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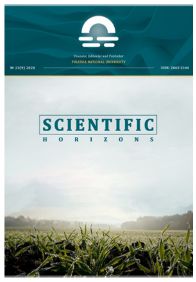

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Influence of Various Forms of Absorbent and Mulching Materials on the Yield of Vining Cucumber and Fruit Quality in the Forest-Steppe of Ukraine

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Abstract. Against the background of global climate change, most of the territory of Ukraine today is semi-arid, which causes a decrease in the efficiency of the vegetable growing industry. Due to aridity and elevated temperatures in summer, the normal growth and development of plants, namely vining cucumber, is disrupted. The efficiency of artificial irrigation is also decreasing due to the rise in the price of fresh water and energy carriers for its supply to plants. Soil absorbents and the use of mulching can solve these issues. The purpose of this study was to investigate the effect of various forms of soil absorbent against the background of the use of various mulching materials of organic and synthetic origin on the productivity of vining cucumber. This study involved field, laboratory, statistical, and computational-analytical methods. Studies have established that upon mulching the soil with black polyethylene film together with the introduction of a soil absorbent in the form of a gel, phenological phases of growth and development occur most quickly in vining cucumber plants, and the fruiting period increases by 11 days compared to the control. The combination of film mulching and absorbent gel allowed increasing the height of the main stem by 15.2%, the number of leaves on the plant by 43.9%, and the leaf area by 26.5% compared to the control version. It was established that the highest commercial yield is provided by mulching the soil with a black film together with the introduction of an absorbent in the form of pellets and gel – 56.6-56.8 t/ha, which is 27.5-27.9% more than the control. The marketability of the yield was 99.2-99.4%. Cucumber fruits for mulching with a film and applying an absorbent in the form of a gel had a high content of dry matter (5.3%) and the sum of sugars (2.20%). Lowest nitrate level (N-NO_3) in cucumber fruits provided mulching with black agrofibre without an absorbent (53.0 mg/kg)

Keywords: gel, pellets, biometric indicators, plant productivity, correlations, yield marketability, chemical composition of fruits

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INTRODUCTION

Ukraine is one of the leading agricultural countries in Europe (Chryniewicz *et al.*, 2016). The soil conditions are very favourable for growing many types of plant production, primarily vegetables. That is why, by the decision of the UN Food and Agriculture Commission, Ukraine is ranked among the states that in the future should become the main food donors in the world against the background of continuous population growth on the planet. According to the National Academy of Agrarian Sciences of Ukraine, if the land is used efficiently, Ukraine can feed about 1.2 billion people (National Academy of Agricultural Sciences of Ukraine).

Global climate change affects various spheres of life and industry, especially agriculture, as it causes a decrease in the efficiency of the plant production industry (Cherlet *et al.*, 2018). Due to aridity and high air temperatures in the summer months, the normal growth and development of plants is disrupted, their suppression and productivity decrease occur.

Water management is a major challenge for all countries. It is estimated that by 2030, the total need for water on the globe will be 50% higher than today, which will lead humanity to water scarcity (Laxmi *et al.*, 2019).

The modern climate in most of the territory of Ukraine is semi-arid. It was found that 46.05% of acreage cannot provide sustainable crop production without irrigation, and 42.65% need irrigation to grow plants with high water use (Lykhovyd, 2021). The need to increase the production of vegetables against the background of a constant decline in soil quality and climate change to a more arid one, causes elevated interest in finding new measures that would provide plants with sufficient water. The productivity of vegetable plants and the accumulation of high vitamin content in food organs directly depends on environmental factors, primarily on moisture (Abd El-Aal, 2010).

To meet the biological needs of plants, the agricultural sector uses a large amount of fresh water, which accounts for two-thirds of what is used on a global scale. Against the background of a decrease in world reserves, fresh water is the most valuable resource on the planet, as evidenced by its constant rise in price. The efficiency of artificial irrigation is constantly decreasing due to the growing cost of water and energy carriers, which are necessary for its supply to plant growing areas. Humanity needs to reduce the use of fresh water for irrigation, increase the rationality of its use in agriculture because this area will soon experience a strong shortage of water. The solution to this issue depends on new methods and elements of technology that contribute to the rational use and optimisation of water resources. First, this problem can be solved by using hydrogels (Shubhadarshi & Kukreja, 2020) and soil superabsorbents, which, apart from preserving moisture in the soil crossover, can considerably improve irrigation efficiency (Wehbahani *et al.*, 2006). The use of absorbents in the cultivation of plant organisms plays a vital role in promoting an innovative approach to human habit and culture in relation to water (Sannino *et al.*, 2009) and a major role in all agricultural production (Dehkordi, 2017).

The use of absorbent polymers (hydrogels) or superabsorbing polymers (SAP) can increase the ability of the topsoil to retain moisture and nutrients for a long time, which may be available for plant growth and development (Yu *et al.*, 2011; Qu & Varennes, 2009). The analysis proves that the use of superabsorbent polymers increases the water content available to plants on different soil types (Banedjschafie & Durner, 2015; Montesano *et al.*, 2015).

Mulching the soil surface is also one of the most efficient measures to preserve moisture in the soil and influence its temperature regime. Covering the soil reduces moisture evaporation, protects the upper soil section from soil erosion, inhibits weed germination, enhances microbiological processes and reproduction of beneficial microorganisms (Zaniewicz-Bajkowska *et al.*, 2012), preserves the structure of the soil and reduces its temperature during the hot summer months (Chakraborty *et al.*, 2008; Kęsik *et al.*, 2007), prevents the penetration of water and nutrients into deeper horizons (Abobatta, 2018).

