Paweł FRĄCKOWIAK[1], Florian ADAMCZYK[1], Grzegorz WĄCHALSKI[1], Michał SZAROLETA[1], Arkadiusz DYJAKON[2], Luigi PARI[3], Alessandro SUARDI[3]
[1] Przemysłowy Instytut Maszyn Rolniczych, ul. Starołęcka 31, 60-963 Poznań, Poland
[2] Uniwersytet Przyrodniczy we Wrocławiu, Instytut Inżynierii Rolniczej, ul. Chełmońskiego 37/41, 51-630 Wrocław, Poland
[3] Consiglio per la ricerca in agricoltura e l'analisi economica, CREA-ING - Unità di ricerca per l'ingegneria agraria. Via della Pascolare 16, 00016 Monterotondo, Roma, Italy
e-mail: office@pimr.poznan.pl ; arkadiusz.dyjakon@up.wroc.pl ; alessandro.suardi@crea.gov.it

A PROTOTYPE MACHINE FOR HARVESTING AND BALING OF PRUNING RESIDUES IN ORCHARDS: FIRST TEST ON APPLE ORCHARD (*MALUS MILL.*) IN POLAND

Summary

Currently the global practice is to collect branches that remain in orchards and vineyards after maintenance pruning sporadically, using specially designed conventional hay balers. The EuroPruning project implemented in the Industrial Institute of Agricultural Engineering (PIMR) in Poznań involved developing the construction of a new machine for compressing branches remaining in orchards and vineyards after maintenance pruning into round bales. The aim of this study was to assess the accuracy and quality of work of the developed research model of PRB 1.75 baler and to identify basic operational parameters of the machine. The tests involved determining the level of power consumption of the machine at idle and during normal operation. The amounts of branches left by the machine in inter-rows have also been measured, thus determining the losses of material. The average area performance of the machine obtained during the tests was 1.25 ha·h^{-1} and the average value of losses amounted to approx. 24%. As the bale chamber filled up, power consumption slowly increased from approx. 3 kW at the beginning of the collection of branches to the maximum of approx. 40 kW at the final stage of bale formation before proceeding to its wrapping.
Key words: *round baler, biomass, pruning, prototype, work parameters, quality of work, bales*

ANALIZA WSTĘPNYCH WYNIKÓW BADAŃ PRASY ZBIERAJĄCEJ DO ZBIORU GAŁĘZI PO PRZEŚWIETLENIACH W SADACH

Streszczenie

Aktualnie na świecie do zbioru gałęzi pozostających w sadach i winnicach po cięciach konserwacyjnych sporadycznie wykorzystywane są specjalnie przystosowane do tego celu konwencjonalne prasy do zbioru słomy. W ramach realizacji projektu EuroPruning w Przemysłowym Instytucie Maszyn Rolniczych (PIMR) w Poznaniu opracowano konstrukcję nowej maszyny do prasowania w cylindryczne bele gałęzi pozostających w sadach i winnicach po przeprowadzeniu cięć konserwacyjnych. Celem badań było dokonanie oceny poprawności i jakości pracy opracowanego modelu badawczego prasy PRB 1,75 oraz określenie podstawowych parametrów eksploatacyjnych tej maszyny. W czasie badań określano wielkości poboru mocy przez maszynę na biegu jałowym oraz w czasie jej normalnej pracy. Wykonano również pomiary ilości pozostawionych przez maszynę w międzyrzędziach gałęzi, będące miarą strat materiału. Uzyskana podczas badań średnia wydajność powierzchniowa pracy maszyny to 1,25 ha·h^{-1}, a średnia wartość poziomu strat wynosiła ok. 24%. W miarę zapełniania się komory prasowania następował powolny wzrost poboru mocy od ok. 3 kW przy rozpoczęciu procesu zbierania gałęzi do maksymalnie ok. 40 kW w końcowym etapie tworzenia beli przed rozpoczęciem procesu jej owijania.
Słowa kluczowe: *prasa zbierająca, biomasa, obcięte gałęzie, prototyp, parametry pracy, jakość pracy, bele*

