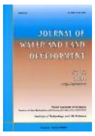

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A novel method and device for plastic mulch retriever

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Abstract

Plastic mulch provides a range of benefits including helping modulate soil temperature, reduce soil erosion, evaporation, fertilizer leaching and weed problems and increasing the quality and yields of the product. But when the crops are harvested, plastic mulch needs to be removed from the ground for disposal. Otherwise, these wastes are mixed with the soil and have a negative impact on yields by reducing the access of nutrients and moisture in the soil. The purpose of the current study is, therefore, to propose a roller for plastic mulch retriever which is applicable when the crops are harvested, and the plastic mulch needs to be removed from the ground for disposal. The winding mechanism of the plastic mulch retriever performs the main function and must have the high-quality performance of the winding operation in the removal technology. Research based on requirements of tensile strength test method and changes of strength characteristics of plastic mulch from various factors under natural conditions. The coefficient of compaction of the used plastic mulch (K_{rel}), was the ratio of the diameter of the standard plastic mulch which was wound in the factory to the diameter of the used plastic mulch during the winding.

Key words: *compaction, microclimatic conditions, mulch retriever, plastic mulch, remove*

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INTRODUCTION

Plastic mulch was first mentioned noted in the 1950s of the last century due to its ability to increase the temperature of the soil [DIVYA, SARKAR 2019]. Interaction of plastic mulch with solar radiation has a direct effect on the temperature of the soil covered because of its heating properties, such as absorption, reflection, and flow capacity [KHAZIMOV *et al.* 2014; 2018]. Plastic mulch provides a range of benefits like modulating soil temperature, reducing soil erosion, evaporation, fertilizer leaching and weed problems and increase product quality and yields.

Besides that, plastic mulch maintains a temperature of the soil at night and during the cultivation period. The colour of the plastic mulch effects on the temperature and humidity conditions of the soil and on the microclimate of the ground air that should be taken into consideration when applying in different climatic zones [JUAN *et al.* 2013; KHAZIMOV *et al.* 2018; LAMONT 2017].

Discovery of polymer materials made a breakthrough in irrigation systems development, allowed to increase yields by 50%, save water by 40%, and even growing crops in desert conditions [VAN DER KOOIJ *et al.* 2013].

In recent decades, use of plastic mulch has increased production of tomatoes, peppers, eggplants, watermelons, melons, cucumbers, pumpkins, and other vegetables [CHUPINA *et al.* 2020; GAŁCZYŃSKA *et al.* 2019]. With the emergence of modern technologies by the production of the polymer materials, which reduced production costs. Which generally plays an important role in crop production. But when the crops are harvested, the plastic mulch needs to be removed from the ground for disposal. Otherwise, these wastes are mixed with soil and have a negative impact on yields reducing delivery of nutrients and moisture into the soil [GAO *et al*. 2019; HE *et al*. 2018].

Research in increasing the effectiveness of biodegradable material has grown considerably in recent years. But the use of a biodegradable material as a mulch has a strong negative impact on plant growth and soil structure by penetrating into the soil after decomposition [QI *et al*. 2018; 2020]. Based on this, the use of biodegradable material as mulch is not acceptable due to the negative impact on the composition of the soil after decomposition.

By using plastic mulch over larger areas, removing the plastic mulch after the post-harvest of vegetables is highly labour-intensive. CARNELL [1978] and KASIRAJAN *et al.* [2012] describe four main ways to disposing plastic mulch, such as burning, physically removing, removing, and storing of plastic mulch.

For farmers, burning of plastic mulch in the field with burners is considered more profitable. Because burning requires no additional resources for collection, transportation and disposal. But during combustion, the plastic film does not burn completely because of low combustion temperature (200–315°C) and about 10% of the plastic mulch embedded in the ground. The burners also require a propane tank, which adds to both the financial and environmental cost. Incineration of plastic mulch produces hazardous fumes and needs environmental controls [KASIRAJAN *et al.* 2012]. Thus, the removing of plastic mulch is important benefits that exist in the area of waste management. The majority of plastic mulch removal is often done by hand and is labour and time-intensive about 64 man-hours per ha [GAO *et al.* 2019; KHAZIMOV *et al.* 2019].

In addition, with the passage of time, the films lose their strength and may break during the physically removing. There are agricultural machines designed for this purpose and available in a range of designs and are typically drawn behind a powered vehicle [KHAZIMOV *et al.* 2019; ROCCA 2012]. Plastic mulch retrievers are available in a range of designs, the main features of which will now be discussed.

