INFLUENCE OF DIFFERENT METHODS OF BIO-PREPARATION USE ON CUTTING CHARACTERISTICS OF WINTER WHEAT RESIDUES

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Abstract

The objective of this work is to establish the influence of different bio-preparation use on cutting characteristics of winter wheat residues. According to the first method the winter wheat crop was sprayed with bio-preparations ("Amalgerol", "Azofit" and their combination) in spring after plant vegetation had renewed. The influence of different bio-preparations on cutting characteristics was investigated and compared with the control. According to the second method bio-preparation "Azofit" was sprayed on plant residues right after winter wheat harvesting. It was investigated how cutting characteristics of plant residues varied in 1, 2 or 3 weeks. The cutting investigation results were compared with the results of cutting winter wheat residues left on the soil surface under natural conditions. Experimental research of physical-mechanical properties of plant residues were carried out at the Institute of Agricultural Engineering and Safety of Aleksandras Stulginskis University, using an experimental research machine "Instron 5960".

The experimental research results indicate that the time of bio-preparation use and impact duration have influence on plant residue cutting force. According to the first method, having sprayed winter wheat with different bio-preparations in spring it was established that after harvesting winter wheat residues required 5 % ("Amalgerol") and 37 % ("Azofit", and "Azofit" and "Amalgerol" combination) stronger force compared with the winter wheat residues without using bio-preparations in the control application. According to the second method, having sprayed plant residues with bio-preparation "Azofit" actually after harvesting in autumn it was established that following three weeks of bio-preparation duration, the force of plant residue cutting decreased significantly (about 28 %) compared with the control application.

Key words: winter wheat, plant residues, bio-preparation, cutting, knife.

INTRODUCTION

With the increasing popularity of no-till agriculture an increasing number of problems arise with plant residues left on the soil surface. Because of their mechanical, biological and other characteristics, plant residues interfere with quality operation of tillage and drilling machinery (ARVIDSSON, 2010, VAITAUSKIENĖ ET AL., 2015, ŠARAUSKIS ET AL., 2012). Therefore, research investigations to establish plant residue cutting characteristics are relevant for the quality of soil tillage and sowing technological processes, manufacture of agricultural machinery and selection of its working parts (HEMMATIAN ET AL., 2012).

Researchers from different countries (HEMMATIAN ET AL., 2012, LINKE, 1998, TAVAKOLI ET AL., 2009, ŠARAUSKIS ET AL., 2013) have noticed that the force required to cut or break plant residues depended on the plant species, stem diameter, plant length, moisture, cell structure and elasticity. The design and technological parameters of working parts have great importance for the ability to cut or break through plant residues (LIU ET AL., 2007, 2010). Canadian researchers established that a coulter with disks of 360 mm diameter and 2 mm thickness, while penetrating 60 or 70 mm into the soil, cut approximately 80 % of the straw on the soil surface, and the remaining 20 % of the straw was pressed into the soil. A larger disc coulter with 460 mm diameter and 4 mm thickness disks cut approximately 95 % of straw while penetrating 60 or 70 mm into the soil. A disc coulter with even larger disks (600 mm diameter and 4.5 mm thickness) cut only approximately 20 % of straw while penetrating 55 mm into the soil. The investigations established that more straw was cut with an increase of penetration depth (KUSHWAHA ET AL., 1983; KUSHWAHA ET AL., 1986).

Iranian researchers state that a greater force is required to cut a rice stem with greater stem cross-sectional area. In addition, the rice stem (moisture content 80 %) cutting force depends on the cutting speed as well. Increasing the cutting speed from 0.6 m s^{-1} to 1.5 m s^{-1} when knife sharpness of 35° cutting force reduces the by about 40 % (TABATABAEE AND BORGHEIE, 2006). Moreover, other Iranian researchers propose as well that the plant residue cutting force

depends on the cutting speed. On the contrary, increasing the cutting speed from 0.3 to 0.9 m s^{-1} the force required to cut a sugarcane stem (moisture content 78 %) increased by about 3 % (HEMMATIAN ET AL., 2012).

