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PRODUCTIVITY OF CROP ROTATION MEASURED AS ENERGY PRODUCED BY INCLUDED PLANTS: A REVIEW

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Abstract
The most important reason for growing field crops is food consumption. Only some of the total amount of field crop species are mostly used for cultivation in the largest part of arable land. These crops ensure high economic income. This is the reason why biological diversity has decreased. Crop rotation is considered to be an instrument of sustainable cropping system and this is confirmed again nowadays. Higher cereal yields have been gained by including oil crops or pulses in the rotation. Each field crop has its own calorific value (MJ kg^{-1}). Grains / seeds and above-ground biomass may have different calorific values because of their chemical composition. Research results from literature confirm that the average net calorific value of winter wheat (*Triticum aestivum*) and triticale (*Triticosecale*) grain and straw are ~17 MJ kg^{-1}, but the net calorific values for oilseed rape (*Brassica napus* ssp. *oleifera*) seeds and straw are – 25.70 MJ kg^{-1} and 16.37 MJ kg^{-1}, respectively. Oilseed rape is also known as energy-rich crop. It is reported that diversified crop rotations also have greater energetic productivity from above-ground biomass (grain / seed yield and by-products) if compared with crops grown in repeated sowings or in monoculture. Crop rotation in combination with different tillage methods (conventional tillage, reduced or minimum tillage and no-tillage) is the way to improve soil quality, but it is not clear whether the soil treatment method has a significant impact on the overall crop rotational energy productivity.
Key words: crop rotation, yield, calorific value, energetic productivity.

Introduction

The main benefit of field crop cultivation in agriculture is the part of harvest intended for the main purpose – mostly it is food. In order to calculate the total yield of arable crops, by-products or post-harvest residues, such as straw, should also be taken into account. Farmers usually choose to grow crops which are profitable, despite the large investments needed for repeated sowings for several years or growing crops even in monoculture. The arable land in Europe is taken up with cereals – 54% (wheat (*Triticum*), barley (*Hordeum vulgare*), maize (*Zea mays*)), plants harvested green – 20%, industrial crops – 12% (oilseed rape (*Brassica napus* ssp. *oleifera*), turnip rape (*Brassica rapa*), sunflower (*Helianthus annuus*), soya (*Glycine max*)), and only 7% is taken up with dry pulses, root crops and vegetables (EUROSTAT, 2016). According to the data of Central Statistical Bureau of Latvia, the arable land in 2016 was used for growing the following crop groups – wheat (*Triticum aestivum*) (39%), oilseed rape (8%), barley (8%), oats (*Avena sativa*) (5%), pulses (3%) (main crop – faba bean (*Vicia faba*)). A particularly high prevalence of wheat over other species suggests that wheat is often grown in Latvia in repeated sowings, or among other cereal species, because other important crop rotation components, such as leguminous plants and oilseed crops, occupied just 11% of the total arable land (Use of Agricultural..., n.d.). A similar distribution of crops is also found in Germany where in the region of Lower Saxony in 2011 more commonly used crops were maize (>30%), winter wheat (25%), winter barley (10%), oilseed rape (8%) and rye (*Secale cereale*) (6%) (Stein & Steinmann, 2018).

Because some crops are more profitable than others and they are able to adapt to different growing conditions, the diversity of crops in farms has decreased. Crop rotations with small diversity of plants are used. We can usually observe cereal monoculture fields; legumes or oil crops are grown once per three to four years of cereal rotation. However, a well-considered plant change is an important cropping tool. Therefore, it is important to confirm again that crop rotation is a relevant part of crop production even nowadays. Employing other species instead of cereals as fore-crops may result in higher grain yields (Rosenberger *et al.*, 2001).

The benefits of crop cultivation are often compared by calculating economic returns. Different crops can also be compared by the produced energy. The total energy of crop rotation is also studied in the world as energy output from various crops' grain / seed yields (Zentner *et al.,* 2004) or from the total biomass (including grain / seed and straw) (Hülsbergen, Feil, & Diepenbrock, 2002).

Different field crops can be compared by determining the energy value (MJ kg^{-1}) of each individual product. Different crops have different energy or calorific value (Alluvione *et al.,* 2011). Similarly, different energy values are characteristic for different crop parts (grains / seeds, straw, roots) because their chemical composition differs. The calorific value is mainly influenced by the composition of the material, but various substances accumulated in the product can be influenced by various external factors, including those that can be partially affected by humans (seed material, fertilizer, etc.) (Zhang, Xu, & Champagne, 2010). Determined energy value can be attributed to the harvested yield t ha^{-1}, in order to calculate the total energy output from the cultivated area.