1. Introduction

In their study Gorzelany and Matłok [13] report that according to analytical sources available there is a very high probability of an energy crisis occurring in the next 15-25 years. Such thesis is made based on the analysis of the following studies [17, 24, 26, 27]. Therefore, what it is very important in the strategy aimed at slowing down unfavourable changes in our climate and at strengthening the energy security of the European Union that are attempts to replace various types of conventional energy sources with biomass in the energy production [3]. After accession to the EU, Poland has been obliged to sign a directive on the share of renewed energy sources (RES) in the energy economy. The Polish parliament approved the "Renewable Energy Development Strategy" that obligated us to reach a 7% share of RES in 2010 and 15% in 2020 [3].

One of the renewable energy sources is provided by biomass. The estimated size of its global resources makes it the third biggest natural energy source [7, 13]. It includes biodegradable solid and liquid substances of vegetable and animal origin derived from products, waste and leftovers from agriculture, orchard, nursery and forestry production, as well as from industries processing their products and parts of other biodegradable types of waste [3, 10, 14, 20].

Among these types, woody biomass from orchards is a considerable, yet largely untapped source of renewable energy. The biggest problem is to estimate the amount of this biomass source. In his report Podlaski [22] confirms that in the scientific literature there is a huge discrepancy of estimates in terms of wood mass available to be acquired in orchards. According to the sources he had studied, potential supply of wood from orchards in Poland ranges from 0.6 to 20 million m^3 per year. According to Hołownicki [16], in orchards between 5 and 6 years old, only 0.5–0.6 t·ha^{-1} may be acquired, while in older semi-dwarf orchards these amounts are much greater: 4–5 t·ha^{-1}, or approx. 5.3- 6.7 m^3. Comparing this data to the EU countries, Podlaski [22] cites a study by Hetsch [15], according to which the average annual increase in biomass from annual cutting of trees in the EU-27 is estimated at 3 $m^3 \cdot ha^{-1}$ for fruit trees, 2.9 $m^3 \cdot ha^{-1}$ for olive trees and 1.5 $m^3 \cdot ha^{-1}$ for vines, while the authors of the application within the project with the acronym EuroPruning (under which the tests described herein are conducted) claim that the potential of these types of crops in the EU-27 amounts to 25.2 million tons of cut branches per year [8, 9, 11].

Others [19, 28], citing data obtained from FAOSTAT, indicate that the global surface of cultivated apple orchards as 4.9 million hectares. Assuming that one hectare of apple orchard during maintenance cutting may yield, depending on the age of trees, from 1 up to 4 tons of branches, then such tillage area, would yield, for the average of approx. 2 tons of branches per hectare, over 10 million tons of valuable woody biomass. It is therefore advisable to promote the use of waste and leftovers from orchard and nursery production for producing energy.

Currently used methods of collecting branches that remain in orchards after maintenance pruning mainly include chipping by attached trailers and, to a limited extent, baling with round and square balers. Such balers are not, however, specialized, but they are machines dedicated for gathering hay, straw and green forage for haylage specially adapted for these works [1, 2, 5, 6, 8, 18, 28, 29]. Therefore, there are neither comprehensive technologies for collecting entire branches that remain in orchards and vineyards after maintenance pruning nor specialized collecting machines. It is expected that the EuroPruning project will fill this lack. Based on the analysis of various literature sources cited, it can be assumed that branches remaining in inter-rows after sanitary thinning of apple trees can be successfully collected with round balers used for collecting hay, straw and green forage for haylage. However, the construction of such a baler, in particular of the pick-up system, needs to be accordingly modified and reinforced [1].

