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Features of growing garden strawberries in open ground conditions

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Abstract. The purpose of this study was to evaluate the effectiveness of strawberry cultivation in the use of PH regulators, synthetic and organic fertilisers, mulching practices, and the use of fungicides, insecticides, and herbicides. The pH of the soil was regulated by applying aluminium sulphate and limestone in the amount of 200 and 900 g per three square metres, respectively. Synthetic preparations with different macro- and microelements, as well as organic compost, were used to test the effect of fertilisers. The growth characteristics of the growing season, including flowering and fruiting indicators, were evaluated. The results showed that a decrease in soil pH has a positive effect on the efficiency of growing the plants under study. The use of

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fertilisers with a high potassium content increased the growth rate of the growing season, and preparations rich in phosphorus had a positive effect on the characteristics of the flowering period. The use of compost provided an increase in the productivity of strawberries, comparable to the use of synthetic fertilisers. Mulching has been shown to reduce the risk of fungal infections in plants and to increase growth indicators. The use of the herbicide was significantly effective in suppressing the growth of pest plants and improving the growth characteristics of strawberries. It was shown that the use of organic farming methods and reduced concentrations of herbicides and insecticides allows achieving high efficiency of strawberry cultivation

Keywords: growth characteristics; organic farming; synthetic fertilisers; mulching; fruit and berry crops

INTRODUCTION

Garden strawberries are an important crop for many farms, providing a significant source of income for them. It is of particular importance for small entrepreneurs who can cultivate strawberries on a smaller plot of land and at the same time earn a high income. This plant is relatively easy to grow and is suitable for cultivation in various conditions, which makes it a universal crop. Garden strawberries are grown in the open ground or in greenhouses, for which both conventional and organic farming methods are used. Strawberries have a short growing season, which means that farms can harvest multiple crops in one year. This makes this plant attractive for entrepreneurs who are interested in getting maximum profit. Strawberries are also an important crop for the local economy, as they are suitable for sale directly to consumers. This helps support small and medium-sized businesses and creates jobs in the community.

Strawberries are widely used in the food industry to make a variety of products, including jams, jellies, syrups, and pastries. Berries are usually consumed fresh, or frozen, used for preservation, as well as dried and used in the manufacture of ready-to-eat foods. Strawberry flavourings are a popular addition to dairy products such as ice cream, yoghurts, and milkshakes. This plant is of high importance for environmental protection, as it is suitable for use in sustainable farming practices (Romero-Gámez & Suárez-Rey, 2020). In the case of using natural methods of pest and infection control, as well as using cover crops and crop rotation to maintain soil health, farms are able to reduce their negative impact on the environment.

Garden strawberries grow in most soil types, but A. Van Bruggen *et al*. (2016) point out that too sandy soil can lead to drought problems, and heavy clay soils with poor drainage can cause diseases such as late blight. Strawberries grow best in fertile soils with a high content of organic substances. They should be well drained, but at the same time able to retain a constant amount of moisture. According to E.P. Bugawisan (2022), a slightly acidic soil pH is optimal for strawberries.

Fertilisers can be a significant benefit for growing strawberries, as they provide plants with the nutrients they need for growth and fruiting. S. Farjana *et al*. (2023) report that strawberries require balanced fertilisers that contain nitrogen, phosphorus, potassium, and trace elements such as iron, magnesium, and manganese. Organic fertilisers such as compost, manure, or fish emulsion are also used to provide the soil with nutrients. These types of fertilisers are often preferred by organic producers because they are less likely to cause environmental problems and can contribute to soil health over time. However, it is important to use fertilisers correctly and in the right amount, as excessive use of them can lead to environmental problems and even harm the plants themselves. G. Costamagna *et al*. (2020) have shown that too much fertiliser can lead to excessive vegetative growth and impair fruit quality and increase the risk of disease. In addition, excess fertilisers can be washed out into ground water or nearby water bodies, which also leads to environmental problems.

The use of herbicides and insecticides for growing strawberries is a subject of discussion among producers and agricultural experts. A. Monteiro and S. Santos (2022) report that while such compounds can be effective in controlling weeds and pests, they can also have a negative impact on the environment and human health if not used properly. Organic producers can resort to alternative pest and disease control methods, which include crop rotation, the use of sustainable varieties, and practices such as pruning and mulching. These methods can be effective in reducing the pressure of pests and diseases without the use of synthetic chemicals.

