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METHOD AND TIME OF ALFALFA SOWING WHEN CLIMATE IS CHANGING

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Abstract. The inspiration to reassess method and timing for establishing alfalfa (*Medicago sativa* L.) is meteorological data documenting that current Polish winters are milder than several decades ago, when management recommendations were worked out for this crop. Additionally, prolonged periods of spring drought occur more frequently, posing significant challenges to the development of alfalfa seedlings under a companion crop. The hypothesis was made that as climatic conditions change, the traditional practice of spring sowing with a barley (*Hordeum vulgare* L.) companion crop may become higher risk, and direct sowing later in the season when rainfall is more dependable would provide advantages. From 2010 to 2014 three series of experiments were carried out over the establishment year and first production year. Establishment success and yield performance of alfalfa sown with a barley companion crop in April was compared to alfalfa direct sown in May, June, July and August. Plant density, overwinter survival, and diameter of the upper taproot from sowings performed in the period April to late July were similar. Plant density with August sowing was significantly higher, but taproot diameter was smaller than in plants sown earlier in spring or summer. Plants from all sowing treatments overwintered well, with the greatest stand loss of only 15% occurring with August sowing. In the first production year, mean dry matter yields were similar for alfalfa sown in the period from April to late July, averaging 11.7 $Mg \cdot ha^{-1}$. First production year yield associated with August sowing was significantly lower, at 8.88 $Mg \cdot ha^{-1}$. In the years and locations of this study, the alternative of direct sowing alfalfa up to late July resulted in similar establishment success to the traditional practice of sowing with a barley companion crop in early spring.

Key words: companion crop, establishment year, lucerne, *Medicago sativa*, production year, taproot

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INTRODUCTION

Alfalfa (*Medicago sativa* L.), synonym lucerne, is grown primarily on dairy farms where a dependable supply of high quality fodder is key to profitability. Because of tolerance to drought, alfalfa is a reliable source of protein and digestible fibre, and there is good understanding of management practices to optimize nutritive value of the forage [Andrzejewska *et al.* 2013a, b]. Reliable methods for seedling establishment are critical because partial or total failure results in lost investment and need to replace anticipated alfalfa fodder with other fodder sources. According to earlier research [Plebański 1970, Staszewski 1975], spring sowing is usually more favourable for alfalfa than during summer. This is associated with water accumulated in the soil during winter. In the spring alfalfa is typically sown with a companion crop, which is most often spring barley (*Hordeum vulgare* L.) harvested for grain, but oat (*Avena sativa* L.) grown for green fodder is also used [Jelinowska 1967, Tesar and Marble 1988, Gaweł and Brzóska 2008]. However companion crops, at one time called "nurse crops", do not protect the seedling as once believed but rather compete for moisture, light, and nutrients. Extended spring droughts are particularly damaging to alfalfa established with companion cereal crops [Andrzejewska 1996].

The alternative to establishing alfalfa with a companion crop is direct sowing. Staszewski [1975] and Jelinowska [1983] reported that in most of Poland alfalfa can be sown until the beginning or middle of July. Wilczek and Ćwintal [1992] obtained dry matter yields of 10 to 12 $Mg \cdot ha^{-1}$ in the first production year after direct sowing in July, independent of sowing rates ranging from 6 to 21 $kg \cdot ha^{-1}$.

Practices for establishing alfalfa vary, not only in Poland but also in other countries [Undersander *et al.* 2011, Hakl *et al.* 2014]. Sowing alfalfa with a companion crop results in reduced weed infestation compared to direct sowing [Tesar and Marble 1988, Zając 2007]; moreover, in the establishment year additional yield from the companion crop is obtained [Jelinowska 1967, 1983]. Sowing alfalfa without a companion crop, however, usually results in better stand density [Sowiński and Nowak 2002].