2. Aim of the tests

The aim of the tests was to assess the accuracy and quality of work of the research model of the Branch Round Baler with the symbol PRB 1.75 and to identify basic operational parameters of the machine. The tests were also supposed to answer the question as to what changes and modifications still need to be done for the machine to meet the requirements under the EuroPruning project. Main requirements provided in the project that the PRB 1.75 baler needs to meet include maximum width of the machine of no more than 2.0 m, amassing and round baling of branches that remain in orchards and vineyards after thinning of trees and shrubs. The applicants anticipated that the tests of the baler would be conducted in plantations, orchards and vineyards in Spain and Germany.

3. Material and methods

The tests were conducted in April and May 2014 at the Industrial Institute of Agricultural Engineering in Poznań and in an orchard of the Agriculture and Pomology Research Farm in Przybroda, an Experimental Farm of Poznań Agriculture University. The research material was provided in the form of branches cut off from two-year apple trees.

The test object was a model of the Branch Round Baler with the symbol PRB 1.75 developed at PIMR under the EuroPruning project. Basic technical data of the baler are presented in Table 1, and its view is shown in Fig. 1.

Massey Ferguson 4512 tractor with a nominal output of 44.7 kW was the drive unit used during the tests.

Table. 1. Assumed parameters of the Branch Round Baler PRB 1.75

Tab. 1. Zakładane parametry prasy zbierającej do gałęzi PRB 1,75

Item	Size	Unit	Value
1.	Length of the machine	mm	4000
2.	Width of the machine	mm	1850
3.	Height of the machine	mm	2100
4.	Width of the pick-up	mm	1750
5.	Mass of the machine	kg	2950
6.	Power consumption	kW	70
7.	Width of the bale chamber	mm	1200
8.	Diameter of the bale chamber	mm	1200

Source: own work / Źródło: opracowanie własne

Source: own work / Źródło: opracowanie własne

Fig. 1. Model of the Branch Round Baler PRB 1.75

Rys. 1. Model prasy zwijającej do gałęzi PRB 1,75

The tests involved determining the level of the power consumption of the machine at idle and during normal operation. Measurements for determining the basic operating parameters of the machine have also been performed.

The level of the power consumption of the machine has been determined by measuring the torque transmitted by the PTO. Torque was measured with a MiR-20 type torque sensor with an accuracy of 10^{-4} Nm (Fig. 2).

Source: own work / Źródło: opracowanie własne

Fig. 2. The MiR 20 torque meter during baler model tests

Rys. 2. Momentomierz MiR 20 w czasie badań modelu prasy

Knowledge of the torque load and the PTO rotation speed values allows you to calculate the power consumption *N* by the baler [4].

The machine worked at PTO rotation speed of 540 min^{-1}.

The tests involved measuring the weight of the made bales, the area from which branches have been collected, operating time of the machine and the weight of branches that remained in inter-rows after the passage of the machine. The obtained data were used to determine the average performance of the machine. The density of each bale was determined by measuring its diameter and assuming the width (height) of the bale to be identical with the width of the bale chamber, i.e. 1.2 m.

The weight of branches remaining in inter-rows was determined for 5 randomly selected bales, in accordance with the methodology set out in [9]. Each bale was measured in terms of losses in five measurement sections with the width equal to that of the inter-row, and length being five times the width thereof.

The width of all inter-rows was 4 m, so that the measurement section was 20 m long.

The moisture content of the material was determined according to PN-EN 14774-1:2010 [21] standard equivalent to CEN/TS 14774-2. In addition, the moisture content of collected twigs was tested on a confirmation basis before each passage with a manual wood moisture content meter 4PROWMT 48805 Ottensten.

4. Test results

Real operating time of the machine during the tests was 2.5 h. Overall, branches from a total of 2 ha of the orchard were collected and baled during the tests. Therefore, the average area capacity of the machine as tested was 1.25 $ha \cdot h^{-1}$. During the tests, the unit was moving at an average speed of 3.5 $km \cdot h^{-1}$. The yield of fresh woody biomass collected from the crops area of the apple orchard was 2.25 tons. The cut off branches were arranged in the centre of the inter-row to form a stack approx. 1.8 m wide and no more than 0.15 m high. Mainly branches cut off several days in advance were collected, so that the average moisture content of the material collected was 35%. Collected branches were, at the thickest point, between 5 mm and 35 mm in diameter. Their length ranged between 0.2 m and 1.5 m. They were mostly non-ramified branches with no larger side shoots.