The purpose of this study was to evaluate the influence of factors such as soil pH, the use of synthetic and organic fertilisers, various concentrations of herbicides, fungicides, and insecticides, and mulching practices on the growth characteristics of various varieties of garden strawberries.

MATERIALS AND METHODS

The study considers seeds of garden strawberries of the varieties "Regina", "Ruegen", "Alexandria", and "Baron Von Solemacher" of the SeedEra company, Ukraine. The seeds were sown in early spring in closed ground conditions. Before sowing, the seeds were treated with a 1% potassium permanganate solution to protect against infections. Seedlings were grown at 25°C in natural light. After eight weeks, the plants were transferred to the open ground. Strawberry bushes were planted on plots of three square metres at a distance of 30 cm

from each other. Irrigation was carried out once a week, the volume of water for irrigation was 40 litres per plot.

To test the effect of the soil pH indicator on the efficiency of growing garden strawberries, experimental plots were treated with solutions of aluminium sulphate and limestone. Aluminium sulphate was used in the amount of 200 g per site, and limestone materials in the amount of 900 g in terms of CaO per site. A manual pH meter model AZ-8694 (AZ-Instruments, Taiwan) was used to determine the pH. The results obtained were compared with soil that was not treated with chemicals, the pH value of which was 6.5.

Fertilisers of the Verde line by Yochem, Ukraine, were used for testing fertilisers. The effectiveness of using VerdeGrow, VerdeBloom, and VerdeMicro separately, a complex of all three preparations, and the effectiveness of using compost and growing garden strawberries without using fertilisers, was evaluated. VerdeGrow is designed to improve the growth and development of young plants and contains 2% by weight of nitrogen in the form of NO_3 and NH_4^+, 1% phosphorus in the form of P_2O_5, and 6% potassium in the form of K_2O. These macronutrients are most important for balanced plant development. Verdebloom fertiliser is designed to nourish the plant during flowering and fruiting and contains 8% phosphorus in the form of P_2O_5 and 4% potassium in the form of K_2O. VerdeMicro fertiliser is designed to provide plants with the necessary trace elements and contains 5% nitrogen in the form of NO_3 and NH_4^+, 3% potassium in the form of K_2O, and 5% calcium, 0.01% boron, 0.0005% cobalt, 0.01% copper, 0.1% iron, 0.05% manganese, 0.0008% molybdenum, and 0.015% zinc. The number of millilitres of fertiliser concentrate per 40 litres of irrigation water is shown in Table 1.

***Table 1**. Use of fertilisers, ml of concentrate per 40 l of irrigation water*

	Week 1-6	Week 7-14	Week 15-21	Week 22-25
VerdeGrow	8	16	12	4
VerdeMicro	8	12	12	12
VerdeBloom	8	4	12	16

***Source:** developed by the authors*

Trichodermin (Enzim Agro, Ukraine) was used to test the fungicide. The effectiveness of the drug was evaluated when it was applied in the amount of 1, 0.5, and 0.25 ml per site. Abamectin (Syngenta, Switzerland) was used to test the insecticide. The effectiveness of the substance was evaluated when it was applied in the amount of 6, 3, and 1 mg per site. Fluazifop-p-butyl (Syngenta, Switzerland) was used to test the herbicide. The effectiveness of the substance was evaluated when it was applied in the amount of 90, 60, and 30 mg per site. The results were compared with the growth characteristics of strawberry plants without the use of synthetic chemicals when using mulching methods and without it.

To determine the effectiveness of growing plants for each site, such indicators as the average number of whiskers after two weeks of growth, the average number of trifoliate leaves at the time of the first flowering, the number of days before the appearance of the first visible flower buds, the number of days before the ripening of the first berries, the number of flowers on the site for the entire flowering period, and the total weight of fruits from the site were evaluated. To assess the effectiveness of the fungicide and mulching practices, the number of plants affected by diseases was also evaluated. All experiments were performed in three repetitions. The tables show average statistically reliable data.

RESULTS

The application of aluminium sulphate allowed reducing the pH of the soil to an average value of 5.2. When using limestone materials, this indicator increased to 7.1. Data on the influence of soil pH on the growth characteristics of garden strawberry plants of various varieties are shown in Table 2.

The pH value of the soil did not significantly affect the number of whiskers formed by strawberry plants after two weeks of cultivation in open-ground conditions. It is worth noting, however, that for most of the varieties, this characteristic was somewhat less when using limestone materials. Acidification of the soil had a positive effect on the number of triple leaves at the time of the first flowering for the varieties "Regina", "Ruegen", and "Alexandria". An increase in the soil pH value reduced this indicator for the varieties "Ruegen" and "Baron Von Solemacher".