One drawback of some mulch retriever is that the unearthed mulch needs to be collected for disposal, which is labour-intensive and inefficient because the unearthed mulch remains strewn along the growing area.

In another plastic mulch retriever design [ROCCA 2012], the unearthed mulch is rolled onto a pair of aligned, rotating rollers rotatably mounted toward a rear of the mulch retriever on a pair of longitudinal arms. An operator stands on a platform to control the speed of rotation of the rollers to be commensurate with the speed of the powered vehicle and the rate at which the mulch is being unearthed. Once all of the mulch has been retrieved, or the rollers are full, each arm comprising one of the respective rollers is swung outwardly, and the rollers separate about a substantially central point allowing the retrieved mulch bundle wrapped around the rollers to fall to the floor for disposal. One drawback of this mulch retriever is that the operator stands on a platform to control the speed of rotation of the rollers what is not safe for the operator.

Also, the cost of the mulch retrievers is estimated in the range from USD4 000 to USD24 00, i.e. the cost is very high since they are used in a very short time during the year.

Once all of the mulch has been retrieved, or the rollers are full, the retrieved mulch wrapped bundle for disposal occupy significantly more volume. Therefore, efficiency is affected because more stops must be made to empty the rollers than would be necessary. All of these can increase transportation costs by transportation to disposal. In order to eliminate the remaining shortcomings at the Kazakh National Agrarian University was designed a device for removing of plastic mulch. This work was supported by the grant project of the Ministry of Science and Education of the Republic of Kazakhstan [KHAZIMOV *et al.* 2018; 2019].

At the first stage of the project, a designed experimental sample of the new device for removing plastic mulch was tested at the field in 2018.

At the field test, the designed experimental sample had disadvantages of the drum roller mechanism for the winding of the plastic mulch were revealed, such as low compaction [KHAZIMOV *et al.* 2019].

In this regard, was modified the winding mechanism and was made a laboratory device. Where was carried out a study on the quality of winding of the used plastic mulch film?

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MATERIALS AND METHODS

THE STRUCTURE AND WORKING PRINCIPLE OF THE PLASTIC MULCH RETRIEVER

One known plastic mulch retriever [KHAZIMOV *et al.* 2019], comprises power take-off *1*, cutting mechanism *2*, a pair of coulter wheels three which cut into the ground and define a channel of ground from which the plastic mulch will be retrieved, conveyor *5* mounted to the elongate side members of the body rearward of the cutting elements with belt drive from a pair of wheels are rotatably mounted to the elongate side members, drum roller *6* for winding of plastic mulch. Drawbacks of this mulch retriever are filling with the drum roller after 50 m, long take-up of wounded plastic mulch. Therefore, efficiency is affected because more stops must be made to empty the rollers than would otherwise be necessary. It is an object of the present invention to provide a plastic mulch retriever that at least ameliorates one or more of the aforementioned problems of the prior art or provides consumers with a useful commercial alternative. According to the agricultural requirements in the development of machinery, the new structure of the plastic mulch retriever is shown in Figure 1. Plastic mulch retriever, comprises a pair of wheels *1*, a pair of coulter wheels *2*, cutting mechanism *3* with power take-off *4*, a conveyor *5* to engage the extracted plastic mulch *6*, and crop residues *7*, a hydro motor *8*, designed new roller *9*.

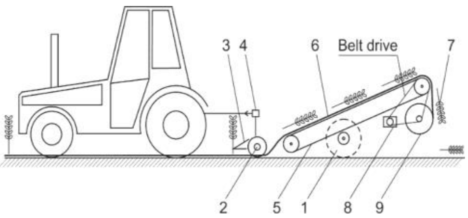

Fig. 1. The structure of the plastic mulch retriever; source: own elaboration

The plastic mulch retriever in the working position is supported by two pair of wheels *1* are rotatably mounted to the elongate side members and a tractor attachment. The cutting mechanism *3* can also comprise twelve or more substantially horizontally mounted cutting elements, which is driven from the PTO 4 of the tractor. A conveyor *5* mounted to the elongate side members of the body rearward of the cutting elements to engage the extracted plastic mulch 6 and crop residues *7*. The conveyor *5* and designed roller device *9* are driven by a hydraulic motor 8 and a belt arrangement that is concealed in or behind a housing for safety.

Since the objective is to study the parameters of the winding process the plastic mulch and the development of a new roller was conducted the following researches: the changes of strength characteristics of plastic mulch from various factors; determination of soil resistance during the winding; the calculation of strength characteristics of PVC pipe (bobbin) of the roller; compaction of the used plastic mulch film on the roller.