In order to determine the quality of work of the baler model, quantitative measurements were conducted of the uncollected twigs that remained after the passage of the machine, i.e. of losses in the orchard (Table 2).

The values of this parameter were to a great extent dependent on the method of preparing branches in the inter-row for the passage of the machine. The working width of the pick-up was 1750 mm. The tested machine had no lateral rotating scrapers, so the stacks of branches to be baled were arranged manually in the central part of the inter-rows. Such a method of preparing branches undoubtedly influenced the amount of losses, with its average value fluctuating around 24%. It is believed that if branches located in the central part of the inter-rows are not formed into rows, the amount of losses will be considerably higher. The use of lateral rotating scrapers mounted to the side walls of the pick-up should improve the amount of branches not collected by the machine.

During the tests, the baler model made bales of different weight ranging from 185 kg to as much as 330 kg (Fig. 3).

Table 2. Tests results and analysis of losses of twigs remaining after the passage of the machine
Tab. 2. Wyniki badań i analiz wielkości strat gałązek pozostałych po przejeździe maszyny

Item	Weight		Collected area	Percentage loss
	of the bale	of the losses		
	kg	kg	m^2	%
1.	271.0	4.60	1160	24.6
2.	238.0	4.05	1080	23.0
3.	250.0	4.10	1280	26.2
4.	210.5	3.85	1000	22.9
5.	259.5	4.25	1200	24.6
Average	250	4.17	1144	24.3
Standard deviation	35.4	0.28	119	
Confidence interval	(231.8;268.2)	(3.77;4.57)	(974;1314)	

Source: own work / Źródło: opracowanie własne

Source: own work / Źródło: opracowanie własne

Fig. 3. Bales made during the tests
Rys. 3. Bele wykonane podczas testów

The average bale weight, as determined by measurements, was 250 kg. Assuming bale diameter and width equal to the dimensions of the bale chamber, i.e. 1200x1200 mm for the determined average weight of the bale, average specific density was found to be 184 kg·m^{-3}. The resulting weight and its associated specific density of the bale are highly dependent on the material collected. In the case of thicker branches and those with numerous offshoots, it was smaller than in the case of straight twigs without many side shoots. Lower specific density of the bale is a parameter adversely affecting the cost of transport, but on the other hand, it is likely to have a very favourable impact on the process of natural drying of the material thus collected. Bales with lower specific density will dry more easily and reach the moisture content acceptable for combustion faster than highly compressed bales, given that lower density, or lower concentration of the material in the bale facilitates the flow of air through its structure.

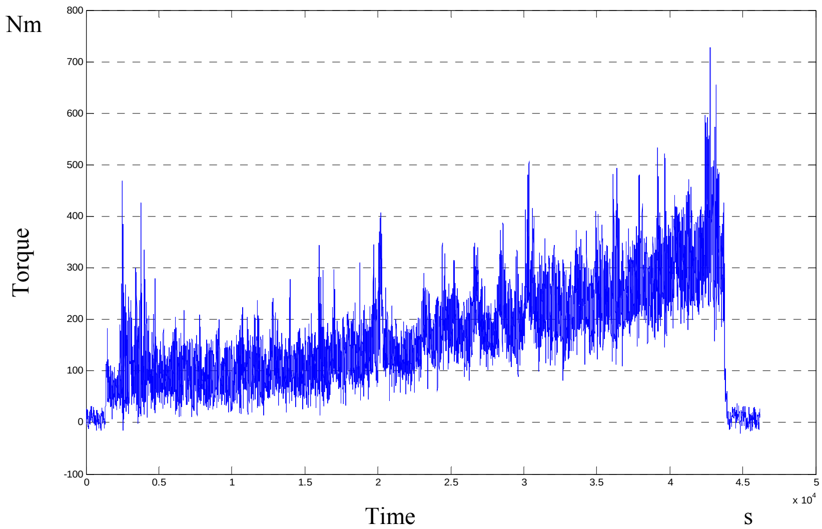
The tests also included performing measurements of energy parameters of work of the baler model in order to determine the power consumption of the tested machine.