***Table 2**. Influence of the soil pH value on the growth characteristics of garden strawberry plants*

	Variety	Number of whiskers per plant	Number of trifoliate leaves per plant	Days before flowering	Days before the first fruits ripen	Number of flowers from the plot	Fruit weight per plot (g)
pH 6.5	Regina	2.8	5	28.3	62.7	130.3	2.645
	Ruegen	2.7	5.6	30.3	58.7	155.7	2.976
	Alexandria	2.4	4.5	25	53.3	112	2.765

Table 2, Continued

	Variety	Number of whiskers per plant	Number of trifoliate leaves per plant	Days before flowering	Days before the first fruits ripen	Number of flowers from the plot	Fruit weight per plot (g)
pH 6.5	Baron Von Solemacher	3.1	6.1	34	65	137.3	2.988
pH 5.2	Regina	2.7	6.2	26.3	63	158.3	2.875
	Ruegen	2.7	7.1	32	57.7	186.7	3.144
	Alexandria	2.5	5.6	24.7	56.3	147.3	3.072
	Baron Von Solemacher	3	6	32.3	68.3	165.3	3.256
pH 7.1	Regina	2.8	4.9	30.7	59	122.7	2.561
	Ruegen	2.8	3.2	29	62.3	143.7	2.875
	Alexandria	2.2	4.6	26.7	57.7	105.3	2.634
	Baron Von Solemacher	2.9	4.5	37.3	66	129.7	2.899

Source: *developed by the authors*

For plants of the "Regina" and "Alexandria" varieties, the introduction of limestone materials did not significantly affect this growth characteristic. There was also no significant effect of the soil pH value on the number of days before the appearance of the first visible flower buds and the ripening of the first fruits. However, this indicator had a significant impact on the number of flowers on the site for the entire flowering period for all the studied varieties of garden strawberries. It was shown that the number of flowers was on average 20% higher when using aluminium sulphate compared to the control variant. For the strawberry variety "Alexandria", this indicator was 130% of the results from the site that was not treated with pH regulators. The number of flowers in the areas treated with limestone materials was slightly lower than the control areas for all the studied varieties of garden strawberries. The total weight of fruits from the site directly correlated with the number of flowers and inversely with the pH value of the soil. The use of aluminium sulphate in the studied concentration demonstrated the greatest effectiveness for growing strawberry plants. The results show that the optimal soil pH for strawberries is shifted to a more acidic side, which can theoretically be explained by the greater bioavailability of nutrients.

The use of fertilisers had a significant impact on the growth characteristics of garden strawberries. Data on the effect of fertilisers and compost on the growth characteristics of strawberry plants of different varieties are shown in Table 3.

Table 3*. Influence of fertilisers and compost on the growth characteristics of garden strawberry plants*

	Variety	Number of whiskers per plant	Number of trifoliate leaves per plant	Days before flowering	Days before the first fruits ripen	Number of flowers from the plot	Fruit weight per plot (g)
N	Regina	2.8	5	28.3	62.7	130.3	2.645
	Ruegen	2.7	5.6	30.3	58.7	155.7	2.976
	Alexandria	2.4	4.5	25	53.3	112	2.765
	Baron Von Solemacher	3.1	6.1	34	65	137.3	2.988
VG	Regina	4.5	6.9	25.3	60.3	139.3	2.756
	Ruegen	3.9	8.7	27.3	57	162.7	3.051
	Alexandria	5	7.1	22.3	54.7	121.3	2.890
	Baron Von Solemacher	6.3	9.2	31.3	62.7	145.7	3.076
VB	Regina	2.9	4.8	24.7	59.7	172.3	2.831
	Ruegen	2.6	5.9	25.3	54	201.3	3.144
	Alexandria	2.6	5.1	21	60.3	156.7	2.917
	Baron Von Solemacher	3.3	6.7	29.7	61	178	3.114
VM	Regina	3.4	5.7	24.3	61	154.7	2.813
	Ruegen	3.8	6.2	29	55.7	176	3.077