RESEARCH OF THE CHANGES OF STRENGTH CHARACTERISTICS OF PLASTIC MULCH FROM VARIOUS FACTORS UNDER NATURAL CONDITIONS

As it, known polymers are used in agriculture, so it is important for scientists and polymer producers to understand the durability and expected lifespan of polymer products. Weather testing of plastic mulch is controlled polymer degradation and polymer coating degradation under natural conditions. The main environmental parameters influencing the degradation of polymeric materials is daylight combined with the effects of temperature, moisture and oxygen. This, combined with the effects of wind and atmospheric gases and pollutants [NEVEROV 2007; SAHNO *et al.* 2014]. Micro-organisms can cause degradation in polymer systems [SAHNO *et al.* 2014].

Weather testing of plastic mulch was to observe controlled polymer degradation and polymer coating degradation under natural conditions. Weather testing of plastic mulch involves placing samples on the field for planting of vegetables oriented at the sun. Typically results in stiffening and cracking, particularly under mechanical stress [KHAZIMOV *et al*. 2016; KRIZHANOVSKY *et al.* 2007; SMYSHLYAEVA 2007].

Results of changes in plastic mulch strength characteristics depending on various factors under mechanical stress were studied using the universal testing machine HUA LONG WDW-0.05C (pdf.directindustry.com) and requirements tensile strength test method (GOST 14236-81). For testing according to the standard of GOST 10354-82 polyethylene films of two marks like ST (thickness 30 µm, 50 µm) and SM (thickness 80 µm, 100 µm, black colour 100 µm) were used.

Data processing of ultimate strength (σ) in MPa was carried out using the following formulas:
– tensile strength (σ_z)

$$\sigma_z = \frac{F_{\max}}{A_0} \tag{1}$$

– ultimate tensile strength (σ_r)

$$\sigma_r = \frac{F_r}{A_0} \tag{2}$$

where: $F_{\max}$ = the maximum stress that a material can withstand while being stretched (N); F_r = the maximum stress before breaking (N); A_0 = the cross-sectional area of the specimen (mm^2).

Elongation (ε) in percent was carried out using the following formulas:
– fracture elongation under tensile stress (ε_z)

$$\varepsilon_z = \frac{\Delta l_{0z}}{l_0} 100 \tag{3}$$

– fracture elongation (ε_r)

$$\varepsilon_r = \frac{\Delta l_{0r}}{l_0} 100 \tag{4}$$

where: l_0 = the length of the sample (mm); l_{0z} = changing the calculated length of the sample by the ultimate strength (mm); l_{0r} = changing the calculated length of the sample by the rupture (mm).

The average values shall constitute the test results.

DETERMINATION OF SOIL RESISTANCE DURING THE WINDING

Seedlings of tomato, pepper, eggplant and cabbage were planted under the plastic mulch to determine the resistance of the soil while removing the plastic mulch. Width of plastic mulch was 500 mm, a thickness of 100 µm. Four seedings per linear meter were planted.

A device for winding of plastic mulch was developed (Fig. 2), which comprises a frame (1), a shaft with a bobbin for winding of plastic mulch, and an electronic torque wrench (3) GROSS Model 14164.

The torque wrench fixed the maximum value of the shaft torque while winding the plastic mulch. Measurements were carried out in a five-fold repetition with overcoming the resistance of residues of the cut plant, as well as without them. The measurement was carried out at the planting sites of tomato and pepper under the plastic

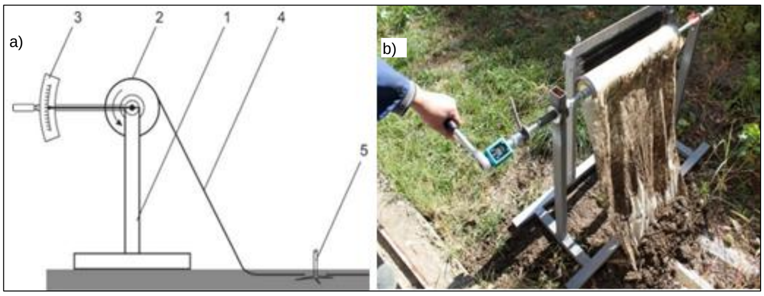

Fig. 2. Device for determining the soil resistance during winding: a) scheme, b) general view (phot.: *K. Khazimov*); *1–5* are explained in the text in p. 3; source: own elaboration

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mulch. The height of the cut of the stems (*5*) from the field surface was 80–100 mm. The resistance of the soil (*R*) during the winding was determined by dividing the torsion moment (*M*) of the torque wrench by the radius (*r*) of the bobbin:

$$R = \frac{M}{r} \tag{5}$$

The structure and working principle of the designed roller for plastic mulch retriever. The geometric model of the roller for plastic mulch retriever introduced into Auto CAD Mechanical 2019 software was shown in Figure 3.