Therefore, a water conservation strategy is key to sustainable population living in arid regions (Chen *et al.*, 2016). *The purpose of this study* was to investigate the influence of various forms of soil absorbent against the background of the use of various mulching materials of organic and synthetic origin on the productivity of vining cucumber and the quality of its fruits in the conditions of Ukrainian forest-steppes.

LITERATURE REVIEW

Superabsorbents are three-dimensional hydrophilic polymers that can absorb and retain large amounts of water and aqueous solutions (Wehbahani *et al.*, 2006; Milani *et al.*, 2017). That is, absorbents are not nutrients, but act as tiny reservoirs for storing water, which ensures normal growth and development of plants. Their application more fully realises the natural varietal potential of plants (Polischuk *et al.*, 2018).

Modern-day agricultural producers can access different varieties of absorbents: hydrogel, water-retaining pellets, ecosoil, agrogel, aquasoil, aquasorb, etc. Their composition and moisture retention are different. Superabsorbents can be produced in the form of pellets, tablets, gel, or as a powdered substance.

Depending on the source of origin, hydrogels are classified into natural, synthetic, and semi-synthetic. Synthetic materials are created based on acrylates and acrylamides, they have high mechanical strength, but due to problems of decomposition and safety for the environment, they are trying to replace them with biopolymers (alginate, agar, cellulose, chitosan, starch) (Skrzypczak *et al.*, 2020). The industry practices the creation of absorbents based on ecological and biodegradable starch, which does not have phytotoxicity and after a certain period completely decomposes in the soil.

To produce hydrogels, natural materials are used, such as carob gum, dextrin, hyaluronic acid, okra gum, etc. Examples of synthetic absorbents are polymethacrylic acid (PMAA), polyacrylic acid (PAA), Poly-N-vinylpyrrolidone (PVP), polyethylene glycol diacrylate/polyethylene glycol dimethacrylate (PEGDA/PEGDMA), polyethylene glycol acrylate/methacrylate (PEGA/PEGMA), polystyrene (PS) (Saini, 2016). Less material and production resources are spent on an absorbent made from natural chitosan material, compared to synthetic absorbents. It can hold up to 610 g of water per 1 g of gel (Alam & Christopher, 2018).

The use of absorbent polymers (hydrogels) or superabsorbing polymers (SAP) increases the ability of the upper soil section to retain moisture and nutrients for a long time, which is available for plant growth and development (Wehbahani *et al.*, 2006; Dehkordi, 2017). This helps them tolerate the heat more easily, and with a large amount of precipitation, the effect of "flooding" is eliminated.

The use of hydrogel polymers is an effective means of improving the efficiency of irrigation water (Moslemi *et al.*, 2011; Lao *et al.*, 2016). It was found that the use of a superabsorbent type A200 polymer reduces the use of irrigation water by 35-45% without reducing the yield, compared to full irrigation without an absorbent (Sakaki *et al.*, 2020). It is known that excessive use of fertilisers and agrochemicals can lead to contamination of groundwater and deterioration of the ecological balance. Absorbent polymers help reduce the rate of application of agrochemicals and increase the efficiency of their use (Skrzypczak *et al.*, 2020; Srivastava *et al.*, 2018).

The results of experiments have shown that by improving the state of soil aggregates, preserving the structure of the soil, increasing and strengthening the state of porosity, ensuring soil moisture, increasing soil permeability and increasing water permeability in it, superabsorbents reduce or even stop soil erosion (Moslemi *et al.*, 2011).

In Ukraine, many scientists are engaged in the study of various forms of absorbents on the productivity of vegetable plants, namely in the cultivation of vining cucumber (Ternavskyi *et al.*, 2017), turnip-rooted celery and salad celery (Polischuk *et al.*, 2018; Ulianych *et al.*, 2019), spinach (Ulianych & Shevchuk, 2020). Scientific progress in the study of absorbents has been achieved by other scientists on black pepper (Rasanjali *et al.*, 2019), soy (Ryan *et al.*, 2020), potato (Salavati *et al.*, 2018) and cotton (Papastylianou, 2020). Soil absorbents improved physiological processes, increased yields, improved seed suitability and root system development. Other scientists have stated that absorbents increase the moisture content of greenhouse soil (regardless of the species) by 14% and improve the absorption of trace elements by plants (Ostrand *et al.*, 2020).

Scientists have studied a biocompatible cellulose-based absorbent that is non-toxic and completely decomposes in the soil. Its ability to absorb moisture up to 400 times its own weight is noted, as well as its positive effect on plant growth and development (Montesano *et al.*, 2015). Other researchers have established the potent effect of AgroHydroGel and AquaSave superabsorbents on soil moisture, which was applied before sowing peas. This contributed to an increase in the number of nodules on the root system of plants, which increased its commercial yield (Gamajunova & Tuz, 2017).

Mulching is a continuous or inter-row coating of the soil surface with materials of organic or synthetic origin. It is considered one of the most efficient measures to preserve moisture in the soil and regulate the temperature regime. Soil temperature changes the absorption of elements by directly affecting the growth and physiology of the root system and the entire plant in general. When the soil temperature is lowered, the plant's moisture absorption decreases, which is caused by an increase in viscosity and a decrease in the level of water absorption by the plant. As a result, this adversely affects photosynthesis, and therefore all processes in the plant (Toselli *et al.*, 1999). Due to the positive impact on the physical properties of the soil and the preservation of moisture in it, it is considered that this measure follows the rules of organic farming (Zaniewicz-Bajkowska *et al.*, 2012).