Table 3, Continued

	Variety	Number of whiskers per plant	Number of trifoliate leaves per plant	Days before flowering	Days before the first fruits ripen	Number of flowers from the plot	Fruit weight per plot (g)
	Alexandria	3.3	4.9	23.7	51.7	134.3	2.987
	Baron Von Solemacher	4	7.1	33.3	64	142	3.054
VA	Regina	3.9	6.8	23.3	57.3	149.7	2.915
	Ruegen	3.7	7.2	24.7	56.3	188.7	3.354
	Alexandria	4.4	6.7	19.3	58	128.3	3.267
	Baron Von Solemacher	4.8	7.1	30	59.7	152	3.162
C	Regina	3.6	7.5	26.3	60	157.3	2.789
	Ruegen	4.1	7.8	27.3	56.7	172.3	3.073
	Alexandria	3.9	7.3	22.7	49.7	139.7	2.890
	Baron Von Solemacher	3.8	7.8	31	63	146.3	3.183

Note: *N – control areas, VG – VerdeGrow, VB – VerdeBloom, VM – VerdeMicro, VA – complex of all three synthetic fertilisers, C – compost*
Source: *developed by the authors*

The greatest positive effect on the number of whiskers formed by plants after two weeks of cultivation and the number of triple leaves at the time of the first flowering was demonstrated by VerdeGrow. The reason for this effect is probably an increased potassium content. The largest indicators of these growth characteristics were possessed by plants of the "Ruegen" variety. It is worth noting that all the tested fertilisers had a positive effect on the growing season of garden strawberries. The use of compost proved to be quite effective and showed results comparable to those in areas where VerdeMicro and VerdeBloom preparations were used. The use of both organic and synthetic fertilisers reduced the number of days before the first visible flower buds appear, as well as the duration of ripening of the first fruits. The most effective preparation was VerdeBloom, which may be conditioned by the high phosphorus content in this fertiliser. The best indicators were shown by the varieties "Regina" and "Alexandria", the effect on plants of the varieties "Ruegen" and "Baron Von Solemacher" was slightly lower.

The use of VerdeBloom, and a complex of all three fertilisers, significantly increased the number of flowers on the site for the entire flowering period. The use of compost also had a positive effect on this characteristic. The largest number of flowers was formed by strawberry plants of the "Ruegen" variety when using VerdeBloom. There was a significant increase in the total weight of fruits from the site when using organic and synthetic fertilisers. The highest productivity was demonstrated by plants of the varieties "Ruegen" and "Alexandria" in combination with all three fertilisers of the Verde line, which indicates the importance of a balanced content of all micro- and macronutrients. Data on the effect of the fungicide and mulching practice on the incidence of strawberry plant disease are shown in Table 4.

Table 4*. Effect of trichodermin and mulching practices on the incidence of garden strawberry diseases*

	Variety	Number of affected plants per site			
		Powdery mildew	Septoria	Brown spotting	Grey rot
Control plots	Regina	0	1.3	1.7	0
	Ruegen	0	0	0.3	0
	Alexandria	0	1	0	2.3
	Baron Von Solemacher	0	2	1.3	2.7
Trichodermin, 1 ml	Regina	0	0	0	0
	Ruegen	0	0	0	0
	Alexandria	0	0	0	0
	Baron Von Solemacher	0	0	0	0
Trichodermin, 0.5 ml	Regina	0	0	0.3	0
	Ruegen	0	0	0	0
	Alexandria	0	0	0	0
	Baron Von Solemacher	0	0	0	0.7

Table 4, Continued

	Variety	Number of affected plants per site			
		Powdery mildew	Septoria	Brown spotting	Grey rot
Trichodermin, 0.25 ml	Regina	0	0	0.3	0
	Ruegen	0	0	0	0
	Alexandria	0	0	0	1.3
	Baron Von Solemacher	0	1	0	2
Mulching	Regina	0	0.7	0	0
	Ruegen	0	0	0	0
	Alexandria	0	0.3	0	0.7
	Baron Von Solemacher	0	1.3	0.3	2.7

Source: *developed by the authors*

The most vulnerable to diseases were plants of the "Baron Von Solemacher" variety. The use of a fungicide in amounts of 1, 0.5, and 0.25 ml per site significantly reduced the frequency of infection of garden strawberry plants with diseases such as septoria, brown spotting, and grey rot. The use of mulching practices has also demonstrated significant effectiveness in controlling these fungal infections, although slightly less compared to fungicide. However, in the case of plants of the "Baron Von Solemacher" strawberry variety, mulching and using a fungicide in the amount of 0.25 ml per site did not demonstrate effectiveness in combating fungal diseases due to the high sensitivity of this variety. Data on the effect of the fungicide and mulching practice on the growth characteristics of garden strawberry plants of various varieties are shown in Table 5.