Most research and management recommendations concerning method and timing of alfalfa establishment in Poland derive from the second half of the 20th century [Jelinowska 1967, Plebański 1970, Staszewski 1975, Jelinowska 1983, Harasimowicz--Hermann and Andrzejewska 1997]. In recent years, rising global temperature has been accompanied by changes in weather and climate. In Poland this is manifested primarily by the occurrence of milder winters as compared with the period from the 1960s and the 1970s [Żarski *et al.* 2009]. Moreover, during spring, especially in the central part of the country, extended periods without rainfall have become more common [Żarski *et al.* 2009]. If an extended dry period occurs in April or May, success of establishment when alfalfa is sown with a cereal companion crop, especially on lighter soils, may be compromised. Therefore the hypothesis has been put forward that with current conditions of milder winters and more frequent rainfall deficits in the spring, it is justified to direct sow alfalfa in the spring, summer, and even late summer instead of early spring sowing with a companion crop. It is particularly important to get establishment right because alfalfa has been identified as a crop able to withstand the projected climate change for Central Europe [Gauly *et al.* 2013].

The aim of this study was to compare alfalfa establishment success and yield in the first production year of alfalfa sown with a barley companion crop in April to direct sowing later in spring and summer.

MATERIAL AND METHODS

Three field experiments were conducted from 2009 to 2014, comprising the establishment year and the first production year for alfalfa. Information on site locations and soil conditions are presented in Table 1.

Table 1. Research sites and soil conditions for alfalfa establishment research
Tabela 1. Lokalizacja badań i warunki glebowe doświadczeń z lucerną

Location – Lokalizacja		Soil quality class Klasa bonitacyjna gleby*	pH in 1n KCl pH w 1n KCl	Plant available nutrients Zasobność gleby, mg·100 g^{-1}		
location/years of study miejscowość/ lata badań	geographic coordinates współrzędne geograficzne			P_2O_5	K_2O	MgO
Plebanka 2009-2010	52° 48′ N 18° 52′ E	III	7.63	76.4 (vh)**	24.4 (h)	9.8 (vh)
Bobrowniki 2011-2012	52° 46′ N 18° 57′ E	V	7.68	13.8 (l)	5.14 (l)	2.37 (l)
Sypniewo 2013-2014	53°22′ N 17°19′ E	IV	5.5	14.6 (m)	15.5 (m)	7.78 (m)

* six classes are distinguished, where class I marks best soils and class VI poorest soils – wyróżnia się 6 klas, gdzie klasa I oznacza gleby najlepsze, klasa VI – gleby najsłabsze
** vh – very high level – zasobność bardzo wysoka, h – high level – zasobność wysoka, m – moderate level – zasobność średnia, l – low level – zasobność niska

Experiments were established in a randomized complete block design with five treatments and four replications. The five treatments were methods and times of alfalfa sowing:

1) sowing with spring barley companion – April,
2) direct sowing – May,
3) direct sowing – June,
4) direct sowing – July,
5) direct sowing – August.

The plot size for each treatment was 10 m^2. The cultivar Ulstar was sown in the first and second series and the cultivar Legendiary in the third. The sowing time fell between the 15th and 25th day of each month.

Phosphorus and potassium fertilizers were applied before sowing, at rates based on soil test recommendations. Available forms of phosphorus and potassium were determined by the Egner-Riehm and magnesium by the Schatchabel methods. Nitrogen fertilizer was applied at a rate of 60 kg·ha^{-1} only to plots with spring barley. In April, 80-100 kg·ha^{-1} of spring barley was sown and then alfalfa was sown with a separate pass. Alfalfa was sown with a drill at the rate of 15 kg·ha^{-1} in the companion crop and direct sowing treatments on all dates.

After emergence, when alfalfa had 2-3 expanded trifoliate leaves, the herbicide Barox 460 SL (bentazon + MCPA) was applied at a rate of 3 dm^3·ha^{-1}. This practice was performed only where alfalfa was grown with a barley companion crop. In pure stands of alfalfa, weeds were controlled by clipping.

In the establishment year one harvest was taken in September from alfalfa direct sown in May and June. Alfalfa that was direct sown in July and August was not harvested in the establishment year. Grain and straw from the barley companion crop were removed in early August, and some alfalfa was clipped to a height of 15 cm in that process. In November of the establishment year plant density was determined by counting plants in a 1 m^2 area of each plot. Plant density was similarly determined in the same area in the spring after establishment. In November of the establishment year, 15-20 plants from 1-meter of row were dug from plots representing each sowing time in a single field replication. The diameter of the taproots were measured just below the first crown branches.