Mulching materials protect the soil cover from erosion, preserve the soil structure, reduce the adverse impact of temperature fluctuations during the day, inhibit the germination of weeds, provided that opaque synthetic materials are used or a layer of organic materials with a thickness of at least 5-7 cm is applied. Theoretically, various materials can be used to cover the soil surface: polyethylene film of assorted colours, white and black agrofibre, sawdust, peat, straw, dry grass, compost, humus, parchment, etc.

When growing cucumbers, mulching with black plastic wrap is often used, the soil temperature under it is more stable, the microclimate in the surface layer of the soil improves, and the relative humidity of the air increases. Today, eight types of polyethylene film are used in agricultural developed countries: transparent, white, black, yellow, black and white, silver, thermal brown, herbicidal green. Each type of film has its own specific features and characteristics, knowing them can influence the creation of favourable conditions for many agricultural plants, considering their biological requirements. Black polyethylene film helps increase the temperature of the soil, light-coloured film can reduce the heating of the soil during the day, enhance biochemical processes, which has a positive effect on plant nutrition (Hallidri, 2001).

Scientists investigated the effect of a polyethylene film of black, transparent, and silver colour on cucumber plants (Yaghi *et al.*, 2013). All types of films increased the length of the main stem of plants and the number of leaves, and the thickness of the stem was slightly affected. The highest soil temperature was under the black film at a depth of 10 cm and 30 cm, which had a positive effect on cucumber plants. Of all types, the best result was achieved by using black polyethylene film, which allowed obtaining the highest total yield, although the highest early harvest was obtained under transparent polyethylene film.

In Syria, the effect of transparent and black polyethylene films on the water demand of cucumber plants under drip irrigation conditions was studied. It was found that the use of light polyethylene film and drip irrigation was the best in terms of the efficiency of water use by plants. Soil temperature and humidity in this variant had the highest rates, and the yield was almost twice as high as in the variant without mulching and watering along furrows (Nimah, 2007).

MATERIALS AND METHODS

The research was carried out during 2018-2021 in the experimental field of the Department of Vegetable Farming of the Uman National University of Horticulture in the forest-steppe of Ukraine according to the methods of G.L. Bondarenko (Bondarenko & Yakovenko, 2001) and Z.M. Gritsayenko (Hrytsayenko *et al.*, 2003).

The soil of the experimental site is podzolised heavy loamy chernozem on the forest with a humus soil section of 40-45 cm. The humus content is 3.2%, pH 6.0-6.2, the degree of soil saturation with bases is 91.0%. The content of mobile forms of nitrogen is 64 mg/kg of soil (according to Kornfield), phosphorus – 119 mg/kg of soil (according to Chyrikov), potassium – 101 mg/kg of soil (according to Chyrikov) (Table 1).

***Table 1**. Physical and chemical parameters of the soil of the experimental site*

Indicators	Factual content
Organic matter (humus),%	3.2
pH	6.0-6.2
NO_3	64
P_2O_5	119
K_2O	101

The study was conducted on the cultivation of an early maturing hybrid of foreign selection Bettina F_1 by seedling method. This hybrid is listed in the State Register of Plant Varieties of Ukraine suitable for distribution in Ukraine. Seedlings were grown in a film spring greenhouse using black plastic cassettes with a cell size of 8×8 cm (64 cm^2). Pre-disinfected cells of cassettes were filled with a soil mixture consisting of turf and humus in a 1:1 ratio. One seed was sown in each cell. In the open ground, seedlings in the phase of two real leaves were planted in the third decade of May according to the placement scheme of 140×15 cm.

The study was carried out using the method of a two-factor experiment with randomised placement of variants in four-fold repetition. The area of one experimental site was 8.4 m^2. The area of the entire experimental site was 403.2 m^2. Technological practices were carried out according to the requirements of the culture and agroclimatic growing zone.

The experiment scheme included the following factors and variants:

Factor A – mulching material: no mulching (A_1); mulching with black polyethylene film (A_2); mulching with black agrofibre (A_3); mulching with sawdust (A_4).

Factor B – absorbent form: without absorbent (B_1); pellets (B_2); gel (B_3).

Combination of variants in the experiment:
- A_1B_1 (control)
- A_1B_2
- A_1B_3
- A_2B_1
- A_2B_2
- A_2B_3
- A_3B_1
- A_3B_2
- A_3B_3
- A_4B_1
- A_4B_2
- A_4B_3

Methods of applying various forms of absorbent

MaxiMarin ready-made gel and Dari Dar moisture-retaining pellets were used as an absorbent. The gel was applied according to the manufacturer's recommendations to the bottom of each seedbed at the rate of 4 g/plant, pellets – to the zone of future placement of the root system at 0.5 g/plant.

Use of mulching materials

A black polyethylene film (50 microns thick) and A-50 grade black agrofibre (50 g/m^2 density) were taken and wood sawdust (deciduous wood species) were taken for the experiment. The width of the mulching strip was 70 cm. The film and agrofibre were prepared with a width of 100 cm, since 15 cm of edges on both sides were laid in prepared furrows and carefully covered with a thin layer of soil. Immediately before planting seedlings in the places of future placement of plants, cross-shaped incisions were made, gel and pellets were added to the bottom of each seedbed. Sawdust was covered with a 5-6 cm thick layer immediately after applying the absorbent and planting seedlings.