In addition, very important is the period during which plant residues are left on the soil surface after harvesting. The force required to break overwintered winter wheat straw is about 3.2-fold lower than the force required to break the straw of winter wheat harvested fresh in autumn. The breaking force for overwintered spring barley straw decreases approximately by about 34% compared with the autumn straw (ŠARAUSKIS ET AL., 2013). Long periods deteriorate the mechanical characteristics of plant residues, however, an opportunity is not always provided for waiting until the plant residue mechanical characteristics, which influence the technological processes of the working parts of tillage and drilling machinery, are weakened under natural conditions. Very often, several weeks after crop harvesting, new plants are already being drilled. The application of no-till and strip-till results in the plant residues from the previous harvest being left on the soil surface, which directly influences the operation process of working parts. Because plant residues left on the surface for a short time can maintain strong mechanical characteristics, disc coulters may fail to cut through or break them. In such cases plant residues will be pressed into the notches. To prevent this, it is necessary to speed up the processes of plant residue mineralization and the associated mechanical weakening. To activate such processes, different biological preparations are being introduced rapidly. The functions performed by biological preparations have great direct and indirect impacts on the growth and quality of crops, the spreading of pests in the soil and plant residues, the distribution of diseases, the rates of nutrient circulation in the soil, the receptivity of soil to water and the consistency of its ecological productivity. They also affect the stability of agroecosystems and the resistance to abiotic environmental factors and stress (BRUSSAARD ET AL., 2007). Biological preparations create a distinctive agricultural culture and ensure long-term and stable fertility of field plants, while maintaining clean environment without causing damage to people (AHMADI, 2010; BRUSSA ARD ET AL., 2007).

These biological preparations are most often used as nutrients for the soil and plants. Plants sprayed with the solution of such preparations can assimilate mineral materials better, grow more vigorously and the productivity of plants increases (DEWAR, 2006; JAKIENĖ ANDLIAKAS, 2013). The biological preparation consists of nitrogen-fixing stem bacteria Acotobactervinelandii and biologically active materials affecting the structure of plant residues. Therefore, the mineralization of plant residues is activated on the soil surface, and at the same time, the nitrogen-fixing bacteria perform the function of speeding up the processes of plant residue decomposition and the weakening of the mechanical characteristics of the residues (AHMADI, 2010; HOLTZE ET AL., 2008; JAKIENĖ, 2011; VAITAUSKIENĖ, 2015).

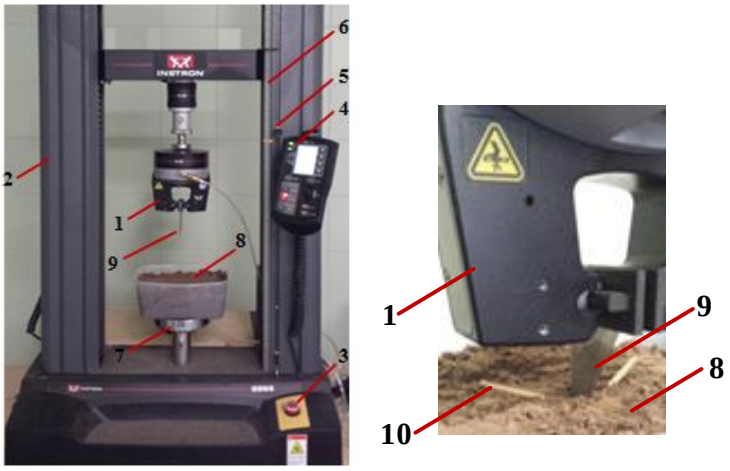
RAUCKIS (2012) states that the plant residues left on the soil surface, soil before drilling and plants in the beginning of vegetation are recommended to spray with the solution of biological preparation “Azofit” or “Amalgerol”. Thus plant residuesmineralisation is faster, nutrients present in plant residues are released sooner and soil aeration as well as soil and seed contact are improved. Due to organic colloid formation soil temperature increases (±2°C) and this reason determines faster and more uniform germination of seeds.

There have been some investigations carried out on the use of biological preparations in different agronomical aspects, however, the impact of biopreparations on the mechanical properties of plant residues depending on the methods of use has not been established.

MATERIALS AND METHODS

Establishing of Cutting Forces

The experimental research was conducted in the Laboratory of the Institute of Agricultural Machinery, Mechanics and Safety Engineering, Aleksandras Stulginskis University. The plant residue cutting forces were determined using an experimental machine for testing low force–mechanical properties “Instron 5960” (Fig. 1) with software “Bluehill”.