Energy difference between the energy output and the energy input (both direct and indirect) is called net energy, and it has been studied extensively in the world. Besides, energy intensity (yield against energy input) and energy ratio (output energy against input energy) are also widely studied (Hülsbergen, Feil, & Diepenbrock, 2002; Zentner *et al.*, 2004; Strašil, Vach, & Smutný, 2015).

Agricultural products and by-products can be variously applied for food, fodder, energy and bioenergy due to their energy values. Also, post-harvest residues are valuable as they improve soil organic matter content.

Other solutions for profitability and productivity increase of crops is the reduction of costs by minimizing the expenses of soil treatment – traditional soil tillage with a minimum tillage or no-tillage is replaced.

The aim of this literature review is to compare how the total energy value of crop rotation is influenced by crops included in it and by soil tillage method.

Materials and Methods

Review summarizes the research findings on the energetic values of winter wheat and other crops in different crop rotations and in different tillage systems. Literature from different scientific journals all around the world has been used. It includes information from studies conducted in Latvia, Germany, Poland, Czech Republic, Austria, Canada, Japan and others. Monographic method was used in this study.

Results and Discussion

Crop rotation

Crop rotation is a part of cropping system. Crop rotation is also a way to ensure crop diversity in farms (Dury *et al.,* 2013). If the same crop has been cultivated using the same management for many years, negative effects on soil quality can be observed, and infection risk with harmful organisms like diseases, weeds and pests increases (Bennett *et al.,* 2012; Stein & Steinmann, 2018). Conventional crop rotations had been researched in the world trying to clarify whether any advantages can be observed, including energy crops in rotation. For the temperate climate of Northern Europe the best choice for species in rotation is oilseed rape, cereals, flax (*Linum usitatissimum*) and legumes, due to the increased yields, better control of diseases, and efficient use of soil resources (Zegada-Lizarazu & Monti, 2011). A way to ensure biodiversity in cereal-based crop rotation can be the use of catch-crops. Small differences of soil quality may also be provided, caused by the prevention of nutrient leaching by catch-crops (Nemecek *et al.,* 2015).

Crop rotations researched in Latvia consist of three treatments (1) wheat in repeated sowings, (2) rotation that includes winter wheat, oilseed rape, barley and faba bean, and (3) oilseed rape that is followed by wheat for two years (Konavko & Ruža, 2017). A long-term trial with similar crops has also been conducted in Canada with the following variants: (1) wheat in repeated sowings, including a fallow period once in four years, (2) spring wheat – spring wheat – flax – winter wheat, and (3) spring wheat – flax –winter wheat – pea (*Pisum sativum*) (Lafond *et al.,* 2006). Farms focusing on crop rotation designing get a stable farm management plan in the longterm, but it is more difficult for them to adapt to changing conditions in cropping (Dury *et al.,* 2013).

Yield and productivity of oilseed rape (Rathke, Christen, & Diepenbrock, 2005) and wheat (Freeman, Raun, 2007) mostly depend on crops' supply with nitrogen, which increases growing input costs. Inclusion of legumes in crop rotation ensures a possibility to reduce the N rate for the next crop due to the biological nitrogen fixation. Break crop also reduces the need for pesticides (Petersson *et al.*, 2007).

In a study in Germany, it was found that winter wheat yields increased when they were sown in the crop rotation after peas, in comparison with the rotation including only cereals. In a two-season long study with three different intensity growing systems, the following wheat yields were obtained: when grown after peas: 5.22 – 7.63 t ha^{-1}, and when grown after cereals: 2.86 – 6.55 t ha^{-1}. Straw yields of winter wheat in all cases were also the highest when wheat was grown after peas, if compared with growing after cereals: 7.77 – 10.35 t ha^{-1} and 2.96 – 7.35 t ha^{-1}, respectively. Such tendency was observed also when triticale was grown after peas and cereals (Rosenberger *et al.*, 2001). When wheat was grown after faba beans, it was possible to obtain grain with higher protein and gluten content if compared to wheat grown in repeated sowings (Konavko & Ruža, 2017). In Canada, it has been concluded that there is no significant difference between wheat yields and energy yields if fore-crop was pea or rape (Nagy *et al.*, 2000).