Phenological observations

The following phenological phases of growth and development of cucumber plants were noted: the formation of the third real leaf, mass flowering of female flowers, and the beginning of the formation of the first fruits. The beginning of each phenophase was the date when 15% of plants entered it, and the date of mass onset of the phase was considered to be 75% of plants.

Biometric parameters

The height of the main stem, the number of leaves and their area were determined during the mass fruiting of cucumber plants, which fell on the third decade of July. The height of the main stem was determined using a measuring ruler. The number of leaves on the plant was carried out by mathematical calculation. The leaf area was determined by the method of V.I.Kamchatny (Kamchatny & Sinkovets, 1997). Biometric indicators were measured for 10 control plants in four repetitions of each of the variants.

Yield accounting

The yield was calculated selectively as the technical maturity of the fruit on the plots by weight. Products from the accounting plots for each harvest were divided into commodity and non-commodity parts according to the requirements of the current cucumber standard (DSTU 3247-95, 1995).

Laboratory tests

In the laboratory, the content of dry matter in the fruit, the sum of sugars and the level of nitrates (N-NO_3) were determined as follows:

— dry matter was determined by thermograviometric method (Peterburzhskij, 1973);

— the sum of sugars — by the ferricyanide method (Hrytsayenko *et al.*, 2003);

— nitrate level — by ion-selective method using the EV-74 device (Najchenko, 2001).

Statistical analysis

Statistical analysis was performed using Microsoft Office Excel, version 2016 (MicrosoftCorp., USA) and methods of B.A.Dospekhov (Dospekhov, 1985). The results were calculated at a significance level of 0.05.

RESULTS AND DISCUSSION

According to phenological observations, it was found that among the mulching materials, the third real leaf was previously formed when covering the soil with a black polyethylene film — on the 9th day from planting seedlings. When mulching with sawdust, this phase occurred 2-3 days later, compared to the variant without mulching (Table 2). The forms of the absorbent within each mulching material did not affect the passage of this phase since this is the initial phase of growth and development of cucumber plants.

Table 2. *The value of interphase periods of cucumber plant development depending on the influence of various forms of absorbent and mulching materials, days from seedling planting (average for 2018-2021)*

Variant		Formation of the third real leaf	Mass flowering of female flowers	Start of formation of first fruits
Mulching material	Absorbent form			
Without mulching	Without absorbent (control)	11	39	45
	Pellets	10	37	43
	Gel	10	36	42
Black polyethylene film	Without absorbent	9	31	37
	Pellets	9	29	35
	Gel	9	27	33
Black agrofibre	Without absorbent	9	34	40
	Pellets	10	33	39
	Gel	10	32	38
Wood sawdust	Without absorbent	13	41	47
	Pellets	13	39	45
	Gel	13	39	45

During the mass flowering of female flowers, a considerable difference in its passage was observed both from the mulching material and from the shape of the absorbent applied. Thus, earlier, plants covered with a black polyethylene film and black agrofibre entered this phase — respectively, for 27-31 days and 30-34 days from planting seedlings. When mulching with wood sawdust, the flowering of female flowers occurred 2-3 days later, compared to the variant without mulching. Notably, the use of different forms of absorbent within each mulching material contributed to the acceleration of this phase by an average of 1-4 days, compared to the variant without the use of absorbent. Among the forms of absorbent, this phase previously occurred in the gel variant.

The first cucumber fruits were formed on average 6 days after the mass flowering phase of female flowers. The first fruits began to arrive from the variant of mulching the soil with a black polyethylene film together with the introduction of an absorbent in the form of a gel — 33 days after planting seedlings, which is 12 days earlier than the control.

This acceleration in the passage of phenological phases of growth and development of cucumber plants under black polyethylene film and black agrofibre can be explained primarily by the higher soil temperature, which is confirmed by the data of other authors (Bucko

& Siwek, 2019). According to them, in the initial period of growth of cucumber plants, the soil temperature at a depth of 10 cm under a black film and black agrofibre was higher by 1.9°C and 0.5°C, respectively, compared to the variant without mulching.

Depending on the forms of absorbent and mulching materials, the duration of fruiting of cucumber plants varied. Thus, the longest fruiting period was upon mulching the soil with a polyethylene film using an absorbent in the form of a gel – 69 days, which is 11 days longer than the control variant (Fig. 1). Among the mulching variants, black film and black agrofibre contributed to prolonging the period of fruit formation of plants. Characterising the forms of the absorbent, within each mulching material, their use increased the duration of fruiting, which was due to a better supply of cucumber plants with moisture during the periods necessary. In the gel application variants, compared to pellets, the fruit formation period was 1-2 days longer.