In the first production year, four cuts were harvested in 2010 and 2014, and three cuts in 2012. Alfalfa in the first, second and third cuts was harvested at the initial bloom stage or late bud stage, and the fourth cut in the vegetative stage. Subsamples were dried at 60°C to determine dry matter content and yields expressed on a dry matter basis.

Weather conditions

The weather data derive from meteorological stations located nearest (10-40 km) to the field sites in each year of the experiment. For Plebanka data were used from the Cultivar Testing Experimental Institute of the Research Centre for Cultivar Testing in Głębokie (52°39' N; 18°27' E) and for Bobrowniki from Głodowo (52°50' N; 19°15' E). Data from the Research Station in Mochełek (53°12' N; 17°51' E) were used for the Sypniewo location and to document long-term trends in central Poland.

The most favourable moisture conditions prevailed in the study period of 2009-2010, and in the other years precipitation was slightly greater than the mean from the period 1949-2013. Mean daily air temperature during 18 months of alfalfa growth at each location was about 1°C higher than the temperature from the years 1949-2013. Temperatures during the 5 month winter period ranged from 0.5 to 2.12°C higher than the 1949-2013 norm (Table 2).

Table 2. Weather conditions during the period from alfalfa sowing to the last harvest in the first production year

Tabela 2. Warunki pogodowe w okresie od siewu lucerny do zbioru ostatniego pokosu w pierwszym roku użytkowania

Location and year Lokalizacja i lata	Total precipitation, mm April – September (18 months) Suma opadów, mm kwiecień – wrzesień (18 miesięcy)	Mean daily temperature, °C Średnia dobowa temperatura April – September (18 months) kwiecień – wrzesień (18 miesięcy)	Mean daily temperature, °C Średnia dobowa temperatura November – March (5 months) listopad – marzec (5 miesięcy)
Plebanka 2009-2010	1032	10.7	0.72
Bobrowniki 2011-2012	773	10.9	0.60
Sypniewo 2013-2014	820	11.0	2.22
Mochełek 1949-2013	736	9.9	0.10

The dynamics of temperature and precipitation in the months of potential alfalfa sowing were worked out for the years 1949-2014, based on the data from the Research Station in Mochełek (Figs. 1 and 2). The data show that in central Poland there is a tendency for increasing mean daily air temperature with years, particularly in April, May and July. Moreover, there is a trend for greater precipitation, particularly in May, June and August. Only in April is there a tendency towards decreasing precipitation, and July constantly remains the month with the highest total precipitation.

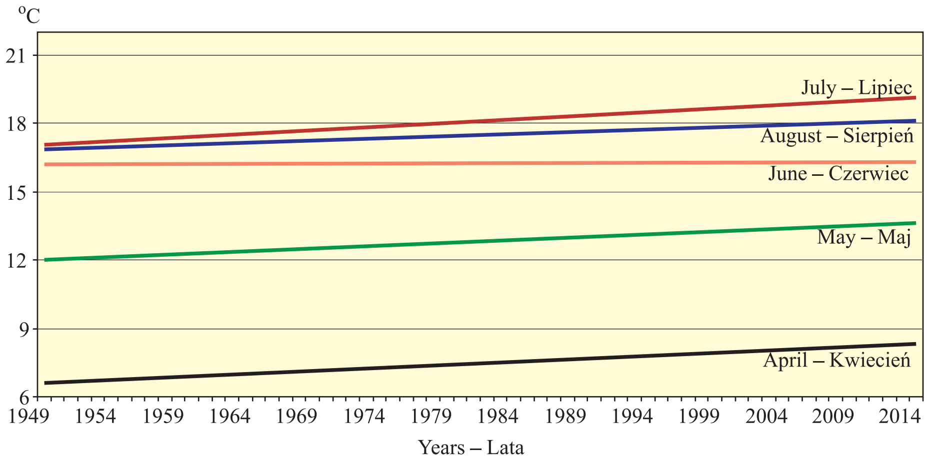

Fig. 1. Dynamics of spring and summer mean air temperature over 64 years in Mochelek
Rys. 1. Dynamika wiosennych i letnich temperatur powietrza w Mochełku w okresie 64 lat