Table 5*. Effect of trichodermin and mulching practices on the growth characteristics of garden strawberry plants*

	Variety	Number of whiskers per plant	Number of trifoliate leaves per plant	Days before flowering	Days before the first fruits ripen	Number of flowers from the plot	Fruit weight per plot (g)
N	Regina	2.8	5	28.3	62.7	130.3	2.645
	Ruegen	2.7	5.6	30.3	58.7	155.7	2.976
	Alexandria	2.4	4.5	25	53.3	112	2.765
	Baron Von Solemacher	3.1	6.1	34	65	137.3	2.988
1T	Regina	3	6.8	26	61	156.7	2.867
	Ruegen	2.5	5.9	32	60	161.3	3.001
	Alexandria	2.8	6.2	23	51	135.3	2.987
	Baron Von Solemacher	3.3	6.6	35	63	166	3.127
0.5T	Regina	2.9	5.7	27	64	155.7	2.976
	Ruegen	2.8	5.6	31	62	151.3	3.016
	Alexandria	2.8	6.4	22	54	139.7	3.056
	Baron Von Solemacher	3.2	6.3	32	67	158.7	3.218
0.25T	Regina	2.9	6.1	27	61	135.7	2.645
	Ruegen	2.6	5.8	32	60	149.7	2.899
	Alexandria	2.7	4.6	24	55	108.3	2.765
	Baron Von Solemacher	3.6	6.9	31	64	143.7	2.988
M	Regina	3.1	5.7	27.7	63.3	129.7	2.901
	Ruegen	3	7.8	29	57.3	157.3	3.140
	Alexandria	2.8	5.5	24	53.7	123.3	2.907
	Baron Von Solemacher	3.6	7.2	33.7	64	129.7	3.177

Note: *N – control areas, 1T – 1 ml of trichodermin, 0.5T – 0.5 ml of trichodermin, 0.25T – 0.25 ml of trichodermin, M – mulching*
Source: *developed by the authors*

The positive antifungal effect allowed achieving slightly higher indicators of such vegetation characteristics as the number of whiskers that plants formed after two weeks of cultivation and the number of trifoliate leaves at the time of the first flowering. It is worth noting that the use of mulching practice led to an increase in these growth characteristics for the Ruegen variety, even though the plants of this strawberry variety were practically not affected by fungal infections in the control areas. A similar effect was not reproduced with the use of the fungicide. This indicates the existence of additional positive effects of mulching, in addition to direct infection control. The growth indicators of plants of the "Ruegen" variety in the control areas and areas that were treated with a fungicide did not differ significantly. The use of a fungicide and mulching practice did not significantly affect such indicators as the number of days before the appearance of the first flower buds and the duration of ripening of the first fruits. At the same time, the use of a fungicide in the amounts of 1 and 0.5 ml per site significantly increased the number of flowers for the entire growing season and the total weight of fruits from the site for all the studied varieties of garden strawberries. The most pronounced effect was observed for plants of the Baron Von Solemacher variety when using the maximum concentration of the drug. The practice of mulching did not significantly affect the total number of flowers from the site for the entire growing season, but its use led to an increase in the total weight of fruits, due to an increase in the average weight of individual berries. Data on the effect of insecticide in different amounts on the growth characteristics of garden strawberry plants of different varieties are shown in Table 6.

Most often, strawberry plants were affected by pests such as mole crickets, may beetle larvae, strawberry-blossom weevils, and strawberry mites. The use of insecticide in the amount of 6 and 3 mg per plot led to a significant positive effect in the control of garden strawberry pests, which was expressed in an increase in growth characteristics. The study preparation at maximum concentration resulted in an increase in the number of triple leaves at the time of first flowering and an increase in the number of whiskers after two weeks of cultivation for most of the studied varieties. The use of insecticide in the amount of 3 mg per plot increased the growth indicators of the growing season of strawberry plants of the "Regina" and "Ruegen" varieties. It is worth noting that the number of trifoliate leaves of plants of the "Regina" variety at the time of the first flowering slightly increased even with the use of the study drug in the amount of 1 mg per plot, which indicates a special sensitivity of this variety to pests.

