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EVALUATION OF THE INFLUENCE OF ENCAPSULATED MINERAL FERTILIZERS ON PLANT GROWTH KINETICS

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Abstract. The work investigated the effect of encapsulated mineral fertilizers on the growth and development of plants for 45 days. As a mineral fertilizer, nitroammophoska was used, which was encapsulated by a shell of different compositions: sample KD1 – a mixture of polystyrene, lignin, and carbon; sample KD2 – a mixture of polystyrene, lignin, and zeolite. The bioindication method was used to determine the effect of encapsulated mineral fertilizers on plant growth kinetics. Based on the study's results, the average rate of germination of ryegrass in the experimental samples and the average rates of the main plant parameters (stem height, root length, plant weight) were determined. It was established that the highest rate of germination was in the sample with encapsulated mineral fertilizer KD1 — 100%, and the lowest in the sample GD – 85 %. The highest average indicators of measurement of the main parameters of ryegrass were in samples KD1 and KD2. The highest average indicators of measurement of the main parameters of ryegrass were in samples KD1 and KD2, and the lowest in the control sample (soil). It was established that on the 45th day, the mineral fertilizer in the KD1 sample was fully absorbed by the plants.

Keywords: encapsulated mineral fertilizer, bioindication, granular fertilizer, plant parameters, biological reclamation.

1. Introduction

Plowing of agricultural land, industrial activity, and other types of human economic activity (formation of landfills and solid waste landfills) negatively affects the state of the land and surrounding ecosystems. This problem is relevant for many countries, especially for Ukraine since thousands of hectares of land have also been negatively affected due to hostilities. To reduce the negative impact on the environment and restore the natural balance, it is necessary to use a set of measures that will restore vegetation cover and soil fertility. One of these complexes is land reclamation, namely the process of biological reclamation, which is carried out after the end of technical reclamation. According to (STC, 2005), the stage of biological reclamation lasts four years and covers such works as selection of perennial grass assortment, soil preparation, sowing, and plant care. One of the key aspects of successful reclamation is using fertilizers, which can provide plants with essential nutrients and improve soil quality (Nagursky; Malovanyy, 2016). This goal can be ensured using encapsulated mineral fertilizers, the rate of release of nutrients from which is adjustable (Synelnikov et al., 2020).

At the current stage of development of agrotechnical technologies, the problem of synthesis of mineral fertilizers, and the rate of release of nutrients from which would be regulated, is becoming more and more urgent. One of the ways to solve this

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problem can be the use of encapsulated fertilizers, since in this case the loss of soluble nutrients into the environment decreases, and the efficiency of their assimilation by plants increases. In addition, the duration of action of fertilizers increases, which is an important factor not only for agricultural technologies cultivation of crops but also technologies of biological reclamation. (Grechanik et al., 2022; Vakal et al, 2021). As it is known, most fertilizers are salts, which quickly dissolve in water during a period of large amounts of precipitation and have the property of migrating in the soil, so the root system assimilates only a part of fertilizers, of which: nitrogen compounds – 50–60 %, potassium – 50–60 %, phosphorous – 10–25 % (Hiraga et al., 2019). Atmospheric precipitation has the greatest impact on the leaching of fertilizers from the soil environment, as a result of which the concentration of nitrates in surface and underground waters increases. This leads to an increase in the process of eutrophication of water bodies. A promising method for solving this problem can be the coating of mineral fertilizer particles with capsules (encapsulated mineral fertilizers). In such fertilizers, the capsules that cover the fertilizer granules are permeable to aqueous solutions and water, thereby extending the period of release of nutrients necessary for plant growth and development into the soil environment (Nagursky, Gumnitsky, 2012). In the vast majority, the time of release is determined by the thickness and composition of the capsule. However, in the case when the capsules are impermeable, but capable of biodegradation in the soil environment, the content of the granule is released during this biodegradation. Therefore, for this option, the release of nutrients is not regulated by the intensity of dissolution of the mineral fertilizer granule, but by the beginning of the biodegradation of the capsule (Hiraga et al., 2019; Rusyn et al., 2020).