The designed roller for plastic mulch retriever comprises drive pinion *10*, friction clutch *11*, the drive shaft *12*, support *13* with a ball bearing *14* mounted at the frame, mounted bobbin *15* between left and right cones *16*. Left cones have two blades *17*, pusher *18* and not moveable parallel to the longitudinal axis of the drive shaft *12*. Right cones comprise limiter *19* which is mounted to bracket *21* with a ball bearing *22* through the cotter pins *20*. Moveable shaft *23* with a ball bearing *24*, arm *25* with spring withdrawal *26*.

The working principle of the roller for plastic mulch retriever. As it, known plastic mulch wound onto a bobbin (paper, PVC pipe) so as to form a reel. Bobbin remains at the end of the planting as waste, which is likely to be disposed of in landfills, incinerated, recycled, or remain as waste in the environment. The designed device works in conjunction with the bobbin remaining from the reel after planting of vegetables. Figure 4 is a schematic side view showing when cones separate, and the bundle of retrieved mulch falls to the ground.

Bobbin *15* compresses between left and right cones *16*. Cranking of the bobbin *15* shall be stopped by blades *17*. The torque of the rotating part of the drum is received through a belt transmission from the hydraulic motor *8* to the drive pinion *10*, then transmitted to the drive shaft *12* through the friction clutch *11* to the left cone, then trough the bobbin *15*, to the right cone and then to the right movable shaft *23*.

The arm *25* mounted to support with a ball bearing *24* and not moveable around to the longitudinal axis of the shaft *23*. Limiter *19* which is mounted to bracket *21* with a ball bearing *22* through the cotter pins *20* can move with the shaft *23*. If the mulch retriever is moving along at a constant speed, as the diameter of the retrieved bundle of mulch wrapped around the cones increases, the speed of rotation of the rollers is reduced because of the friction clutch. The friction clutch can also be safe a plastic mulch before breaking.

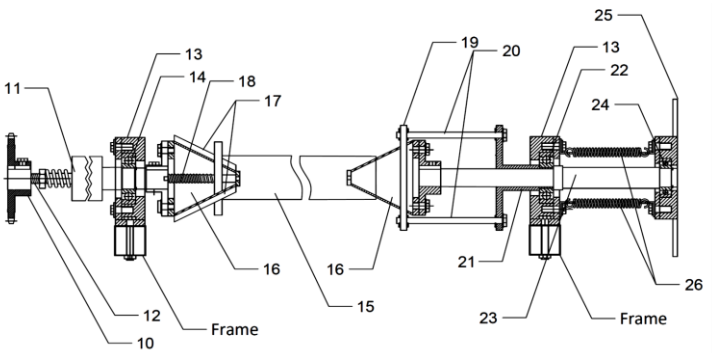

Fig. 3. The geometric model of the designed roller for plastic mulch retriever; *10–26* are explained in the text in p. 4; source: own elaboration

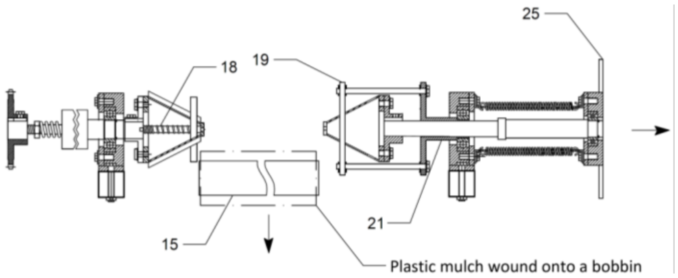

Fig. 4. Bundle of retrieved mulch falls to the ground; *15*, *18*, *19*, *21* and *25* are explained in text in p. 4; source: own elaboration

After the unit (tractor with the retriever) stops and the operator moves the handle *25* to the right, the movable shaft 23 moves to the right with the right cone relative to the bracket *21* and the bundle using the spring mechanism *18* moves to the right until the limiter *19* and when cones separate, and the bundle of retrieved mulch falls to the ground.

The calculation of strength characteristics of PVC pipe. Under the influence of the wound plastic mulch, tangential stresses occur in the pipe, which tends to deform it. Tangential stresses occur as a result of the tension of the wound plastic mulch due to the resistance of the soil when pulling the plastic mulch out of the soil. In order to verify the stability and structure rationality of device, Inventor Professional 2018 software was used to simulate: maximum soil resistance during the winding; the maximum stress before breaking. Characteristics of the PVC pipe for calculating strength are shown in Table 1.