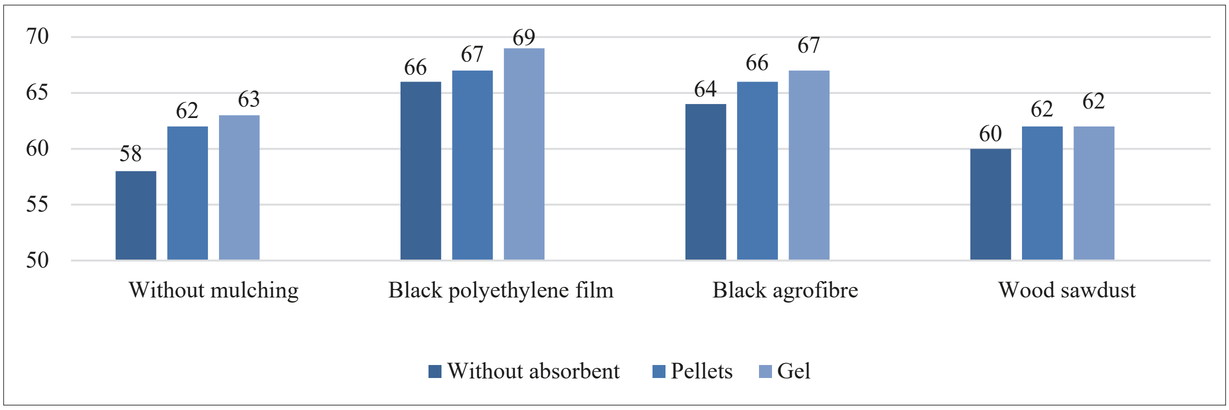

***Figure 1**. Duration of cucumber fruiting depending on the influence of various forms of absorbent and mulching materials, days (average for 2018-2021)*

Forms of absorbent and various mulching materials affected the value of biometric indicators of plants, which were determined during their mass fruiting. The highest height of the main stem was when mulching with a film using an absorbent in the form of a gel – 180.8 cm. In the same variant, the largest number of leaves and the area of their assimilation surface was formed – 36.4 pcs/plant and 4,290 cm^2/plant, respectively (Table 3). The worst indicators of plant biometrics were when mulching the soil with sawdust without an absorbent: the height of the main stem was 145.8 cm, the number of leaves – 21.9 pcs/ plant, leaf area – 2,490 cm^2/plant. Among mulching materials, the use of polyethylene film and agrofibre helped improve the biometric parameters of plants, while the use of sawdust, on the contrary, worsened them. Biometric indicators on average for four years of research increased under the influence of absorbent pellets by 3.7-8.3%, while the absorbent in the form of a gel contributed to their increase by 6.1-11.8%.

***Table 3**. Biometric indicators during mass fruiting of plants depending on the influence of various forms of absorbent and mulching materials (average for 2018-2021)*

Variant: Mulching material (factor A)	Variant: Absorbent form (factor B)	Height of the main stem, cm	Number of leaves, pcs/plant	Leaf area, cm^2/plant
Without mulching	Without absorbent (control)	156.9	25.3	3,390
	Pellets	164.1	27.4	3,610
	Gel	170.3	28.6	3,720
Black polyethylene film	Without absorbent	171.9	33.5	4,050
	Pellets	178.0	36.0	4,250
	Gel	180.8	36.4	4,290
Black agrofibre	Without absorbent	166.5	28.9	3,770
	Pellets	175.4	32.9	3,910
	Gel	178.3	33.8	4,140
Wood sawdust	Without absorbent	145.8	21.9	2,490
	Pellets	149.3	23.0	2,610
	Gel	151.8	23.7	2,680
HIP_{05}	A	5.4	1.4	149
	B	4.7	1.2	129
	A×B	9.3	2.5	258
	CV%	7.93	17.81	18.15

Other scientists also prove that the addition of hydrogel to the soil promotes the growth of plant habit, which is caused by an increase in the amount of available moisture in the area where the root system is located (Helalia & Letey, 1989). Hydrogels increase the efficiency of irrigation water, reduce soil density, and improve its drainage (Ekebafe *et al.*, 2011). All this certainly affects the improvement of biometric parameters of cucumber plants. Mulching, in turn, also affects the biometric parameters of plants. Studies have shown that black polyethylene film, compared with silver and transparent film, has a greater effect on improving the vegetative growth of cucumber plants (Hallidri, 2001). Other scientists have shown that under black plastic wrap, moisture evaporation is 81% lower compared to a site without mulch (Zribi *et al.*, 2015).

On average, over four years of research, the highest commercial yield was obtained for mulching the soil with a polyethylene film against the background of using an absorbent in the form of a gel – 53.2 t/ha, which is 8.8 t/ha more than production control (Table 4). The lowest commercial yield was for mulching with sawdust without an absorbent – 41.7 t/ha, which is 2.7 t/ha less than the control variant. Among the mulching materials, polyethylene film and agrofibre contributed to an increase in plant productivity, while sawdust reduced it. The absorbent considerably increased the commercial yield of plants, especially in the form of a gel. Thus, water-retaining pellets increased the commercial yield of plants by 4.1-8.1% relative to the variant without an absorbent, while gel – by 5.0-11.0%.

***Table 4**. Cucumber yield depends on the influence of various forms of absorbent and mulching materials, t/ha (average for 2018-2021)*

Variant				
Mulching material (factor A)	**Absorbent form (factor B)**	**Total yield**	**Commercial yield**	**Early harvest as of 07/20**
Without mulching	Without absorbent (control)	45.2	44.4	27.3
	Pellets	48.8	48.0	31.0
	Gel	50.1	49.3	32.2
Black polyethylene film	Without absorbent	54.6	54.1	31.7
	Pellets	56.9	56.6	34.2
	Gel	57.3	56.8	35.8
Black agrofibre	Without absorbent	49.9	49.2	30.5
	Pellets	52.6	52.0	33.9
	Gel	53.7	53.2	35.1
Wood sawdust	Without absorbent	42.5	41.7	20.5
	Pellets	44.1	43.4	21.9
	Gel	45.8	45.0	23.6
HIP_{05}	A	1.7	2.3	2.1
	B	1.5	2.0	1.8
	A×B	2.9	4.0	3.6
	CV%	10.35	11.17	18.86

The highest early harvest yield was obtained upon covering the soil with a black polyethylene film with an absorbent in the form of a gel – 35.8 t/ha, which prevailed over the control by 8.5 t/ha. Notably, film and agrofibre contributed to an increase in the size of the early harvest, while sawdust reduced the yield of the early harvest. Under the action of the absorbent, the early yield increased, to a greater extent from its use in the form of a gel.