To increase the availability of encapsulated mineral fertilizers in the process of biological reclamation, the use of polymer waste and improvement of the technology of coating fertilizer granules can be a promising method (Synelnikov et al., 2020). Polymeric waste is used in many types of industrial activities, which leads to its accumulation in large quantities in solid household waste (MSW) landfills. Therefore, using them as a material for encapsulating fertilizers, on the one hand, will ensure a competitive price and wider use of encapsulated fertilizers. On the other hand, solves the problem of plastic waste disposal, since their uncontrolled accumulation creates an environmental hazard (Nagursky et al., 2022). Considering the above, the task of this study was to determine the effect of mineral fertilizers encapsulated with polystyrene on biological reclamation agroecosystems. In particular, the influence of fertilizers on the growth and development of plants (determination of mass, stem height, and root length) was investigated.

2. Materials and Methods

The research used mineral fertilizers encapsulated in polystyrene with improved solubility, which plays a crucial role in the process of creating a film-forming composition and applying a coating to mineral fertilizer granules.

The research was conducted using dark gray podzolized soil and various types of mineral fertilizer (nitroammophoska), which were carried out according to the scheme:

- soil – control (K);
- soil + granular fertilizer (GD);
- soil + encapsulated fertilizer (polystyrene + lignin + carbon) – KD1;
- soil + encapsulated fertilizer (polystyrene + lignin + zeolite) – KD2.

To determine the effect of mineral fertilizer on the growth and development of plants, the bioindication method was used (DSTU, 2004; DSTU, 2002). For this, 10 seeds of ryegrass (*Lolium perenne*) were planted in a 100 ml container filled with soil and mineral fertilizer. During the experiment, the time of emergence of sprouts, their number per day, total germination, and the length of the stem were measured. At the end, measure the length and mass of the root, and measure the height and mass of the stem. To reduce the statistical error during data processing, the experiments were carried out in fourfold repetition.

3. Results and Discussion

The results of bioindication, namely the determination of the average rate of germination of ryegrass, in experimental samples are presented in Table 1.

The results are given in the Table 1 show that the first sprouts of ryegrass appeared on the fourth day of the experiment, while the best average germination rate was observed in the control sample (soil), which was 65 %, and the lowest in the KD2 sample – 20 %. As for the GD and KD1 samples, the average was lower than the control sample by 38.5 and 11.5 %, respectively. However, already on the 8th day, the highest average rate of germination of ryegrass was in the control sample and the KD1 sample, which was 100 %. In contrast to the GD and KD2 samples, in which this indicator was lower by 17.5 and 32.5 %, respectively. On the 10th day, in the samples of GD and KD2, the average indicator was lower than the control by 15 and 12.5 %, respectively. In addition, starting from the tenth day of the experiment until its completion, the average germination rate remained constant in all samples and was: for control (K) and KD1 – 100 %, for GD – 85 %, for KD2 – 87.5 %.

Table 1

The average rate of germination of ryegrass in the studied samples, %

Variant	Days						
	4	6	8	10	20	30	45
K	65	97.5	100	100	100	100	100
GD	40	82.5	82.5	85	85	85	85
KD1	57.5	95	100	100	100	100	100
KD2	20	50	67.5	87.5	87.5	87.5	87.5

Fig. 1 shows the general appearance of plants on the 10th and 45th day of the experiment.

As can be seen from Fig. 1, on the 10th and 45th day of the experiment, ryegrass stalks were larger and more branched in the control sample and the KD1 sample. This indicates that the nutrients contained in the encapsulated mineral fertilizer were released gradually, feeding them to the plant as needed.

Therefore, based on the results of determining the average germination rate, it can be concluded that the use of KD1 and KD2 mineral fertilizers has a positive effect on the germination of ryegrass, in contrast to the use of ordinary granular fertilizer.

To determine the effect of encapsulated mineral fertilizers on the growth of ryegrass during the experiment, the height of the ryegrass stem was measured, the results of which are presented in Table 2 and Fig. 2.

As can be seen from the Table 2, on the 10th day, the highest indicator was observed in the control sample and was 8.92 cm, and the lowest in the sample with encapsulated fertilizer (KD2) – 8.08 cm. On the 30th day, the highest indicator was already observed in the sample with granular fertilizer (GD) – 23.04 cm, the lowest in the sample KD2 – 19.58 cm.