Selected changes of torque transmitted by the PTO from the tractor to the machine aggregated thereto, recorded when the machine was operating, are shown in Figure 4.

Using the formula (1), for the following measured values: PTO rotation speed and the torque transmitted to the machine by the PTO, power consumption values of the unit were determined. Average power consumption value for work at idle, without any load, was determined at 1 kW. As the bale chamber filled up with collected branches, power consumption slowly increased from approx. 3 kW at the beginning of the collection of branches to approx. 30 kW when the bale rotating in the bale chamber was being wrapped in mesh. This is due to the technological requirements of the wrapping process, which is optimal when the bale is rotating at the maximum possible rotation speed. The need to temporarily increase the rotation speed of the bale is the direct cause for the need to increase the rotation speed of the machine drive and consequently, the rotation speed of the tractor engine. This leads to a temporary increase in the transmitted torque value, thus generating an increased power consumption of the machine. Maximum values of power consumption appeared in the final stage of bale formation before it was being wrapped with mesh and they reached 40 kW. The obtained maximum power consumption values are lower than those originally projected of the order of 70 kW. It should be noted, however, that the tested prototype was not equipped with lateral rotating scrapers, which if mounted, would probably increase the power consumption of the machine.

5. Discussion of test results

So far, the possibility of using a round baler to collect branches, in particular those remaining after thinning in orchards and vineyards, has not been examined in detail. There is some research available on the subject [1, 5, 6, 18, 19, 25, 28, 29]. However, not all of these studies relate to the use of balers in orchards and vineyards. Lavoie et al. [18] in their study discuss the possibility of using a round baler to collect (i.e. to cut and compress into round bales) the trees of the rapid rotation type, such as willow and poplar. Those are, therefore, two different matters. In their studies [5, 6, 19] present tests involving compressing branches after tree removals performed with an Italian LERDA 110 round baler. These tests, however, were largely conducted in vineyards, therefore in conditions different to fruit and vegetable crops. Another problem that renders comparative analysis somewhat difficult is the fact that the studies referred to above put the emphasis on analysing the aspect of economical operation of the machine. In their studies, Cavalaglio et al. [5]; Cavalaglio, Cotana [6] obtained a level of branch losses of the order of 31% (following adjustments made to the machine, as the value was initially 50%), which, compared to the average values obtained in the preliminary tests of the 1.75 PRB baler, is a higher and less preferred value. Magagnotti et al. [19], however, also carried out tests in apple orchards, but chipping machines were their main objects of interest. Round baler tests constituted an additional source of information.



Source: own work / Źródło: opracowanie własne

Fig. 4. Chart of the torque on the drive shaft of the baler PRB 1.75 model during operation
Rys. 4. Wykres momentu obrotowego na wale napędowym modelu prasy PRB 1,75 w czasie pracy

It is hard, however, to find any detailed data on the tested machines except the data concerning power consumption, which was 48 kW in the case of LERDA 100 machine and the information that only one 237 kg bale was made in the orchard, being thus similar to the model of the PRB 1.75 baler. It should be noted that the size of the briquetting chamber of this baler is smaller than the one of the 1.75 PRB. It is 1000 mm in diameter and 1100 mm wide. Moreover, although losses in plantations have been studied, they were classed by plant varieties without specifying which varieties were collected with a baler, and which with chipping choppers, thus rendering a proper comparison impossible. The losses determined in the study for branches in apple orchards ranged between 3.5% and 12.4%. In all cases, cutting was done manually, so it is likely that the branches were thrown into the middle of the inter-row, which undoubtedly was the direct cause of such a low level of losses.