Table 1. Characteristics of PVC pipe for strength calculation

Parameter	Value
Mass density	1.4 g·cm^{-3}
Yield stress	46.53 MPa
Ultimate tensile strength	52.36 MPa
Young's modulus	3400 MPa
Poisson ratio	0.4
Shear modulus	1214.29 MPa
Diameter	50 mm

Source: own elaboration

COMPACTION OF THE USED PLASTIC MULCH FILM ON THE DESIGNED ROLLER

Well compacted mulch bundle reduces the transportation costs, where the cost is based on the mass and volume of the bundle. Good compacted mulch bundle also reduces commuting and freight transportation times. To simulate the winding process was made the laboratory stand. Scheme and general view of the stand shown in Figure 5 and comprises: soil bins *1*; mobile platform *2*; frequency converters of motor *3*; drive system of the platform *4*; roller drive system *5*; frequency converters of roller drive system *6*; belt drive *7*; designed roller *8*; means for clamping the plastic mulch *9*; the bundle of retrieved mulch *10*. The platform has the ability to move on the rail. The roller *8* was driven by an electric motor of the roller drive system *5* via a belt drive *7*. The speed of the roller *8* is controlled via a frequency converter *6*. The means for clamping *9* controlled the tension force of plastic mulch during the winding.

During the winding, the speed of the roller was 90 rpm, that corresponds to the average speed of the tractor (average speed of the tractor MTZ – 82.1 equal 3 km·h^{-1}). The tension force of plastic mulch corresponded from 3 N to 135 N.

The coefficient of compaction of the used plastic mulch (k_{rel}) was the ratio of the diameter of the standard plastic mulch (D_0) which was wound in the factory to the diameter of the used plastic mulch (D_1) during the winding: $k_{\mathrm{rel}} = \frac{D_0}{D_1}$.

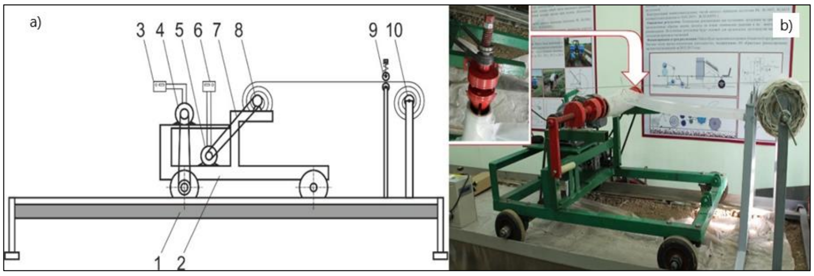

Fig. 5. The laboratory stand to simulate the winding process: a) scheme, b) general view (phot. *A. Niyazbayev*); *1–10* are explained in the text in p. 5; source: own elaboration

In the research, plastic mulch was used, which were exposed under natural conditions with a length of 100 m. The diameter of the used plastic mulch was measured with five times frequency.

FIELD TEST OF DESIGNED ROLLER

Test samples of the plastic mulch had a thickness of 30, 50, 80, 100 µm. And were laid on April 27, 2019, at the test field of the Kazakh Research Institute of Potato and Vegetables, Almaty region, Karasay district, Kainar village. The test field is 100 m long and 50 m wide.

RESULTS AND DISCUSSION

RESULTS OF THE CHANGES OF STRENGTH CHARACTERISTICS OF PLASTIC MULCH FROM VARIOUS FACTORS UNDER NATURAL CONDITIONS

Weather testing showed that plastic mulch under natural conditions changed the colour. Besides that, plastic mulch had cracks. The brittle of polymeric materials with the effects of temperature increase. As it known brittle materials absorb relatively little energy prior to fracture, even those of high strength. The tensile strength of a plastic mulch under natural conditions shown in Figures 6 and 7.