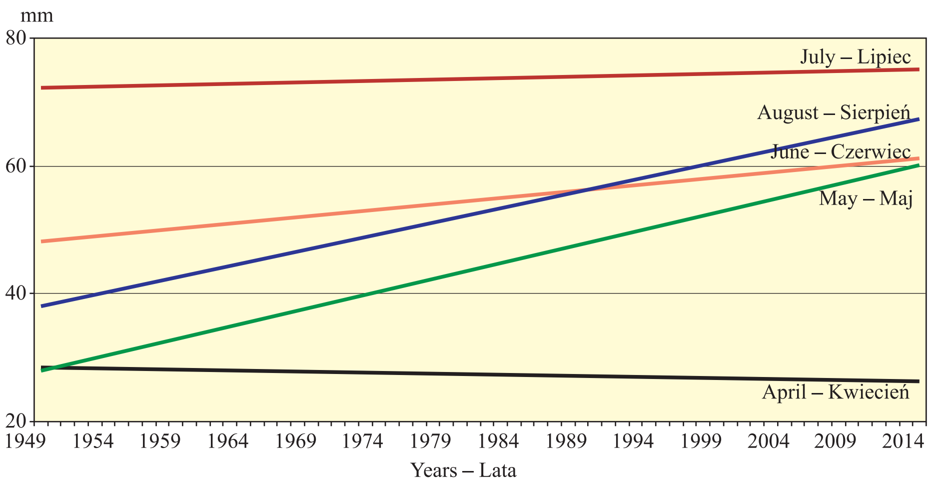

Fig. 2. Dynamics of spring and summer rainfall over 64 years in Mochelek
Fig. 2. Dynamika wiosennych i letnich opadów w Mochełku w okresie 64 lat

Statistical analyses

The results of plant density and dry matter yield were subjected to analysis of variance, and mean separation was accomplished with Tukey's test. The statistical software ANWAR developed at UTP by Rudnicki was used. For root diameter measurements, standard deviations were calculated using the spreadsheet Excel 2007.

RESULTS

In the autumn of the establishment year, highest density of alfalfa plants was obtained from the August sowing (Table 3). There was also a tendency for greater density in both autumn of the establishment year and spring the year after establishment with later sowing dates from April to late July. Although highest over-winter plant losses were observed with the August sowing date, spring plant density still remained highest in this treatment. Plant losses over winter were minimal when sowing was performed in the period from April to late July.

Table 3. Plant density of alfalfa before winter in the establishment year and in spring in the first production year (plants·m^{-2})
Tabela 3. Obsada roślin lucerny przed zimą w roku siewu i na wiosną w pierwszym roku użytkowania (rośliny·m^{-2})

Period of determinations Okres oznaczeń	Companion crop Wsiewka	Direct sown – Siew czysty				LSD$_{0.05}$ NIR$_{0.05}$
	April kwiecień	May maj	June czerwiec	July lipiec	August sierpień	
Autumn – Jesień	159	171	174	181	244	26
Spring – Wiosna	157	168	172	175	217	20
Losses – Ubytki, %	1.3	4.0	2.3	5.7	15.0	–

values are means over three locations

Root diameter, measured in November of the establishment year, decreased systematically with delay of sowing time from May to August (Table 4). Taking into account standard deviations, it is noted that plants sown in August had the smallest root diameter.

Table 4. Taproot diameter of alfalfa at the end of the establishment year (means over three locations), cm
Tabela 4. Średnica szyjki korzeniowej lucerny po zakończeniu wegetacji w roku siewu (średnie z trzech lokalizacji), cm

Character Cecha	Companion crop Wsiewka	Direct sown – Siew czysty			
	April kwiecień	May maj	June czerwiec	July lipiec	August sierpień
Toproot diameter Średnica szyjki korzeniowej	0.83±0.23*	0.86±0.19	0.74±0.23	0.51±0.32	0.22±0.16

* ± standard deviation value – wartość odchylenia standardowego

Highest dry matter yield of alfalfa forage in the first production year was obtained in 2010 from sowings performed the previous year in the period from April to July, and in 2012 from April to June (Table 5). In 2014 a large differentiation in first production year yields associated with sowing time was observed. Highest yield was harvested from alfalfa sown in May, followed by June sowing, and then from sowing performed in April or July. In each year of the study the lowest first production year yield was obtained from alfalfa sown in August.

