylwański, gleba lekka, termin siewu, nawożenie przedsiewne, materiał rozmnożeniowy

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