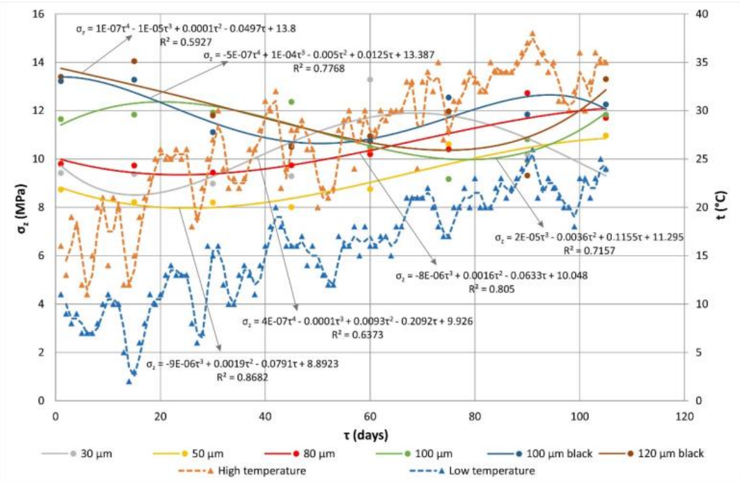

Fig. 6. The tensile strength (σ_z) of a plastic mulch under natural conditions; τ = time duration, t = temperature, R^2 = coefficient of determination; source: own study

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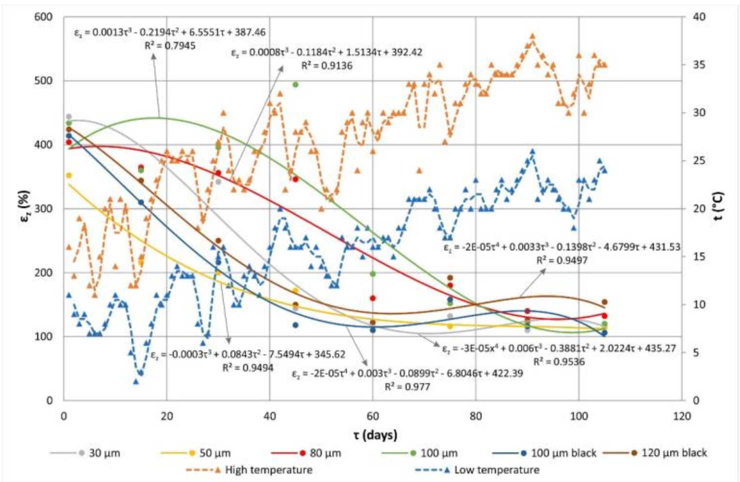

Fig. 7. Fracture elongation (ε_z) under tensile stress; τ, t, R^2 as in Fig. 6; source: own study

These results indicate that the tensile strength of a plastic mulch under natural conditions decreases. Figure 6 shows the results of changes in strength properties on different plastic mulch which are tested for 105 days. The results indicate that the tensile strength (σ_Z) did not significantly change in all samples. But the tensile strength of some samples during the time was changed. After 80 days of the experiment, the samples of 30 µm and 50 µm during visual inspection showed micro-cracks, which caused the plastic mulch to become brittle. After 105 days of the experiment, it was impossible to conduct experiments because of high brittle of plastic mulch.

Figure 7 shows that after 60 days, the samples of 30 µm, 50 µm, 100 µm (black), 120 µm (black) fracture elongation under tensile stress (ε_Z) decreased to 110%, which gives reason to believe about their brittle. The fracture elongation under tensile stress was reduced for 120 µm (black) samples by 82% and for 80 µm samples by 67%. The change of ultimate tensile strength (σ_r) is shown in Figures 8 and 9, which shows that during the first test period, the strength of some samples increase and then decrease.

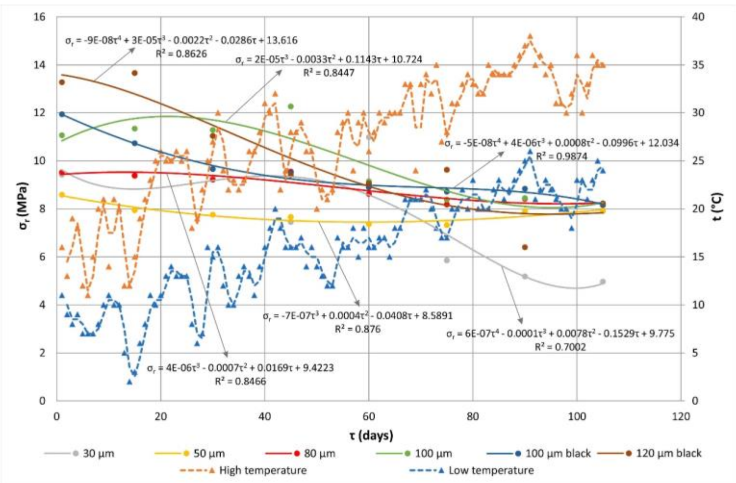

Fig. 8. The ultimate tensile strength (σ_r) of a plastic mulch under natural conditions; τ, t, R^2 as in Fig. 6; source: own study