The results of five-year field experiments in Sweden with five year rotation of cereal crops showed no difference between the effect of ploughless tillage and mouldboard ploughing on winter wheat yield in good conditions. Yield loses of winter wheat were observed in one of trial years in repeated winter wheat sowings where reduced tillage and direct drilling was used. Nevertheless, these losses can be attributed more to inappropriate wet conditions during tillage (Arvidsson, 2010).

Yield, biomass and energetic productivity

The increasing world population makes a challenge for food and energy production and provision of other basic needs. Land, soil and water resources are limited and exposed to climate changes. Agriculture needs to get higher yields and productivity of cropping systems (Cacho *et al.*, 2018).

In different sources of literature, crop yield and by-products (altogether – biomass) are often divided into different materials. Biomass components (cellulose, hemicellulose, lignin, lipids, simple sugars, water, carbon, ash and other components) are presented in different structures and ratios depending on species and different types of biomass (e.g., grain / seed, straw) (Erol, Haykiri-Acma, & Küçükbayrak, 2010). The concentration of biomass components varies according to the tissue type, plant development phase in which the biomass is harvested, and growing conditions (Zhang, Xu, & Champagne, 2010).

Various mathematical models can be selected when determining the energetic values of different biomass materials named as calorific value or heating value (Friedl *et al.*, 2005; Erol, Haykiri-Acma, & Küçükbayrak, 2010; Vargas-Morenoa *et al.*, 2012). Calorific value can also be determined by automatic equipment (bomb calorimeter) (Erol, Haykiri-Acma, & Küçükbayrak, 2010). Calorific value is divided in gross calorific value or higher heating value (Friedl *et al.*, 2005) and net calorific value or lower heating value (Erol, Haykiri-Acma, & Küçükbayrak, 2010). The difference between gross calorific value (HHV) and net calorific value (LHV) is in the amount of water vapour. In HHV it is included as condesated water, but in LHV water vapour remains as vapour; however, in the first one more heat is recovered. The gross calorific value can be determined by bomb calorimetry (Friedl *et al.*, 2005). Both mentioned values have been used in different studies, but it is not mentioned which of them are better for comparing energy output per hectare.

Biomass is an important renewable energy source that can be used for heat generation from burning. Biomass as fuel has economic and ecological benefits (Erol, Haykiri-Acma, & Küçükbayrak, 2010). The use of materials derived from plant biomass for the production of thermal energy is advisable as they do not emit more carbon dioxide in the atmosphere if compared with the amount plants absorb during the photosynthesis. Plants continue also to assimilate this carbon dioxide, so it does not have a significant impact on the greenhouse effect (Sakalauskas *et al.*, 2011; Qi *et al.*, 2018).

Energy value of different plants has been studied in Turkey. One of the studies has shown that the heating value is directly affected by the ash content. If the plant parts have high ash content, less heat is produced. Demirbas (2002) has also compiled literature on earlier studies to calculate the heating value. Morrison and Boyd in 1983 wrote that the amount of heat increases with higher carbon and hydrogen quantities, and the proportion of mentioned elements to oxygen (cited from Demirbas, 2002). The same researcher also found a close correlation between the heating value and lignin content in biomass (Demirbas, 2001).

The most widely cultivated crops in Latvia are various species of cereals and oilseed rape. The usage directions of these species and energy values have been studied in Latvia and in the world. The main end product of cereals is grain used for food production, mainly for the production of flour. Grains that do not meet the food requirements are mostly used for forage production. Grains, due to their high energy value, can also be a source for bioenergy, for example, bioethanol, where the result is directly determined by the amount of starch; therefore, low protein content is preferable for bioethanol production (Jansone & Gaile, 2012; 2013). Wheat straw is also used for bioenergy production, e.g. for bioethanol, thanks to its energy value and cellulose content (Dai *et al.*, 2016; Townsend, Sparkes, & Wilson, 2017) and as a heating material, etc. Energy value of grain yield and biomass depends on the growing technology, which should be selected according to the desired cultivation purpose – food, feed, bioenergy.