Other scientists also prove the positive effect of black film on the productivity of cucumber plants. Thus, under black polyethylene film and black polypropylene film, commercial cucumber yields increased by 184.1% and 138.4%, respectively, compared to the variant without mulching (Siwek, 2002). The advantage of black film as a mulching material was also proved in hot climates (Mexico), where it increased the commercial yield of cucumber by 50%, early yield by 34.6% and total yield by 42.6%, compared to the variant without mulching (López-Tolentino *et al.*, 2016).

In terms of productivity, the greatest yield stability was in the variants of mulching the soil with agrofibre and polyethylene film without an absorbent – (K_{sf}=1.06-1.07). The lowest yield stability was achieved by mulching the soil with sawdust using an absorbent in the form of pellets (K_{sf}=1.21) (Fig. 2).

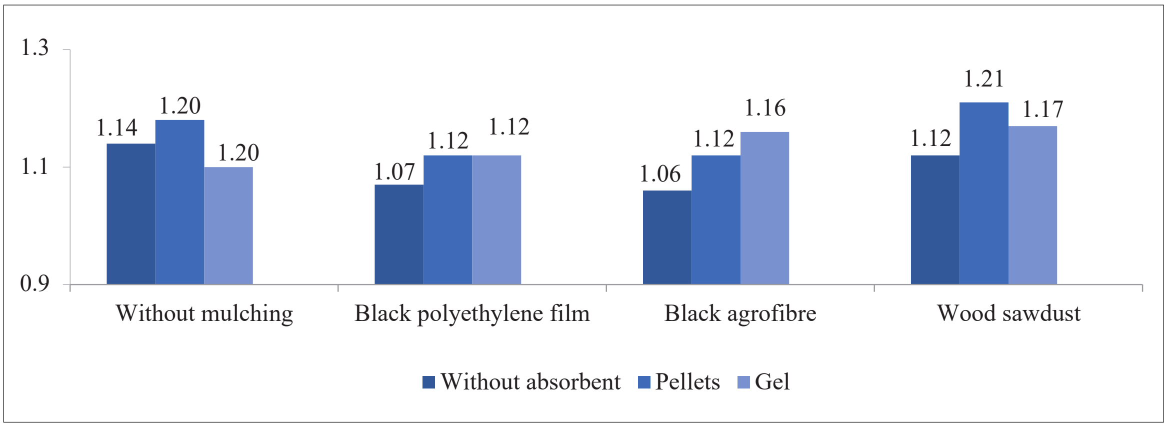

***Figure 2**. Levis stability factor (K_{sf}) by commercial cucumber yield depending on various forms of absorbent and mulching materials (average for 2018-2021)*

As a result of the conducted dispersion analysis of data, it was found that the value of commercial plant yield was most affected by factor A – mulching material – 73.0%, factor B – form of absorbent affected with a force of 8.0%. The interaction of both factors in the experiment determined the value of commercial yield by 1.0%. Other factors (plant disease, pest damage, mechanical injury to plants, yield losses, level of agricultural technology) accounted for 19.0% (Fig. 3).

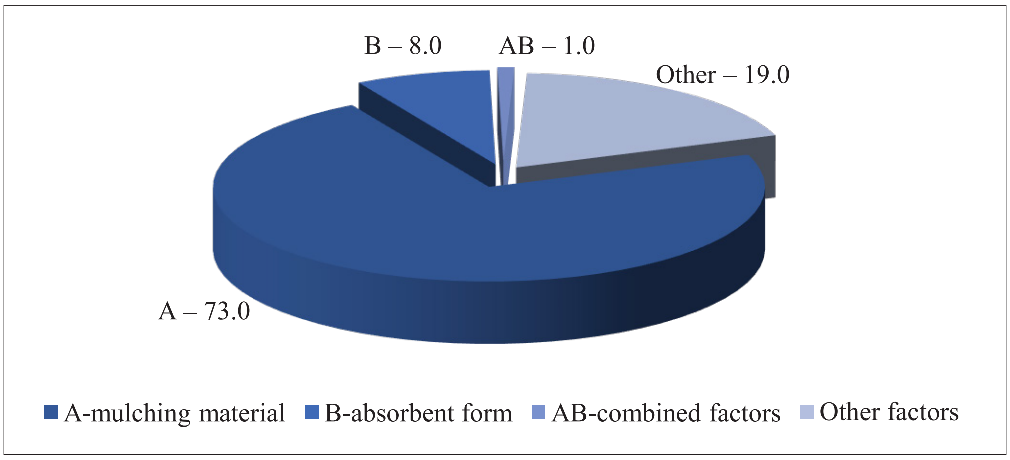

***Figure 3.** Strength of influence of factors on the value of commercial cucumber yield, % (average for 2018-2021)*

The correlation coefficients between different indicators in the experiment were calculated according to the method of correlation analysis. Strong direct correlations were established between the height of the main leaf and the number of leaves on the plant (r=0.97); between the height of the main stem and the area of the leaves (r=0.97); between the number of leaves on the plant and the area of their assimilation surface (r=0.95). The analysis also showed that the value of commercial yield has a strong direct dependence on the leaf area (r=0.93), the height of the main stem (r=0.96) and the number of leaves per plant (r=0.99) (Table 5).