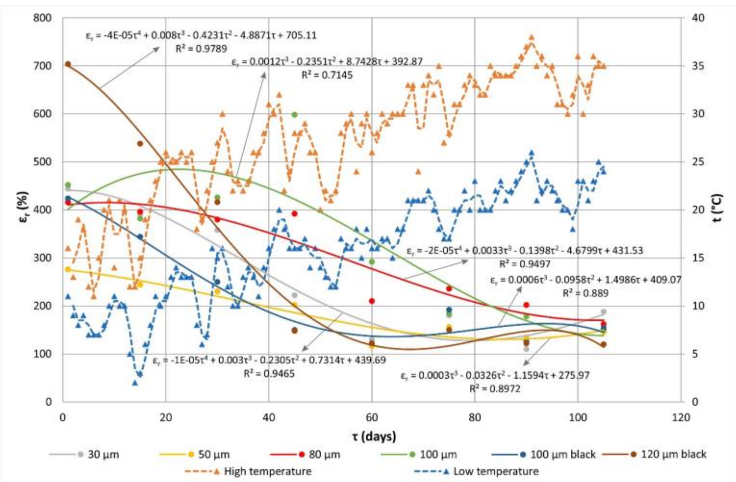

Fig. 9. Fracture elongation of a plastic mulch under natural conditions; τ, t, R^2 as in Fig. 6; source: own study

All samples of plastic mulch had the same strength. But the strength of the sample of 30 µm decreased by 47%. Besides that, all tested samples of plastic mulch for 105 days reduced the fracture elongation. The maximum fracture elongation of a plastic mulch with a thickness of 120 µm (black) decreased by 82% and the minimum fracture elongation of a plastic mulch with a thickness of 50 µm decreased by 47%.

RESULTS OF SOIL RESISTANCE DURING WINDING

Diagram of soil resistance during winding of plastic mulch with root residues of tomato and pepper and without plant residues is shown in Figure 10.

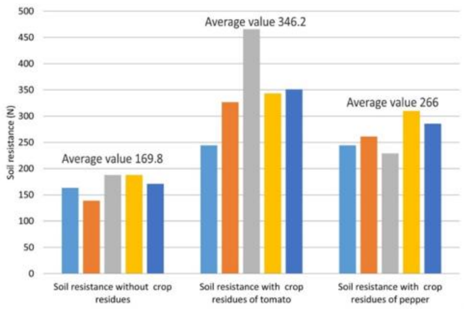

Fig. 10. Soil resistance during the winding; source: own study

Z komentarzem [U5]: What do colours mean in bars?

The average value of soil resistance showed the following results: without crop residues – 169.8 N; with crop residues of tomato – 346.8; with crop residues of pepper – 266.0 N. The showed that crop and soil residues affect to the soil resistance during the winding of plastic mulch. The findings of the study indicate that the brittleness and other strength characteristics can be evaluated during the design of the roller.

RESULTS OF THE STUDY OF THE COMPACTION OF THE USED PLASTIC MULCH

The graphs of the changing of the wound roll diameter and the coefficient of relative compact versus tension force of the used plastic mulch during the winding shown in Figure 11.

Initially, there was a direct linear relationship between tension force and diameter. With an increase of tension force graph sharply changes direction. This is due to the presence of damage on the plastic mulch, which forms emptiness between the layers of the plastic mulch. The graph shows that the roll diameter increase with a decrease in tension force and the coefficient of relative compaction falls. Because of this, increasing the coefficient of relative compaction can progressively increase the sustainability of long-
-distance freight transport and the operational efficiency of the plastic mulch retriever (Fig. 12).

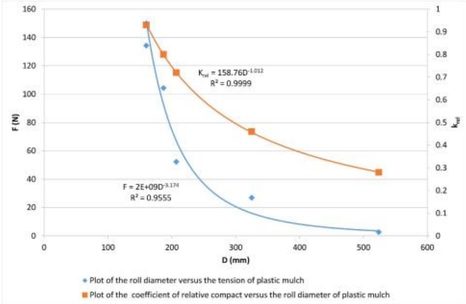

Fig. 11. The roll diameter (*D*) and coefficient of relative compact (k_{rel}) versus the tension (*F*) of used plastic mulch; source: own study

Fig. 12. Compacted bundle of used plastic mulch (right) compared to the standard mulch bundle (left) (phot. *K. Khazimov*)

Overall efficiency improvements in long-distance freight transport are necessary for agriculture. Good compacted mulch bundle reduced the transportation costs also reduce commuting and freight transportation times.