In Canada, the average energy value of winter wheat grain set in a long-term experiment with three different soil treatments was – 18.71 MJ kg^{-1} (Zentner *et al.*, 2004). In Germany, the following HHV were established for cereals in a long-term experiment: winter wheat grain – 18.6 MJ kg^{-1}; winter wheat straw – 17.7 MJ kg^{-1}; spring barley grain – 18.4 MJ kg^{-1}; spring barley straw – 18.1 MJ kg^{-1} (Hülsbergen, Feil, & Diepenbrock, 2002). In Hungary, considerably lower heating values (determined with a bomb calorimeter) of winter wheat straw were established if compared with the above mentioned – HHV 16.4 MJ kg^{-1}, and LHV 14.9 MJ kg^{-1}; there is no information about the wheat yield and its growing technology (Sebestyén *et al.*, 2012). In Latvia, after determining the heating value of different winter cereal species, it was concluded that dry matter of winter cereal straw has a higher energy value if compared with dry matter of grains. At the same time, higher dry matter yield of grain, if compared with that of straw, was established and therefore more energy per ha was produced by grain (Jansone & Gaile, 2015). In Germany also it was established that straw of cereals has a higher heating value if compared with grains. Energy value of wheat and triticale grain dry matter was 17.0 and 16.9 MJ kg^{-1}, respectively, but that of straw – 17.2 un 17.1 MJ kg^{-1}, respectively (Boehmel, Lewandowski, & Claupein, 2008). In Poland, the energy efficiency of winter oilseed rape was studied in a three-year trial. It was concluded that by using an intensive cultivation technology (by energy input) the highest amount of generated energy was obtained: 268.5 GJ ha^{-1}. Intensive cultivation technology included soil tillage treatments before sowing, hybrid seed material, soil fertilization (501 kg ha^{-1} NPKS), weed control, and three insecticide and three fungicide sprays. Energy value obtained from the oilseed rape seed yield and oil yield when the intensive cultivation technology was used was significantly higher in comparison with other technologies. The calorific value was determined using adiabatic combustion calorimeter. Straw did not show significant differences in the energy output, depending on the intensity of farming activities. Specified net energy values for rape were: seed – 25.7 MJ kg^{-1}, straw – 16.4 MJ kg^{-1}. Energy obtained from seeds under intensive growing conditions were 100.2 GJ ha^{-1}, but in low-input conditions – 81.1 GJ ha^{-1}. In this study, the seed mass was about 30% of the total surface biomass (4.17 t ha^{-1} seed, 10.31 t ha^{-1} straw) (Budzyński, Jankowski, & Jarocki, 2015). In Germany, it was also found that the lower heating value for oilseed rape seeds is much higher than the value of straw – 26.5 and 17.1 MJ kg^{-1}, respectively (Boehmel, Lewandowski, & Claupein, 2008).

After researching the gross energy of the field crops in crop rotation, it is concluded that there is a big difference between various crops in energy value, e.g. gross energy for maize grain was 18.9 MJ kg^{-1}, for wheat grain 18.4 MJ kg^{-1}, for soybean – 23.65 MJ kg^{-1} (Alluvione *et al.,* 2011), for rape seed – 26.5 MJ kg^{-1} (Boehmel, Lewandowski, & Claupein, 2008), for sugar beet – 17.4 MJ kg^{-1}, for potato – 17.6 MJ kg^{-1} (Koga, 2008). Energy values of cereals, oilseeds and pulses straw did not differ significantly (Alluvione *et al.,* 2011; Strašil Vach, & Smutný, 2015), but energy value of crop residues was lower for such crops as sugar beet (16.6 MJ kg^{-1}) and potatoes (13.6 MJ kg^{-1}) (Koga, 2008).

Since the total energy value obtained per ha depends on the total biomass and grain yield, it can also be affected by grain – straw ratio. Similarly, the ratio of grains / seeds and straw differs for various species and varieties within the species. In the USA, the relationship between straw yield and harvest index (HI) was studied in different wheat growing regions (eight states) and for different wheat grades. The average HI was 0.45. The results showed that soft white wheat had the highest grain (7.6 t ha^{-1}) and straw (9.4 t ha^{-1}) yields (HI – 0.49), soft red winter wheat had the highest HI (0.61) and lowest straw (3.4 t ha^{-1}) yield and lowest above-ground biomass (8.6 t ha^{-1}). HI does not suggest that the higher grain yield is always related to a high harvest index and low straw yield. Biotic stresses may also impact HI (Dai *et al.*, 2016). Researchers from the United Kingdom (UK) consider the possibility to create new varieties of wheat with an increased straw yield. As discussed above, wheat straw is used to produce bioenergy. UK farmers, producing livestock products in addition to crop production, are also interested in growing such varieties. Greater straw yield can be obtained mainly by extending the stalk. Increase in straw mass should not lead to the reduction in grain yield (Townsend, Sparkes, & Wilson, 2017).