(a) (b)

Fig. 1. – Equipment for testing force–mechanical characteristics of materials "Instron 5960": a) machine ready for investigating cutting forces of plant residues: 1 – knife fixing clamp; 2 – frame; 3 – emergency shutdown button; 4 – control panel; 5 – movement limit stop; 6 – measuring scale; 7 – base; 8 – container with soil; 9 – cutting knife; 10 – experimental sample; b) sliding-cutting simulating a disc coulter with serrated cutting edge

The plant residue cutting investigations were performed by a knife with the edge of 0.4 mm in width, 4 mm in length and penetration depth – up to 70 mm (Fig. 1, b). The knife edge was sharpened at an angle of 30º. To obtain the most natural conditions possible, the experiments were conducted with the residues in contact with the soil. Light loam soil with moisture content of 15.0±1.3 % and penetration resistance of approximately 1.0±0.06 MPa was used for the experiments. Such soil penetration resistance corresponds to no-till conditions (CANNELL, 1985). In order to improve the quality of cutting plant residues, the disc coulters with serrated edges are often used in no-till equipment (BIANCHINI ET AL., 2008; ŠARAUSKIS ET AL., 2013A). For this purpose, another way of cutting plant residues with the knife positioned at an angle of 60º (Fig. 1, b) was investigated, the cutting of plant residues in the indentation of the disc coulter edge was simulated. Thus, a sliding process of cutting plant residues was performed.

In this study, the rate of knife movement was 20 mm·min^{-1}. After each plant residue cutting experiment, the soil was densified over, and the penetration resistance and moisture content were measured by an Eijkelkamppenetrologger with 3 replications to ensure uniform physico-mechanical soil characteristics and experimental conditions.

Sample Properties

Winter wheat residues were investigated as this crop is most widely cultivated for industrial purposes in Lithuanian and other Baltic countries. According to the first method 4 applications were installed. In application 1 winter wheat plots were sprayed with bio-preparation "Azofit" at a spraying rate of 1.0 l. ha^{-1}, in application 2 "Amalgerol" was used at a spraying rate of 4.0 l ha^{-1} and in application 3 – "Azofit" (1.0 l·ha^{-1}) and "Amalgerol" (4.0 l. ha^{-1}) combination. The spraying was carried out in spring – on 4 April 2015. An additional application (control) was installed to compare investigation results, in which no bio-preparations were used. During the same year right after harvesting the investigations of the cutting force of winter wheat residues were conducted.

The experimental research according to the second method was carried out in two applications. Application 1 was a control one: after harvesting winter wheat its residues were left on the soil surface under natural climatic conditions. In application 2 plant residues were sprayed with bio-preparation "Azofit" at a spraying rate of 1.0 l ha^{-1}.

Biological preparations were mixed with 200 l of water. The area of sprayed plots was less than 1 ha, therefore, the rate of biological preparations was adjusted accordingly. Having evaluated the fact that in agriculture after harvesting in autumn there is no much time left before sowing of new crops, a 3 week period was chosen for the experimental research according to the second method, during which the investigations were conducted once a week every seven days. At the start, initial experimental investigations were conducted to establish characteristics of the forces required to cut plant residues. The samples of plant residues collected (100 mm in length, 4 mm in diameter on average, uncrushed) were weighed and

dried in a desiccator at 105ºC as recommended by many researchers (SILVA–FERNANDES ET AL., 2015; WOOD ET AL., 2014). When the plant residues reached air-dried mass (approximately 24 hrs) their moisture contents were calculated. The experiments on cutting plant residues were conducted with 5 replications. Randomized sample taking of plant residues from five different spots of each plot was performed. Assuming that it is complicated to maintain uniform moisture content of different plant residues under natural climatic conditions, the plant residue moisture content was measured during each investigation of cutting characteristics.

Statistical Data Analysis

The data obtained during the experimental research were analysed by dispersion (ANOVA) analysis method using Excel software. The arithmetic means, their standard deviations and intervals of confidence were determined with the probability level ($P<0.05$) respectively. Significant differences between the investigated data options were established by calculating the honestly significant difference HSD at 0.05 probability by Tukey's HSD method (TARAKANOVAS AND RAUDONIUS, 2003). In the pictures, the letters indicate significant differences between the factors. Common letters indicate no significant difference.

RESULTS AND DISCUSSION

The force required to cut through plant residues is a very important technological indicator in agriculture, which demonstrates how easily machinery working parts cuts or fails to cut plant residues. The experiments assessed the efficiency of biological preparations in facilitating the winter wheat residues using the angled knife.

According to the first method moisture content of the winter wheat residues analysed was 6 % on average and according to the second method – it was 30 % on average (Tab. 1).