Fig. 2 shows how the average stem height in the test samples changed every 5 days. Growth parameters of ryegrass on the 10th day are taken as 100 %.

On the 15th day, the average stem height changed the most in sample KD2 (Fig. 2, *d*), which increased by 27.84 %, the lowest indicator was in sample KD1 (Fig. 2(c)) – 17.79 %. If we compare these data with the control sample, the KD2 sample exceeded it by 6.81 %, and the KD1 sample, in turn, was smaller than the control by 3.24 %. On the 20th day, as in the previous case, compared to the 10th day, the average indicator changed the most in the KD2 sample – by 51.59 % for the control, this indicator changed the least by only 14.48 %. On the 30th day, a sharp increase in the average stem height was observed in all samples. For example, in the KD2 sample, it increased by 136.72 % compared to the 20th day, in the GD sample by 102.42 %, in the sample KD1 – by 122.65 %, and in the control sample (K) – by 87.22 %. If we compare these data with the control sample (30th day), the KD2 sample was higher by 49.5 %, the GD sample by 15.2 %, and the KD1 sample by 35.43 %.

Thus, the samples KD1 and KD2 had the best effect on the change in the average indicator of the height of the ryegrass stem during the experiment.

Table 3 presents the average measurements of the main parameters of ryegrass in the experimental samples at the end of the experiment (45th day).

According to the results given in the Table 3 shows graphs of changes in the average indicators of the main parameters of ryegrass in experimental samples (Figs. 3, 4). Ryegrass growth parameters in the control sample (soil) are taken as 100 %.

The obtained results show that the highest average value of stem height was in sample KD2 and exceeded the control sample by 6.54 %. In the samples of GD and KD1, as can be seen in Fig. 3, *a*, the mean was also higher than the control by 2.03 % and 4.34 %, respectively.

As for the roots, the highest indicator was observed in sample KD1, which exceeded the control (K) by only 1.59 %, in sample KD2 the average indicator exceeded the control by 1.22 %. In the sample with granular fertilizer, as in the previous cases, the average indicator was also higher than the control and was 0.73 %.

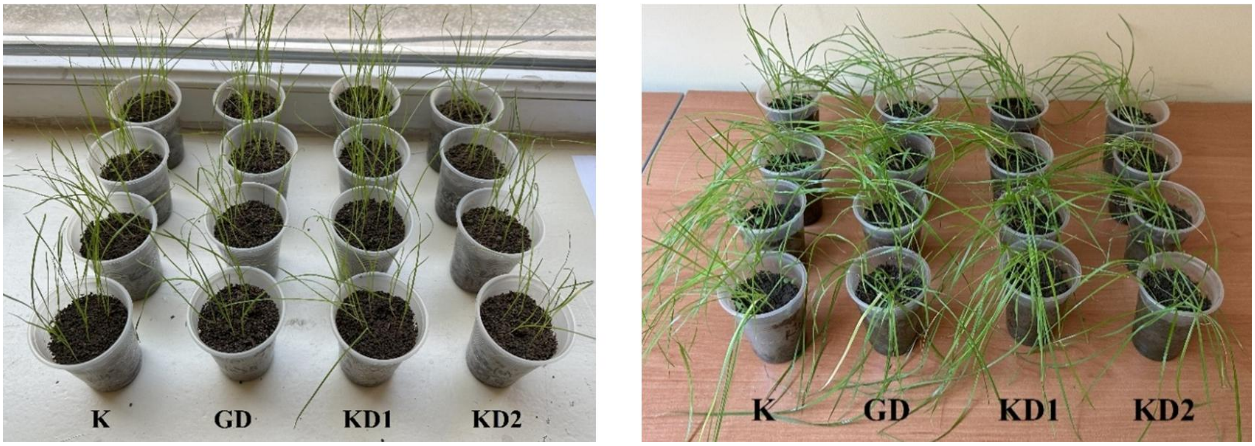


Fig. 1. General appearance of plants in the studied samples on the 10th and 45th day

Table 2

The change in the length of the ryegrass stem in the studied samples during the experiment, cm