Table 5. Dry matter yield of alfalfa in the first production year after sowing at different dates in three environments, Mg·ha^{-1}
Tabela 5. Plony suchej masy lucerny w pierwszym roku użytkowania w zależności od lokalizacji i lat badań, Mg·ha^{-1}

Locality/year Miejscowość/rok	Companion crop Wsiewka	Direct sown – Siew czysty				$LSD_{0.05}$ $NIR_{0.05}$
	April kwiecień	May maj	June czerwiec	July lipiec	August sierpień	
Plebanka/2010	9.3	8.9	8.2	9.0	6.1	1.75
Bobrowniki/2012	13.3	13.2	14.1	12.0	10.7	0.97
Sypniewo/2014	11.3	15.3	13.5	12.1	9.17	0.93

The mean first production year yields of alfalfa sown in the period April – July did not differ significantly (Table 6). Alfalfa sown in August yielded significantly less, on average by 2.78 Mg·ha^{-1}, compared with mean yields from all earlier sowing times. Similar tendencies were found in individual cuts except for the fourth cut, when the yields from all the sowing times were similar (Table 6).

Table 6. Harvest distribution among cuts and total annual dry matter yield in the first production year of alfalfa depending on method and time of sowing (means over three locations), Mg·ha^{-1}
Tabela 6. Rozkład plonów w pokosach i całoroczny plon suchej masy w pierwszym roku użytkowania lucerny w zależności od sposobu i terminu zakładania plantacji (średnie z trzech lokalizacji), Mg·ha^{-1}

Cut Pokos	Companion crop Wsiewka	Direct sown – Siew czysty				Mean Średnia
	April kwiecień	May maj	June czerwiec	July lipiec	August sierpień	
1th	4.23	4.51	4.12	4.20	3.16	4.05
2nd	3.90	3.94	4.28	3.85	3.19	3.95
3rd	2.35	3.12	2.84	2.40	1.92	2.52
4th	0.78	0.78	0.69	0.63	0.62	0.70
Total – Suma	11.27	12.35	11.93	11.08	8.88	–

$LSD_{0.05}$ for the total harvest 1.28 – $NIR_{0,05}$ dla sumy plonu 1.28

DISCUSSION

Air temperatures during the study, particularly in the winter months, were higher than the mean temperature over the last 64 years. This reflects tendencies reported by Żarski *et al.* [2009] concerning the occurrence of milder winters in central Poland and it confirms the usefulness of undertaking this research. Although April precipitation in recent years has been lower than the long-term normal, no prolonged dry periods were noted in the years of this study, thus there were favourable conditions for alfalfa established with a spring barley companion. As a result, first production year yields from alfalfa sown with a barley companion crop were comparable to yields from alfalfa direct sown in the period from the second half of May to late July. In Sypniewo highest yields were obtained from direct sowing in May and June. These results confirm the opinions of other authors [Borowiecki *et al.* 1997] that alfalfa forage yield in the first production year depends to a larger degree on the weather conditions in the current season than on the method of establishment. Additionally, Hakl *et al.* [2014], who conducted a study in the Czech Republic, indicated that alfalfa yield is determined by simultaneous effects of soil and weather factors, not by the effect of the soil factor alone. In the present study, because of favourable rainfall distribution, high dry matter yields of alfalfa were obtained even in the light soil in Bobrowniki.

Sowiński and Nowak [2002] reported that the density of alfalfa plants when established with a companion crop was lower than the density from spring and early summer direct sowing. This trend was observed in the current research, but was not statistically significant. Plant density from August sowing was on average higher by 30% in autumn and by 23% in spring than the plant density from spring or earlier summer sowing. A distinctly thinner root measured at the end of the establishment season was probably the effect of considerably shorter period of plant growth when sown in August, but the greater plant density could also have increased plant-to-plant competition. A similar effect was described by Hakl *et al.* [2011]. However plant density is always equal to or greater than required for maximizing yield (Tesar and Marble 1988). Assuming the mean dry matter yield from sowing in the period April – July as 100%, the decrease in yield with sowing performed in August was 24%. This is such a substantial yield reduction that August sowing cannot be considered a viable alternative to either April sowing performed with a companion crop or to direct sowing in the period May – July. Justes *et al.* [2002] report that alfalfa sown in August, as compared with sowing in July had shorter roots and also accumulated less root nitrogen reserve even with application of nitrogen fertilizer. However, it should be noted that August alfalfa sowing can be performed after the harvest of a main crop. Therefore, in the economic analysis of the crop rotation, the lower production year yield may be compensated for by the value of the main crop.