***Table 6**. Effect of abamectin on the growth characteristics of garden strawberry plants*

	Variety	Number of whiskers per plant	Number of trifoliate leaves per plant	Days before flowering	Days before the first fruits ripen	Number of flowers from the plot	Fruit weight per plot (g)
N	Regina	2.8	5	28.3	62.7	130.3	2.645
	Ruegen	2.7	5.6	30.3	58.7	155.7	2.976
	Alexandria	2.4	4.5	25	53.3	112	2.765
	Baron Von Solemacher	3.1	6.1	34	65	137.3	2.988
6A	Regina	4.1	7	25.3	55.3	156.3	2.910
	Ruegen	3.5	5.9	27.3	54.7	187.7	3.303
	Alexandria	3.1	5.1	22.3	49.7	134.3	3.042
	Baron Von Solemacher	3.3	6.4	30.7	60.7	150	3.212
3A	Regina	3.6	5.7	24.7	59.7	147.7	2.777
	Ruegen	3.2	6.4	28.3	55.3	179.3	3.125
	Alexandria	2.6	4.7	23.7	49.3	128.3	2.903
	Baron Von Solemacher	3.1	6.3	32.7	61.3	145.3	3.137
1A	Regina	2.7	5.4	26.3	60.3	136.3	2.617
	Ruegen	2.9	5.4	28.7	54.7	172.7	3.007
	Alexandria	2.5	4.4	23	50.3	121	2.792
	Baron Von Solemacher	3.2	5.8	31.7	62.3	127.7	3.017

***Note:** N – control sites, 6A – 6 mg abamectin, 3A – 3 mg abamectin, 1A – 1 mg abamectin*
***Source:** developed by the authors*

The use of insecticide allowed reducing the number of days before the first visible flower buds appear by an average of 11% and the period required for the first berries to ripen by an average of 7% compared to the control areas. The most pronounced reduction in the ripening period of fruits by 12% was observed for strawberry plants of the "Regina" variety. The use of 6 mg of insecticide per site had a positive effect on the number of flowers during the entire flowering period and the total weight of fruits from the site. The highest results of fruiting productivity in this experiment were demonstrated by plants of the "Ruegen" variety when using the maximum amount of the test drug. It is worth noting that small concentrations of insecticide, namely 3 and 1 mg per plot, also had a positive effect on the total weight of fruits from the plot for most of the varieties of garden strawberries. The results obtained indicate that even low concentrations of insecticides can effectively eliminate this negative factor.

The growth of pest plants was observed in all areas where the herbicide was not used. The most pronounced growth was observed in areas where organic and synthetic fertilisers were used. When using the maximum amount of herbicide, it was possible to achieve complete elimination of pest plants at all experimental sites, but this led to a decrease in a number of indicators of strawberry plants themselves, which indicates the sensitivity of this crop to fluazifop-p-butyl. Data on the effect of herbicide in different amounts on the growth characteristics of garden strawberry plants of different varieties are shown in Table 7.

Table 7. *Effect of fluazifop-p-butyl on the growth characteristics of garden strawberry plants*

	Variety	Number of whiskers per plant	Number of trifoliate leaves per plant	Days before flowering	Days before the first fruits ripen	Number of flowers from the plot	Fruit weight per plot (g)
N	Regina	2.8	5	28.3	62.7	130.3	2.645
	Ruegen	2.7	5.6	30.3	58.7	155.7	2.976
	Alexandria	2.4	4.5	25	53.3	112	2.765
	Baron Von Solemacher	3.1	6.1	34	65	137.3	2.988
90F	Regina	2.2	4.7	27.3	63.7	114.7	2.546
	Ruegen	2.1	5.1	31.7	57	175.3	3.254
	Alexandria	1.9	4.6	26.3	52.7	98.7	2.645
	Baron Von Solemacher	2.5	5.8	35.3	64.3	120.7	2.872
60F	Regina	3.5	6.4	26	57.3	127.7	2.634
	Ruegen	3.4	7.2	25.7	49.7	176.3	3.199
	Alexandria	2.5	4.4	23	49.3	122.7	2.701
	Baron Von Solemacher	3.9	7.8	31.3	58.3	145	2.933
30F	Regina	3.3	5.2	27.7	63.3	132.7	2.654
	Ruegen	3.2	5.4	26.3	52.3	161	3.011
	Alexandria	2.8	4.7	24.3	51.7	109.7	2.785
	Baron Von Solemacher	3.7	5.9	32.3	63.3	148.3	2.876