***Table 5**. Matrix of correlations between indicators depending on different forms of absorbent and mulching materials (average for 2018-2021)*

Indicator	Height of the main stem, cm	Number of leaves, pcs/plant	Area leaves, cm^2/plant
Number of leaves, pcs/plant	0.97	–	–
Leaf area, cm^2/plant	0.97	0.95	–
Commercial yield, t/ha	0.96	0.99	0.93

All fruits collected in the experiment for each harvest were divided into standard and non-standard parts according to the DSTU requirements (DSTU 3247-95, 1995). Non-standard products included deformed fruits affected by diseases and damaged by soil pests. This also included underdeveloped and overgrown cucumber fruits.

The highest yield marketability was obtained by mulching the soil with a black polyethylene film using an absorbent in the form of a gel – 99.4%. It was the lowest in the variant of mulching with sawdust without an absorbent – 98.1% (Fig. 4).

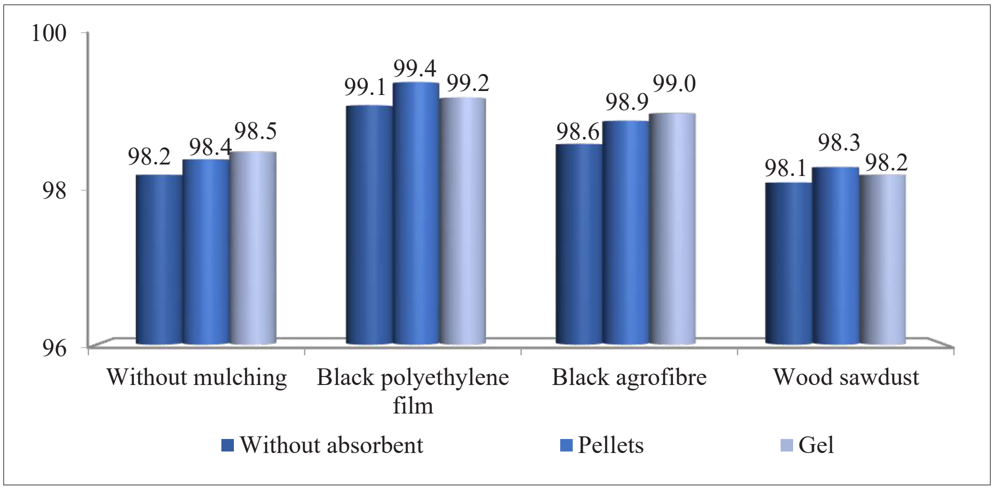

***Figure 4**. Yield marketability of cucumber depending on the influence of various forms of absorbent and mulching materials, % (average for 2018-2021)*

Analysis of marketability depending on mulching showed that the use of polyethylene film and agrofibre contributed to an increase in the yield of marketable products. When various forms of absorbent were added to the soil, the marketability of fruits also increased. In the variant without mulching and upon mulching the soil with black agrofibre, gel had a greater positive effect on marketability, and upon mulching with film and sawdust – water-retaining pellets. The use of various forms of absorbent increased marketability by an average of 0.1-0.4 percentage points, compared to the variant where the absorbent was not introduced. This was due to better moisture supply of plants during the growing season, as a result of which plants experienced less lack of water on hot and critical days, the functionality of the root system was better, and therefore plants formed less crooked and deformed fruits.

Depending on the effect of different forms of absorbent and mulching materials, some biochemical parameters of cucumber fruits changed. The highest dry matter content was due to mulching with a black film against the background of applying an absorbent in the form of pellets and gel – 5.3% each. The lowest amount of dry matter was contained in fruits from the sawdust mulching variant without an absorbent – 4.5% (Table 6).

***Table 6.** Chemical composition of cucumber fruits depending on the influence of various forms of absorbent and mulching materials (average for 2018-2021)*

Variant: Mulching material (factor A)	Variant: Absorbent form (factor B)	Dry matter, %	Sum of sugars, %	Nitrate level *(N-NO_3), mg/kg
Without mulching	Without absorbent (control)	4.8	2.02	79.0
	Pellets	4.9	2.06	82.0
	Gel	5.0	2.09	88.0
Black polyethylene film	Without absorbent	5.2	2.14	58.0
	Pellets	5.3	2.18	61.0
	Gel	5.3	2.20	63.0
Black agrofibre	Without absorbent	5.0	2.10	53.0
	Pellets	5.2	2.13	59.0
	Gel	5.2	2.15	62.0
Wood sawdust	Without absorbent	4.5	1.95	71.0
	Pellets	4.7	1.99	72.0
	Gel	4.7	2.01	74.0
HIP_{05}	A	0.14	0.05	2.1
	B	0.12	0.04	1.8
	A×B	0.24	0.08	3.6
	CV%	5.96	4.34	15.63

***Note**: * – MDR (no more than 150 mg/kg)*

The highest sugar content was observed when mulching with a film against the background of applying an absorbent in the form of a gel (2.20%). Notably, mulching with polyethylene film and black agrofibre increased the content of dry matter and the sum of sugars in the fruit. Mulching with sawdust reduced the dry matter content and sugar content compared to the variant without mulching. The use of an absorbent also helped improve the chemical composition of cucumber fruits, to a greater extent this applies to the gel. The improvement in the biochemical parameters of cucumber fruits is explained by the fact that mulching with black film and black agrofibre had a higher soil temperature, which considerably improves the absorption of nutrients by the root system, especially against the background of the use of an absorbent. Better absorption of nutrients has a direct impact on the growth and physiology of the root system, as well as the entire plant in general. When the soil temperature is lowered, the plant's moisture absorption decreases, which is caused by an increase in viscosity and a decrease in the level of water absorption by the plant, which adversely affects photosynthesis, and therefore all processes in the plant (Toselli *et al*., 1999). In addition, the use of hydrogel affects the improvement of chemical parameters of fruits, as it reduces the leaching of trace elements from the soil, increases the efficiency of water consumption (Dehkordi, 2017).