Another study [28] presents the test results of CAEB 730 CNG minibaler, i.e. of fixed chamber round baler, but with the width of the bale chamber being 600 mm and the diameter 400 mm and the power consumption 10 kW. It is, as one can see, a miniaturized machine designed primarily for work in mountainous areas, in plantations located on the slopes inclined up to 20%. During the tests, the machine worked in vineyards on slopes inclined from 3 to 18%, and it has collected a total of 3.1 tons of material. The measured amount of remaining branches (losses) ranged from 7 to 28%, with the average value of 17%. Estimated value of the losses has been determined during the discussed preliminary tests of a PRB 1.75 baler model (see Table 2). Similar resulting losses (20.2%), however related to harvesting grapes using a different type of CAEB baler, are presented in the study by Spinelli et al. [29].

6. Summary

In conclusion, the tests confirmed literature data and authors' own expectations that branches remaining in inter-rows after sanitary thinning of apple trees can be successfully collected with round balers used for collecting hay, straw and green forage for haylage. However, the construction of such a baler, in particular of the pick-up system, needs to be accordingly modified and reinforced.

Preliminary test of a research model of a round baler for branches, PRB 1.75, designed at PIMR in Poznań, evidenced that it operated properly providing a good work quality. The determined power consumption during operation amounted to approx. 40 kW in the final phase of the bale formation cycle. At the beginning of the working cycle, without load, the machine used about 3 kW of power. The width of the machine was 1750 mm.

Losses in inter-rows amounted to 24.3% of the collected material, this being undoubtedly a good result compared to other similar machines known from the literature. The amount of losses determining the work quality of this type of machine is heavily dependent on how the material is prepared to be collected and on the condition, type, shape and thickness of the collected twigs. The tests involved collecting straight branches without many offshoots or ramifications, with a diameter of no more than 35 mm at the thickest point.

During the tests, over 2.5 hours 2.25 tons of branches have been collected from a 2 ha orchard. The average performance of the machine was 1.25 $ha \cdot h^{-1}$.

7. References

[1] Adamczyk F., Dyjakon A., Frąckowiak P., Romański L.: Conception of machine for pressing branches with pruning tree fruit. Journal of Research and Applications in Agricultural Engineering, 2014, 59 (2): 5-9.

[2] Berien Elbersen: Atlas of biomass supply for 2020 and 2030 from EU27, Brussels European Parliament: Workshop designing policy to meet Europe's future bioenergy needs, 20 March 2012.

[3] Bieniek A., Żołnierz-Rusinek A.: Wierzba *Salix Viminalis* jako źródło energii odnawialnej na przykładzie plantacji założonych na terenie Kotliny Kłodzkiej. Inżynieria Rolnicza, 2008, 4(102), 111-118.

[4] Botwin M. []: Podstawy użytkowania maszyn leśnych. Warszawa: Wydawnictwo SGGW, 1993.

[5] Cavalaglio G., Cotana S., Barbanera M., Giraldi D.: Valorizzazione energetica degli scarti di potatura dei vigneti. (Energy recovery from waste left after pruning vineyards) 7th CIRIAF National Congress*,* 30-31 March 2007, Peruvian.

[6] Cavalaglio, G., Cotana, S.: Recovery of vineyards pruning residues in an agro-energetic chain. 15th European Biomass Conference and Exhibition, 7th – 11th May 2007, Berlin.

[7] Ciechanowicz W.: Bioenergia a energia jądrowa. Wyższa Szkoła Informatyki i Zarządzania, Warszawa, 2001.

[8] CIRCE Report: Mapping and anlysis of the pruning biomass potential in Europe. Report of EuroPruning – Development and implementation of new and non-existent logistics chain for biomass from pruning Theme: KBBE.201.1.2-01 (unpublished), 2013.

[9] CIRCE Report: Specification of demonstrations and handbook for demonstrations. Report of EuroPruning – Development and implementation of new and non-existent logistics chain for biomass from pruning Theme: KBBE.201.1.2-01 (unpublished), 2013.

[10] Dubas J.W.: Uprawa wierzby i jej przetwarzanie na cele energetyki cieplnej. Warszawa: Wydawnictwo PWN, 1992.