Note: *N – control sites, 90F – 90 mcg fluazifop-p-butyl, 60F – 60 mcg fluazifop-p-butyl, 30F – 30 mcg fluazifop-p-butyl*
Source: *developed by the authors*

The greatest positive effect of the studied preparation was demonstrated on the growth parameters of the vegetation period, such as the number of trifoliate leaves at the time of the first flowering and the number of strawberry whiskers after two weeks of cultivation. This effect was observed due to the fact that strawberry plants are most sensitive to competition in the early periods of their growth. The introduction of herbicide in the amount of 60 micrograms per plot increased these indicators in garden strawberry plants of the varieties "Regina", "Ruegen" and "Baron Von Solemacher". The use of the test drug in the amount of 60 micrograms per site also reduced the periods required for the appearance of the first visible flower buds and berry ripening by an average of 8% and 12%, respectively. The most pronounced effect of reducing these periods was

observed for strawberry plants of the "Ruegen" variety when using an herbicide in the amount of 60 and 30 micrommes per plot, which indicates an increased sensitivity of this variety to pest plants. The introduction of the herbicide did not lead to a significant increase in the total number of flowers from one site during the flowering period and the total weight of fruits. The use of the test drug in the amount of 90 micrommes per site, on the contrary, led to inhibition of flowering and fruiting productivity of experimental sites. The exception was strawberry plants of the garden variety "Ruegen", which showed an increased number of flowers and total fruit weight even when using the maximum amount of herbicide, which suggests an increased tolerance of this strawberry variety to herbicides.

DISCUSSION

The pH value of the soil is an important factor that affects the growth and development of plants. According to G.W. Thomas (1996) the pH level determines the presence of nutrients and the activity of microorganisms in the soil. Different plants have different preferences for soil pH, and maintaining an optimal pH range for a particular species can contribute to better growth, yield, and overall crop health. A. Läuchli and S.R. Grattan (2017) have shown that if the soil pH is too low or too high, it can cause nutrient deficiencies, toxicity, and other problems that can negatively affect plant growth. Their findings suggest that too acidic soil can reduce the availability of essential nutrients such as phosphorus, calcium, and magnesium, leading to stunted growth, yellowing leaves, and other symptoms of nutrient deficiency. On the other hand, if the soil is too alkaline, it can reduce the availability of trace elements such as iron, manganese, and zinc, which can also lead to a corresponding deficiency and poor plant growth and fruit quality. According to G.M. Darrow (1966), the optimal soil pH for strawberries ranges from 5.7 to 6. In this paper, the pH of untreated soil was 6.5, which exceeds the limits of the optimal range established from literature sources. Reduction of this indicator by adding aluminium sulphate allowed improving the characteristics of the growing season of strawberry plants and increasing the number of flowers and the total weight of fruits from the site. This may indicate that the bioavailability of minerals for garden strawberries is higher at more acidic soil pH values. Maintaining this factor in the optimal range is essential to ensure that plants have access to the nutrients they need for healthy growth, flowering, and fruit formation.

Nitrogen, phosphorus, and potassium, often abbreviated as NPK, are three important macronutrients crucial for strawberry growth and development. Each of these nutrients plays a unique role in supporting the plant's physiological processes, including photosynthesis, energy production, and root, flower, and fruit development. The greatest stimulating effect in the early stages of strawberry plant development was demonstrated by VerdeGrow with a high potassium content. According to A.K. Srivastava *et al.* (2020), this macronutrient is involved in many aspects of plant growth, including water balance regulation, enzyme activation, and stem and root development. R. Johnson *et al.* (2022) have shown that proper potassium levels can help increase plant resistance to environmental stresses such as drought, cold, and heat. A mixture of all three fertilisers, including VerdeMicro, which also contains a significant amount of potassium, demonstrated a stimulating effect on fruit development, which is consistent with data from literature sources. According to A. Nakro *et al.* (2022) potassium is important for fruit quality, especially in terms of improving taste, colour, and texture.

VerdeMicro with a high nitrogen content has demonstrated significant effectiveness at all stages of strawberry plant development. According to the study by J. Wang *et al.* (2021), the bioavailability of nitrogen has been shown to have a positive effect on the growth of plant leaves and stems. This element is a key component of chlorophyll, and, therefore, is necessary for photosynthesis and the formation of new plant tissues. Data by S. Farjana *et al.* (2023) indicate that the correct level of nitrogen is crucial for the development of strawberry leaf plates, which can effectively photosynthesise and support fruit growth. G. Costamagna *et al.* (2020) reported that excessive levels of this element can lead to undesirable vegetative growth, reduced flowering and fruiting, and increased susceptibility to pests and diseases. The results obtained did not demonstrate a decrease in the intensity of flowering and fruiting when applying maximum nitrogen concentrations. The question of the effect of fertilisers on the susceptibility of strawberry plants to biotic factors requires further investigation.