Days	Variant			
	K	GD	KD1	KD2
10th	8.92	8.63	8.67	8.08
15th	10.79	10.88	10.21	10.33
20th	12.08	14.21	14.5	14.46
30th	21.13	23.04	25.13	25.51

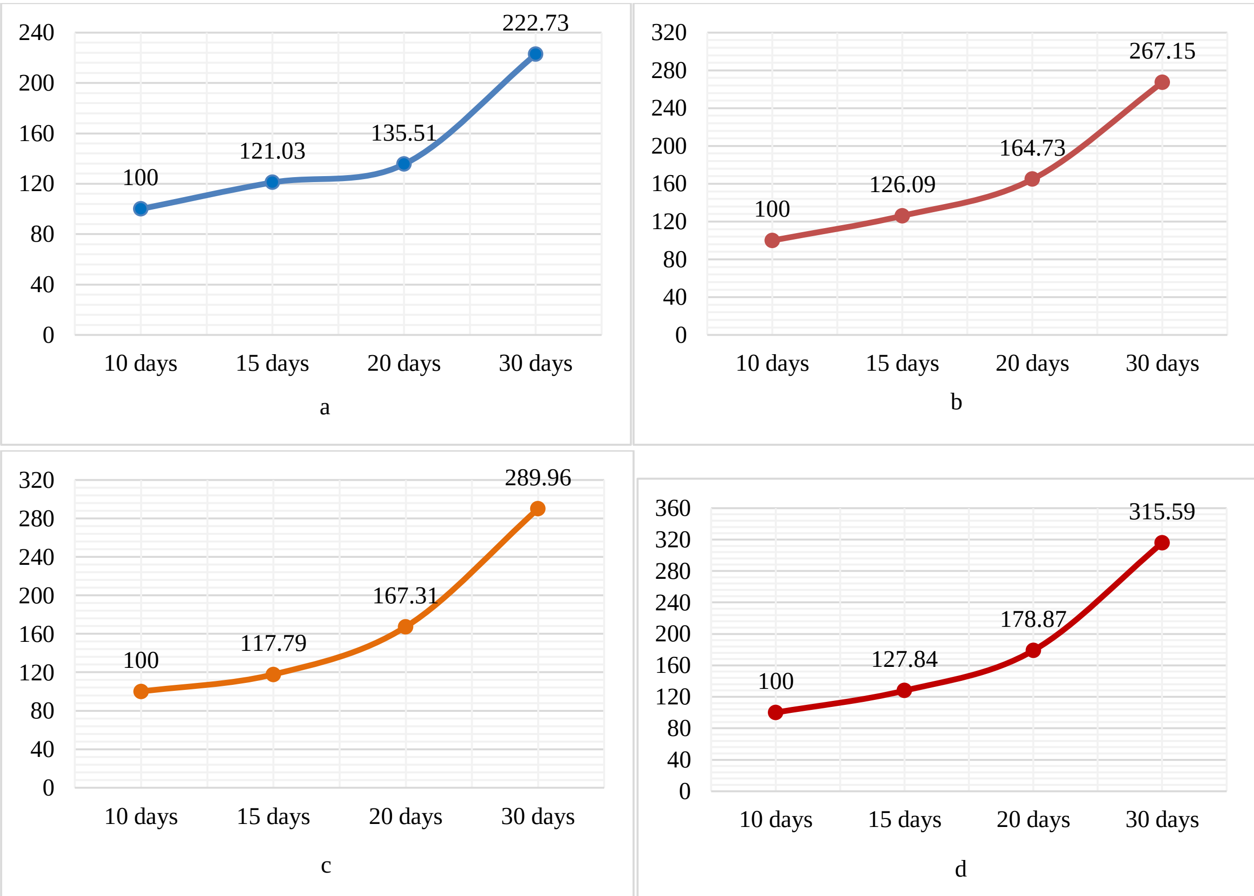


Fig. 2. Change in the average ryegrass stem height in the studied samples during the experiment, %:
a – control (K); b – GD; c – KD1; d – KD2

Table 3

Average indicators of measurement of the main parameters of ryegrass development in experimental samples