In the research under discussion, the alfalfa cultivar Ulstar was used in two of the environments. Based on the research of COBORU [Domański, 2012] it is known that this cultivar overwinters well, particularly during the first winter. The present study confirmed winter hardiness of this cultivar, even with late August sowing. Use of another cultivar in 2013-2014 had no effect on realization of the goals of the experiment. Although the yield potential of the cultivar Legendiary is greater than that of Ulstar, other functional characters are similar [Domański, 2012]. Other authors also emphasize the small effect of genotype on diversity of yields and other functional characters of modern, adapted alfalfa cultivars [Wilczek and Ćwintal 2002, Hakl *et al.* 2011].

Previous recommendations sometimes state that direct sowing might be an alternative to establishing alfalfa with a companion crop, but sowing must be performed by the middle of July [Staszewski 1975, Jelinowska 1983]. The results of the current research indicate that summer sowings can also be successful in late July. This is essential, because it enables sowing alfalfa after early-harvested main crops, e.g. after winter barley. Establishing alfalfa in May or June is also a viable option e.g. after early harvested oat grown for green fodder. In addition to the previous crop in a system, the factor most limiting alfalfa establishment in the period in question will be the state of soil moisture.

The issue of alfalfa establishment in the face of climate change has been studied for Polish conditions but climate change is a global concern affecting many crops in many regions. Agronomic recommendations should be reviewed and adjusted to the current and predicted climate conditions [Rankinen *et al*. 2013; Bloch *et al.* 2015].

CONCLUSIONS

1. As winters become warmer and summer rainfall more abundant, direct sowing alfalfa from the end of May to the end of July becomes a viable alternative to establishing alfalfa with a barley companion crop in April.

2. Direct sowing alfalfa in the second half of August, despite good winter survival, resulted in nearly 25% decrease in yield in the first production year.

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SPOSÓB I TERMIN SIEWU LUCERNY W WARUNKACH ZMIENIAJĄCEGO SIĘ KLIMATU

Streszczenie. Inspiracją do wznowienia badań nad sposobami i terminami zakładania plantacji lucerny są dane meteorologiczne dowodzące, że obecnie w Polsce występują łagodniejsze zimy niż przed kilkudziesięcioma laty, kiedy dla tego gatunku opracowano zalecenia uprawowe. Dodatkowo często występują długotrwałe wiosenne okresy posuszne, stanowiące istotne zagrożenie dla rozwoju wsiewek. Postawiono hipotezę, że w takich warunkach klimatycznych zamiast wiosennego, ryzykownego siewu w roślinę ochronną, należy zalecać zakładanie plantacji lucerny w siewie czystym w terminie późnowiosennym, letnim, a nawet późnoletnim. W latach 2010-2014 przeprowadzono trzy serie badań obejmujące rok siewu i rok użytkowania. Na tle kwietniowego terminu, kiedy lucernę uprawiano jako wsiewkę w jęczmień, wykonano siewy czyste w drugiej połowie maja, czerwca, lipca i sierpnia. Obsada roślin, ich przezimowanie i grubość szyjki korzeniowej roślin z siewów wykonanych w okresie kwiecień – lipiec były zbliżone. Obsada roślin z siewu sierpniowego była znacząco większa, ale grubość szyjki korzeniowej mniejsza niż u roślin wysianych wcześniej. Rośliny z wszystkich terminów siewu przezimowały dobrze i jedynie 15% straty w obsadzie wystąpiły, gdy siew wykonano w sierpniu. W pierwszym roku użytkowania z lucerny wysianej w okresie od kwietnia do lipca średnie plony suchej masy były podobne i wynosiły średnio 11.7 $Mg\cdot ha^{-1}$. Z siewu sierpniowego zebrano plon istotnie niższy – 8.88 $Mg\cdot ha^{-1}$. W rejonie przeprowadzonych badań alternatywą dla wsiewki lucerny w jęczmień jary jest siew czysty wykonany nie później niż w drugiej połowie lipca.

Słowa kluczowe: *Medicago sativa*, rok siewu, rok użytkowania, roślina ochronna, szyjka korzeniowa

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