[11] Dyjakon, A., Boer, J., Bukowski, P.: EuroPruning – a new direction for energy production from biomass. Inżynieria Rolnicza, 2014, 3 (151): 29-39.

[12] FAOSTAT. 2013: Available from http://faostat.fao.org default.aspx - Accessed on 07.20.2015.

[13] Gorzelany J., Matłok N.: Analiza energetyczna biomasy odpadowej z produkcji drzewek owocowych na terenie województwa podkarpackiego. Inżynieria Rolnicza, 2013, 3 (146), t.2: 77-83.

[14] Grzybek A.: Kierunki zagospodarowania biomasy na cele energetyczne. Wieś Jutra, 2006, 9 (62): 10-11.

[15] Hetsch S.: Potential Sustainable Wood Supply in Europe. UNECE/FAO Timber Section, October 2008. Geneva:1-34.

[16] Hołownicki R.: Drewno z sadu na opał. Hasło Ogrodnicze, 2006, 3.

[17] Kopetz H., Jossart J.M., Ragossnicg H., Metschina C.: European Biomass Statistics. Bruksela. AEBIOM, 2007: 73.

[18] Lavoie F., Savoie P., D'Amours L., Joannis H.: Development and field performance of a willow cutter-shredder-baler. Applied Engineering in Agriculture, 2008, 24 (2): 165-172.

[19] Magagnotti N., Pari. L., Picchi G., Spinelli R.: Technology alternatives for tapping the pruning residue resorce. Bioresource Technology, 2013, 128: 697-702.

[20] Makieła Z.: Źródła biomasy na cele energetyczne. Jarosław, Bioenergetyka Podkarpacka, 2007, 105-187.

[21] PN-EN 14774-1:2010. Solid biofuels - Determination of moisture content - Oven dry method - Part 2: Total moisture - Simplified method (CEN/TS 14774-2).

[22] Podlaski S.: Ocena możliwości pozyskania drewna na cele energetyczne do 2020 roku. Warszawa. Wykonano w ramach projektu: „Nowoczesne technologie energetycznego wykorzystania biomasy i odpadów biodegradowalnych (BiOB) - konwersja BiOB do energetycznych paliw gazowych". (unpublished), 2010.

[23] Project EuroPruning. Annex I - "Description of Work". (unpublished), 2012.
[24] Ramsay W.: Security of energy supply in the European Union International Energy Agency, 2007.
[25] Romański L., Dyjakon A., Adamczyk F., Frąckowiak P.: Problems with deriving the fruit tree pruned biomass for energy use. Inżynieria Rolnicza, 2014, 3 (151): 157-167.
[26] Roszkowski A.: Energia a rolnictwo. Materiały IX Konferencji Naukowej Teoretyczne i Aplikacyjne Problemy Inżynierii Rolniczej. 19-22 June 2007, Wrocław-Polanica Zdrój: 261-262.
[27] Roszkowski A.: Technika rolnicza a GMO. Inżynieria Rolnicza, 2007, 8 (96): 219-224.
[28] Spinelli R., Lombardini C., Pari L., Sadauskiene L.: An alternative to field of pruning residues in mountain. Ecological Engineering, 2014, 70: 212-216.
[29] Spinelli R., Magagnotti N., Nati C.: Harvesting vineyard pruning residues for energy use. Biosystems Engineering, 2010, 105: 316-322.

The works were performed in the framework of the EuroPruning project. The EuroPruning project is co-financed with the Seventh Framework Programme of the European Commission for Research and Innovation, Knowledge Based Bio-Economy (KBBE). Objectives of PIMR were partly financed with funds for science in the years 2013-2016 allocated for implementation of an international co-financed project.
The authors wish to thank Mr Jerzy Mazur, Director, and the Employees of the Agriculture and Pomology Research Farm in Przybroda, an Experimental Farm of University of Life Sciences in Poznań, for the authorisation to conduct the tests and for their assistance in performing them.