Variant	Average stem height, cm	Average root length, cm	The average weight of the plant, g	The average mass of the stem, g	Average root mass, g
K	24.63	8.19	0.516	0.45	0.066
GD	25.13	8.25	0.771	0.643	0.127
KD1	25.70	8.32	0.809	0.696	0.133
KD2	26.24	8.29	0.780	0.634	0.145

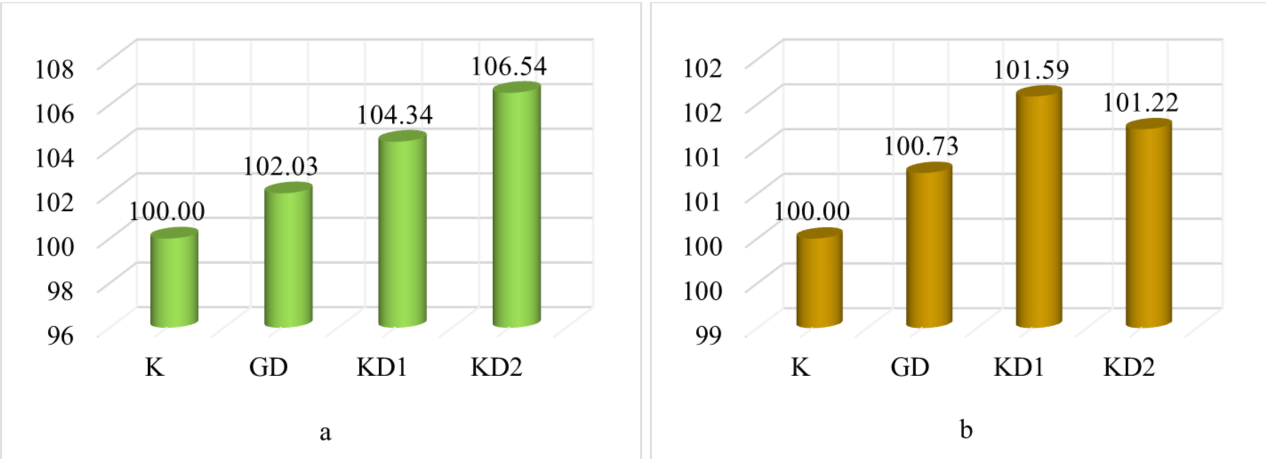


Fig. 3. Changes in growth indicators of ryegrass in experimental samples: a – stem; b – root

As can be seen, in both cases, the change in the average rate of plant stem and root growth was greater in samples with fertilizers compared to the control The average stem weight (Fig. 4, *a*) in all samples with mineral fertilizer content was higher sample, which indicates the gradual saturation of plants with substances necessary for their growth and development.

Fig. 4 shows the change in the mass of the main plant parameters.

than the control. Thus, in the sample KD1, t he average indicator was higher than the control by 54.67 %, in the sample KD2 – by 40.89 %, and in the sample GD – by 42.89 %.

As in the previous case, the average value of root mass (Fig. 4, *b*) was also greater than the control sample in all variants. At the same time, the highest indicator was in the KD2 sample, which was higher than the control by 119.69 %, in the KD1 sample – by 101.51 %, in the GD sample – by 92.42 %. As you can see, when mineral fertilizers were used, the average root weight in some samples exceeded the control by more than two times.

As for the average indicator of the mass of ryegrass plants (Fig. 4, *c*), the highest indicators were in samples KD1 and KD2 and were higher than the control by 56.78 % and 51.16 %, respectively. In the sample with granular fertilizer (GD), this indicator was also higher than the control – by 49.41 %. However, if we compare it with KD1 and KD2, it was smaller by 7.36 % and 1.74 %, respectively.

Thus, in all three cases, sample KD1 had a positive effect on plant development. As for sample KD2, it had the best effect on the root mass of ryegrass plants.