RESULTS OF FIELD TEST

Field tests were conducted on September 10, 2019, at the test field of the Kazakh Research Institute of Potato and Vegetables, Kainar village, Karasay district, Almaty region, Kazakhstan. The outside temperature was 17°C. Field tests of the developed roller device in comparison with the drum roller are shown in Figure 13.

The main technical parameters of plastic mulch retriever are presented in Table 2.

Field tests showed that samples of 30, 50 µm of plastic mulch are difficult for mechanized removal due to its breaking during the winding. More suitable were plastic with a thickness of 80 µm and higher, which have a tensile strength at least 8.22 MPa. During the field test after passing 50 m, the rotating of the drum-type winding device (left) stopped, and winding of plastic mulch suspend. The new device which was driven by a hydraulic motor (right) showed a high degree of compaction of the plastic mulch to the end of the field.

Fig. 13. Field tests of the developed roller device (right) (phot. *A. Niyazbayev*) in comparison with the drum roller (left) (phot. *K. Khazimov*)

Table 2. Main technical parameters of plastic mulch retrievers (old and new)

Parameter	Plastic mulch retriever with the	
	drum roller	new roller
Length×width×height (mm×mm×mm)	2500×2200×1400	2500×2200×1400
Weight (kg)	380	270
Working speed (km·h^{-1})	2.4	5.0

Source: own study.

Increasing water demand in the world following rapid population growth has increased the importance of optimal use of this vital substance. Due to the existence of serious water shortages, especially in arid and semi-arid regions, the need for use optimal and high water efficiency is very important in this sector. Therefore, many studies have been conducted to investigate and analyse the use of mulch in agriculture and its effects on reducing evaporation losses and increasing water use efficiency [BANDOPADHYAY *et al*. 2018; GHIMIRE *et al*. 2018; SINTIM, FLURY 2017]. The results of various studies have shown that mulch reduces the temperature and prevents the growth of weeds by creating shade and preventing the penetration of light, and also reduces the temperature and increases the moisture content of the soil by preventing the evaporation of water from the soil surface [QI *et al.* 2018; SAGLAM *et al*. 2017].

As it mentioned earlier, one of the advanced and new tools and methods that has recently opened its place in agriculture is the use of plastic mulch. This method, by preserving and storing soil moisture, makes possible the maximum use of water, especially in the cultivation of row crops. As a result, more water can be stored for planting fallow and barren lands, or with less water than the original level of the crop. Plastic mulch provides a range of benefits including helping modulate soil temperature, reduce soil erosion, evaporation, fertilizer leaching and weed problems and increasing the quality and yields of the product. But when the crops are harvested, plastic mulch needs to be removed from the ground for disposal. Otherwise, these wastes are mixed with the soil and have a negative impact on yields by reducing the access of nutrients and moisture in the soil. Several studies have tried to provide a solution to this problem. Some of these studies have focused on changing the genus of mulch to make it so-called environmentally friendly. But some other studies have focused to introduce a novel method and device for plastic mulch retriever.

CONCLUSIONS

1. When the crops are harvested, the plastic mulch needs to be removed from the ground for disposal. Otherwise, these wastes are mixed with the soil and have a negative impact on yields by reducing the access of nutrients and moisture in the soil. The paper developed a device, which could remove and wind plastic mulch with good compaction for disposal. Good compacted plastic mulch can increase the sustainability of long-distance freight transport and the operational efficiency of the plastic mulch retriever.

2. Prevention of frequent break of the plastic mulch during the winding was achieved using the results of laboratory studies. Laboratory studies determined the soil resistance during the removal of the plastic mulch and changes of strength characteristics of plastic mulch from various factors under natural conditions. These studies allowed to determine the ultimate tensile strength of the plastic mulch, to adjust the necessary torque of rotation of the device through the friction clutch.

3. The Inventor Professional 2018 software was used to simulate the winding process on the proposed device. The simulation was based on the data of soil resistance and strength characteristics of plastic mulch. Results of simulation showed that the PVC pipe under the impact of soil resistance during the winding of plastic mulch, displacement from its central axis to 451 mm. This displacement is assumed to be acceptable in order to maintain a stable state of the PVC pipe.

4. The simulation results were reliable, which was proved during the winding of plastic mulch in the laboratory and by the field tests. The graph of the compaction of the used plastic mulch depending on the force was obtained in the laboratory. The simulation results were basically consistent with the field test. These indicated that the structure of the developed device was reasonable, and the performance was stable by the thickness of plastic mulch

80 µm or higher. The plastic mulch lower than 80 µm should be removed as soon as possible after use ceases.

For future studied it is suggested to undertake research into alternative materials to plastic in the future (more environmentally friendly).

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