The by-products of cereals, legumes and oilseeds can be used for bioenergy production because of their composition, but it is not a reasonable long-term solution, as straw is necessary for improvement of the soil organic matter and nutrient uptake in the soil (Bauer *et al.,* 2007; Hernanz *et al.,* 2014).

Total productivity of crop rotations affected by included plants and soil tillage

In the study in Canada (Zentner *et al.*, 2004), winter wheat was grown in repeated sowings on heavy clay soil with pH 6.7 – 7.0. Winter wheat grain yield energy output was on average 45.7 GJ ha^{-1} (for yield in the trial < 3 t ha^{-1}, straw was not taken into calculation, as they were incorporated in the soil). If wheat was grown after flax, energy increase was about 22%; Zentner *et al*. believe that this effect is due to inhibition of root and leaf disease thanks to plant change. In this study, a significant increase in energy output was obtained through the diversification of plants in crop rotation. Analysing the effect of soil tillage method on growing winter wheat, it was concluded that zero tillage (ZT) does not influenced the energy output of winter wheat if compared to conventional tillage (CT). In the same study, oilseeds (flax) and legumes (peas), included in the crop rotation after cereals, provided higher energy yields in conservation soil tillage (minimum tillage (MT) and ZT) variants (by 13% for flax and by 7% for peas) if compared to CT. In this experiment, the soil tillage method had a small effect on energy yield of cereals grown in monoculture and in rotation of cereals, legumes and oilseeds. However, the energy yield was significantly higher in the rotation of cereals and oilseeds when MT was used if compared to CT and ZT treatments. Energy produced by growing winter wheat after cereals (wheat or barley) did not differ significantly between the soil tillage treatments (42.2 GJ ha^{-1} CT, 39.7 GJ ha^{-1} MT, 41.5 GJ ha^{-1} ZT), but it was significantly higher when wheat was grown after oilseed rape (51.0 GJ ha^{-1} CT, 50.7 GJ ha^{-1} MT, 48.8 GJ ha^{-1} ZT) with no-till technology (ZT). Results of this study showed that the use of conservation soil tillage showed small reductions in the energy produced using minimum and zero treatments if compared to the traditional soil tillage method. Authors concluded that by diversifying plants in the crop rotation and by using different soil cultivation techniques, more efficient yields can be produced and also the efficiency of non-renewable energy use increased (Zentner *et al*., 2004).

Earlier studies in Canada (Nagy *et al*., 2000) did not show a significant effect of soil tillage method on crop yields. However, the average energy output of a four-year crop rotation significantly differed between the crop rotations. The highest total productivity was obtained by the crop rotation which included oilseed rape followed by three years of cereals (oilseed rape–wheat–barley–barley) (57.1 GJ ha^{-1}). A slightly lower energy output was obtained from the crop rotation with oilseed rape–barley–peas–wheat – 54.7 GJ ha^{-1}, but significantly lower it was for crop rotation with two oil-crops included: oilseed rape–peas–flax–barley – 44.9 GJ ha^{-1}. In this experiment, grain / seed yields were as follows: barley 2.6 – 3.8 t ha^{-1}, wheat 2.8 – 5.0 t ha^{-1}, oilseed rape 1.8 – 2.1 t ha^{-1}. Straw was not considered in the energy calculation (Nagy *et al*., 2000).

Insignificant effect of soil tillage methods was found on winter wheat, spring barley and white mustard (*Sinapis alba*) yields and energetic outputs also in Czech Republic. Three crop rotations were used in combination with three soil tillage systems (CT, MT, and ZT). Gross calorific value of the total biomass was 175.35 GJ ha^{-1} for winter wheat, 149.11 GJ ha^{-1} for barley and 87.27 GJ ha^{-1} for white mustard. Winter wheat also had the highest grain and residue yields (Strašil, Vach, & Smutný, 2015).