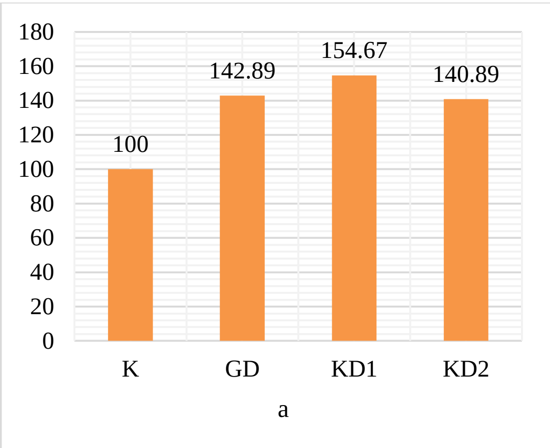
Fig. 5 shows the appearance of the mineral fertilizer capsule in samples KD1 and KD2 on the 45th day of the experiment. As can be seen, plants absorbed nutrients from the encapsulated KD1 mineral fertilizer on the 45th day in full, as proven by the measurements of the main plant parameters, and the capsule began to decompose.

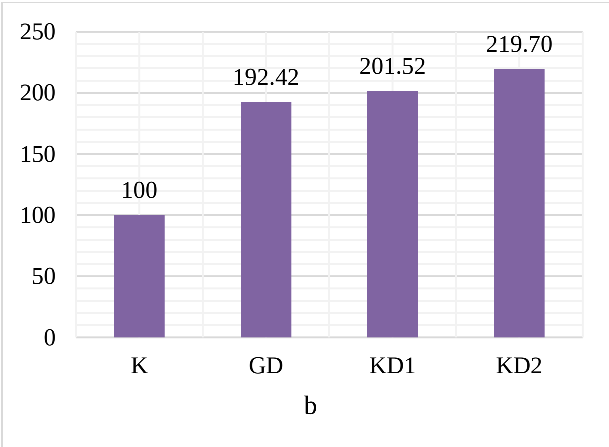
As for sample KD2, on the 45th day, there was still a significant amount of fertilizer in the capsule, i.e., the plants had not yet received all the nutrients, and the capsule itself was beginning to break down.

4. Conclusions

Therefore, the obtained results of the conducted research indicate that the use of encapsulated mineral fertilizers has a positive effect on the growth and development of plants. Thus, the highest average rate of germination was in sample KD1 – 100 %, and the average indicators of the main plant parameters exceeded the control by 54.67 % – when determining the weight of the stem, by 56.78 % – the weight of plants, by 1.59 % – the height of the stem, by 101.52 % – root mass. Sample KD2, in turn, exceeded the control in terms of such parameters as average root weight (by 119.69 %) and average stem height (by 6.54 %). Also, according to the results of the research, it was established that on the 45th day of the experiment in sample KD1, the mineral fertilizer was fully released from the capsule, and the capsule itself began to decompose.

Thus, the use of encapsulated mineral fertilizers for biological reclamation can reduce the loss of soluble plant nutrients in the environment. It can also increase the efficiency of their absorption by plants, increase the duration of the fertilizers, and reduce the number of operations for their application. In addition, the use of biodegradable polystyrene in the process of encapsulating fertilizers can solve the problem of its accumulation in landfills.





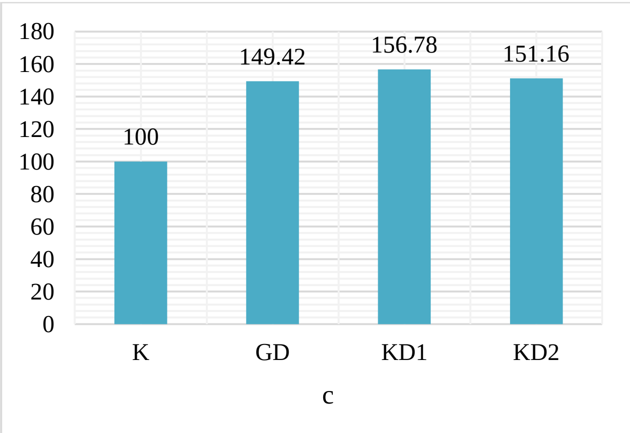


Fig. 4. Change in the weight of the main plant parameters in the experimental samples: a – average weight of the stem; b – average mass of the root; c – average weight of the plant

Fig. 5. Appearance of a mineral fertilizer capsule on the 45th day: a – KD2, b – KD1

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