Tab. 1. – Geometric means and moisture content of plant residues during experimental research period

Plant residue (method)	Diameter mm	Length mm	Moisture content %			
			0 (start)	After 1 week	After 2 weeks	After 3 weeks
Winter wheat (method 1)	4±0.5	100±2.5		6±0.9		
Winter wheat (method 2)	4±0.4	100±2.6	30±1.2	34±2.5	30±2.1	25±1.7

The cutting process of winter wheat residues as well as the residues of other plants on the soil surface depends highly on the physical and mechanical characteristics of the soil and the plant residues. The penetration resistance of the soil surface and the moisture content of plant residues are of the utmost importance. If the soil penetration resistance is not sufficient and the plant residues are of high moisture content, the residues are most often left uncut because they would only be pressed into the soil by a coulter. To cut through plant residues, the penetration resistance of the soil has to be higher than the normal stresses of plant residues (KUSHWAHA ET AL., 1986; LINKE, 1998; ŠARAUSKIS ET AL., 2005). 1.0 MPa penetration resistance of soil was used in this experimental research, which most often corresponds to no-till and strip-till conditions on the light loam soils and it was sufficient to cut through the plant residues in all cases of the experiments. This resistance, however, was too low for winter wheat residues with high moisture content to be cut through.

During the experiments according to the first method it was established that the use of biological preparations "Amalgerol", "Azofit" and their combination resulted in significantly stronger force for cutting winter wheat residues (approximately 7 N) compared with the control application. In other cases significant differences were not established (Fig. 2 a). The same experiments established how the depth of knife penetration into soil varies (Fig. 2 b) until plant residues are cut through. Though cutting through winter wheat residues affected by biological preparations required the force which was significantly different in certain cases, plant residues were cut through when the knife penetrated the soil at similar depths (24 mm on average). There were no significant differences between the applications examined.

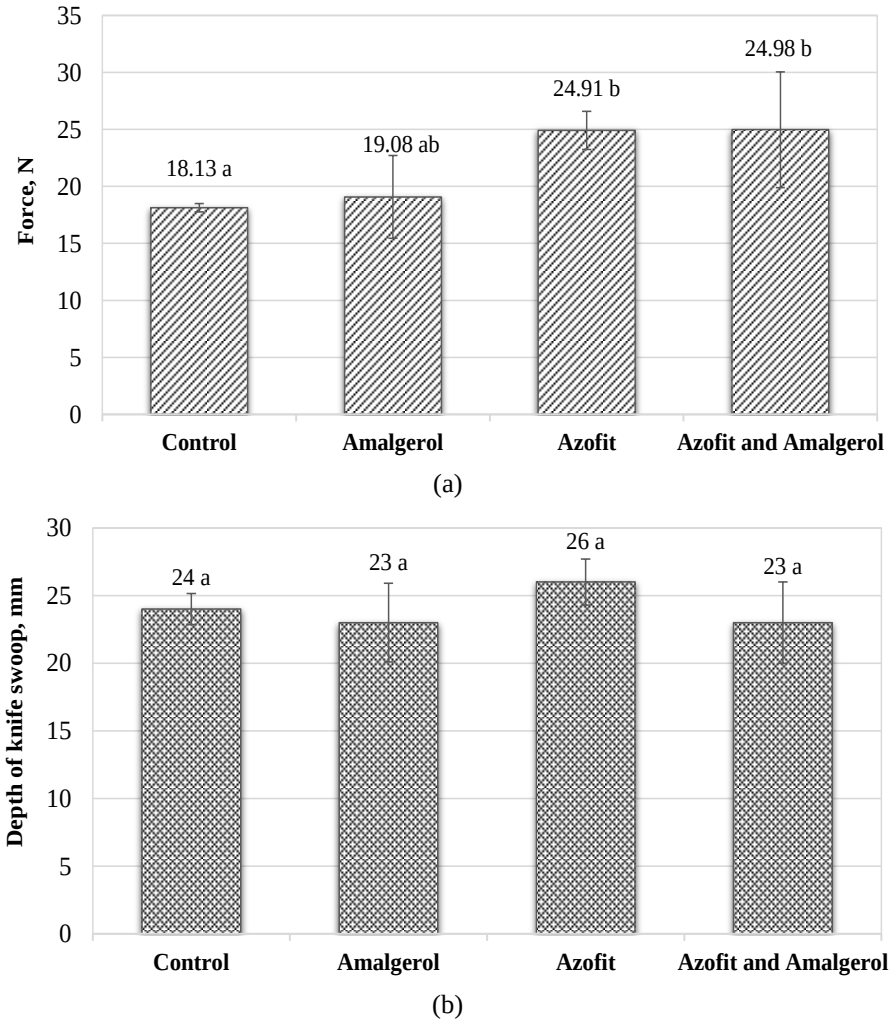


Fig. 2. – Influence of biological preparations on cutting force (a) of winter wheat residues and depth of knife swoop (b)

The research results achieved by using the first method indicate that spraying of winter wheat crop in spring with biological preparations can entail strengthening of plant mechanical characteristics and such plants can resist unfavorable meteorological conditions during vegetation more easily.