In Germany, Hülsbergen and Kalk (2001) established that continuous winter wheat sowings showed lower net energy output (168 GJ ha^{-1}) if compared with the situation when winter wheat was grown after clover (218 GJ ha^{-1} per year in rotation with 20% clover), and after lucerne (226 GJ ha^{-1} per year in crop rotation with 40% lucerne) (cited from Hülsbergen, Feil & Diepenbrock., 2002).

Energy output from the crop rotation is also studied in Japan, in the main agricultural region – Tokachi. Traditional crop rotation in this region is winter wheat–sugar beet–beans–potatoes (*Solanum tuberosum*). Calorific value of dry matter yield and post-harvest residue samples were measured with an automatic bomb calorimeter. The greatest energy output per hectare was gained from sugar beet – 252 GJ ha^{-1} (in total, including residues – 346 GJ ha^{-1}), dry biomass yield was 20 t ha^{-1}. In this research, calorific value of winter wheat was established 19.1 MJ kg^{-1} for grain and – 18.4 MJ kg^{-1} for straw; the same values were calculated for beans (*Vigna angularis* (Willd)). Potato and sugar beet showed a lower energy value per kg, but they had higher yields than cereals and legumes. Dry biomass yield of sugar beet in this experiment was 2.5 times higher than that of winter wheat, but energy output was 2.3 times higher (Koga, 2008). Sugar beet has shown the highest energy output per hectare also in another research with other crop rotations (Hülsbergen, Feil & Diepenbrock, 2002). Thus, by including the sugar beet or potato in crop rotation between the cereals, it is possible to obtain higher total energy from crop rotation, as these plants ensure higher energy output per hectare if compared to cereals (Koga, 2008).

Potential of energy output from specially designed crop rotations, including energy crops and traditional crops – used for food, feed and energy, have been explored in Austria. Intercrops (clover (*Trifolium* sp.) and lucerne (*Medicago sativa*)) before spring crops (spring barley and grain maize) were included in these crop rotations in order to obtain the maximum total energy yield from the crop rotation (Bauer *et al.,* 2007).

In Germany, traditional field crop rotation versus energy crop repeated and perennial sowings were compared. Traditional field crop rotation included oilseed rape with cereals – winter wheat and triticale. The average annual energy yield from this rotation was from 100 GJ ha^{-1} with no nitrogen fertilizer and with no-till technology to 262 GJ ha^{-1} with nitrogen rate – 160 kg ha^{-1} for winter wheat, and 240 kg ha^{-1} for oilseed rape in both soil tillage technologies – ploughing and no-till technology. If annual energy yields were compared in high nitrogen level between energy crops and field crop rotation, field crop rotation gave a higher energy output than switchgrass (*Panicum virgatum*); while significant difference was not found between average annual energy output of traditional crop rotations and willow (*Salix alba* L.), and miscanthus (*Miscanthus* sp.) energy yields (Boehmel, Lewandowski, & Claupein, 2008).

The effect of soil tillage on energy production by crop rotation was studied in a long-term experiment (1983 – 2002) in Latvia. The six-field crop rotation included the following species: winter wheat, oat, barley, barley undersown with perennial grass-clover mixture, perennial grass-clover mixture (2 years). Soil tillage treatments included (1) yearly deep ploughing; (2) yearly shallow ploughing + deep ploughing once per rotational cycle before winter wheat; (3) similar treatment to the 2nd, except deep ploughing was performed before sowing grasses. It was shown that the average energy productivity of the crop rotation was higher in the variant, where ploughing was carried out every year (1st treatment), but it was not significantly lower if deep ploughing was carried out once per rotational cycle – before winter wheat sowing. In general, from agronomical point of view, the reduction in yield and energy value between soil tillage treatments was not high (Kroģere *et al.,* 2005).

Conclusions

Crop rotation and soil tillage method affect crop yield and energy output. The total energy output per hectare depends on crops included in the rotation, their yield and total biomass, and calorific value of harvested yield and by-products. In different studies, for the same species the calorific values were different depending on growing conditions and varieties. It is possible to increase the total energy value, or it is possible to create benefits for the following plant by plant diversification.

It is possible to gain higher energetic productivity from the crop rotation if cereals are grown in rotation with oil crops, pulses, root crops and vegetables, but not in monoculture.

This literature review did not prove that any of the soil treatment methods could be the most suitable for higher energy output by yield. Significant differences were not found in yield parameters depending on soil tillage method in most part of articles reviewed, only in some cases the energy value was higher or lower depending on the soil type and conditions during tillage.

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