The nitrate content in the fruits of all variants of the experiment did not exceed MDR (no more than 150 mg/kg) and ranged from 53.0 mg/kg to 88.0 mg/kg. However, the reduction of nitrates in fruits was influenced by all mulching materials, especially black polyethylene film. When various forms of absorbent were added to the soil, the level of nitrates slightly increased. The lowest nitrate content was in the variant of mulching the soil with black agrofibre without an absorbent – 53.0 mg/kg, and the highest was in the variant without applying covering materials against the background of using an absorbent in the form of a gel – 88.0 mg/kg.

CONCLUSIONS

It was found that during mulching with a polyethylene film and the use of an absorbent in the form of a gel, the phenological phases of growth and development of cucumber plants occurred most rapidly. The longest fruiting period (69 days) was in the variant of mulching the soil with a film and applying an absorbent gel.

When mulching the soil and using various forms of absorbent, the biometric characteristics of cucumber plants were considerably improved. In particular, the introduction of gel into the soil against the background of its mulching with a black film increased the height of the main stem, the number of leaves on the plant and their area by 15.2%, 43.9%, and 26.5%, respectively, compared to the control.

The highest commercial yield was obtained by mulching the soil with a black film and applying an absorbent in the form of gel and pellets – 56.8 t/ha and 56.6 t/ha, respectively. In the same variants, the largest early harvest was obtained – 35.8 t/ha and 34.2 t/ha, respectively. According to the Levis stability coefficient (K_{sf}) the most stable yield was in the variants of mulching the soil with black agrofibre and black film without an absorbent – 1.06 and 1.07, respectively.

According to the method of dispersion analysis, it was found that among the two factors in the experiment, factor A – mulching material (73.0%) had a decisive influence, while factor B – the form of the absorbent determined the value of commercial yield with a force of 8.0%. Correlation analysis showed a strong direct correlation between commercial yield and the number of leaves per plant (r=0.99). Correlations of similar strength were also found between the height of the main stem (r=0.96) and the leaf area (r=0.93).

The use of black polyethylene film and black agrofibre as mulching materials contributed to an increase in the yield marketability. The introduction of various forms of absorbent using all mulching materials also improved marketability. The highest yield marketability was achieved by mulching with polyethylene film and applying an absorbent in the form of granules to the soil – 99.4%.

Mulching materials and various forms of absorbent affected the chemical properties of the fruit. The highest content of dry matter and the sum of sugars was upon coating the soil with a black film and the introduction of an absorbent in the form of a gel. The lowest nitrate content in cucumber fruits was upon mulching with black agrofibre without an absorbent.

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Вплив різних форм абсорбенту та мульчувальних матеріалів на урожайність шпалерного огірка та якість плодів в умовах лісостепу України

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Анотація. На фоні глобальної зміни клімату більша частина території України сьогодні є напівпосушливою, що викликає зниження ефективності галузі овочівництва. Через посушливість та високі температури влітку порушується нормальний ріст і розвиток рослин, зокрема, шпалерного огірка. Знижується і ефективність штучного зрошення через подорожчання прісної води та енергоносіїв для її подачі до рослин. Вирішити ці проблеми можуть ґрунтові абсорбенти та застосування мульчування. Метою досліджень було вивчення впливу різних форм ґрунтового абсорбенту на фоні застосування різноманітних мульчувальних матеріалів органічного та синтетичного походження на продуктивність шпалерного огірка. У процесі досліджень було використано польові, лабораторні, статистичні та розрахунково-аналітичні методи. Дослідженнями встановлено, що за мульчування ґрунту чорною поліетиленовою плівкою разом із внесенням ґрунтового абсорбенту у формі гелю, у рослин шпалерного огірка фенологічні фази росту і розвитку відбуваються найшвидше, а період плодоношення, порівняно з контролем, збільшується на 11 діб. Комбінація мульчування плівкою та абсорбенту-гелю дозволила збільшити на 15,2 % висоту головного стебла, на 43,9 % кількість листків на рослині та на 26,5 % площу листків, порівняно з контрольним варіантом. Визначено, що найбільшу товарну урожайність забезпечує мульчування ґрунту чорною плівкою разом з внесенням абсорбенту у формі гранул та гелю — 56,6—56,8 т/га, що на 27,5—27,9 % більше контролю. Товарність урожаю при цьому становила 99,2—99,4 %. Плоди огірка за мульчування плівкою та застосування абсорбенту у форму гелю мали високий вміст сухої речовини (5,3 %) та суми цукрів (2,20 %). Найнижчий рівень нітратів ($N\text{-}NO_3$) у плодах огірка забезпечило мульчування чорним агроволокном без застосування абсорбенту (53,0 мг/кг)

Ключові слова: гель, гранули, біометричні показники, продуктивність рослин, кореляційні зв'язки, товарність урожаю, хімічний склад плодів