The second method helps to achieve a different objective – biological preparation spraying on plant residues speeds up the processes of plant residue mineralization and weakens the mechanical characteristics of the residues to reduce their negative influence on the working parts of soil tillage and drilling equipment as much as possible. The experimental research established the influence of biological preparation "Azofit" on cutting through winter wheat residues. The comparison of the cutting forces applied on the spring rapeseed residues treated and untreated with biological preparation "Azofit" established that significantly lower force was required after the three week biological treatment (Fig. 3). In other cases there were no significant differences among the applications analysed.

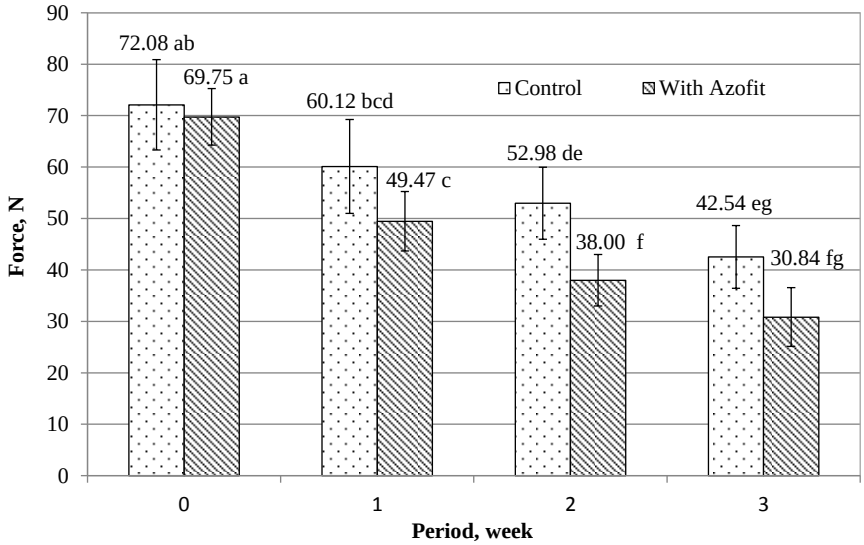


Fig. 3. – Influence of biological preparation and its action period on cutting force of winter wheat residues

In summarizing the experimental results, we can state that the biological preparation use has influence on the force of cutting winter wheat residues. In trying to achieve fast plant residue decomposition after harvest it is expedient to treat plant residues with some biological preparation. This fact has to be emphasized as in such way the use of biological preparation can both intensify the processes of plant residue decomposition and weaken residue mechanical characteristics. Rapid breakdown of the mechanical characteristics of plant residues is of key importance in applying no-till and strip-till technologies, where the impact of plant residues on the quality of drilling is very high. If plant residues are not removed from a seed-drilling notch, seeds can be left unincorporated or incorporated into plant residues. In such cases, seed germination can fail and plant development can be retarded.

CONCLUSIONS

It was established that the use of bio-preparations "Amalgerol", "Azofit" or their combination in spring results in strengthening of mechanical characteristics of winter wheat residues. A stronger plant residue cutting force (approximately by 5 % with "Amalgerol") and (about 37 % with "Azofit", and "Azofit" and "Amalgerol" combination) was achieved compared with the control application.

The experiments established that the use of bio-preparations "Amalgerol", "Azofit" or their combination had no substantial influence on the cutting depth through winter wheat residues. In all cases analysed, plant residues were cut through, when the knife penetrated the soil at similar depths (24 mm onaverage).

It is of key importance in no-till and strip-till technologies that the plant residues left on the soil surface do not prevent the working parts of tillage and drilling machinery from performing their functions well. The force required to cut through plant residues is a very important technological indicator of how easily the working parts of no-till and strip-till machinery cut or fail to cut plant residues. The application of "Azofit" biological preparation reduces the force needed to cut through the winter wheat residues. After three weeks of biological preparation impact it was established that the difference was substantial (approximately 28 %).

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