The most effective preparation from the standpoint of stimulating flowering was VerdeBloom with a significant phosphorus content. L.T. Le *et al.* (2021) have shown that this element plays a crucial role in root development, flowering, and fruiting processes. It is involved in the generation of DNA, RNA, and ATP. The necessary levels of phosphorus can help strawberry plants form a strong root system, which is essential for absorbing nutrients and water. A.J. Abbott (1968) indicated that phosphorus is important for the development of strawberry flowers and fruits, which is also consistent with the results obtained. An important aspect of this study was the comparison of organic and synthetic fertilisers. The findings show that the use of compost shows results comparable to some of the tested fertilisers. Thus, the use of natural fertilisers allows achieving efficient cultivation of garden strawberries, which can reduce the intensity of use of synthetic fertilisers and, accordingly, the negative impact on the environment.

Fungal diseases can have a significant negative effect on the growth and yield of strawberries. According to S.T. Koike *et al.* (2007), the most common

pathogens of such diseases are fungi of the *genera Fusarium, Phytophthora, Botrytis, and Verticillium*. During the experiment, *Botrytis cinerea* (Grey rot) fungi posed a significant problem for a number of garden strawberry varieties under study. M. Panth *et al.* (2020) have shown that fungal diseases can lead to a delay in plant growth and a decrease in their overall growth rates, which can lead to a decrease in yield. The use of trichodermin and mulching practices allowed eliminating the negative effects of infectious agents, which led to an increase in the growth parameters of strawberries. The "Baron Von Solemacher" garden strawberry variety turned out to be the most sensitive to fungal diseases, so the effect of using a fungicide and sanitary practice was the most pronounced for it. Mulching showed a positive effect on the growth parameters of strawberries, even for those varieties that suffered little from infections. J.P. Pinto *et al.* (2022) claim that mulching helps retain moisture in the soil, reducing the need for frequent watering. This is especially important for strawberries, which have shallow roots and are sensitive to drought. D. Neri *et al.* (2021) have shown that mulching can suppress weed growth by reducing competition for water, nutrients, and light. According to M. Meyer *et al.* (2021), mulching has been shown to help lower soil temperature, keeping it cooler in hot weather and warmer in cold weather. During heavy rains, mulching can help prevent soil erosion by reducing runoff and holding it in place during heavy rains. When mulching breaks down, it turns into a kind of organic fertiliser that promotes root growth and overall plant health. Thus, the results obtained regarding the effectiveness of mulching practices for growing garden strawberries are consistent with the data of other researchers. The results of this study showed that mulching shows an effect comparable to low concentrations of trichodermin and can serve as a more environmentally friendly alternative to the use of fungicides.

Insect pests can have a significant negative impact on strawberry plants and their fruits. According to S. Lahiri *et al.* (2022), this may include a decrease in yield, a decrease in fruit size, their deformation, and premature rotting of plants. The results obtained partially confirm this, because the use of insecticide made it possible to increase the total weight of strawberry fruits from the site. However, this effect was observed not by increasing the size of fruits, but by increasing their total number. The most resistant to pests was the "Ruegen" garden strawberry variety. This variety also proved to be the most sensitive to plant pests and at the same time the most resistant to the negative effects of high concentrations of fluazifop-p-butyl. The findings showed that even small amounts of insecticide and herbicide show a significant positive effect on the growth characteristics of garden strawberries. By reducing the use of these drugs, farmers can reduce the negative impact on the environment, while maintaining high productivity of strawberry plants.

CONCLUSIONS

The study considered the impact on the growth characteristics of different varieties of garden strawberries of such factors as the introduction of soil pH regulators, the use of organic and synthetic fertilisers, the use of different concentrations of trichodermin, abamectin and fluaziphop-p-butyl, and the use of mulching practices was tested. It was found that the introduction of aluminium sulphate in the amount of 200 g per plot of three square metres to reduce the pH value of the soil has a positive effect on the efficiency of growing strawberry plants of the varieties under study. The reduced pH of the soil turned out to be more optimal for this type of plant. The use of both organic and synthetic fertilisers allowed increasing the growth characteristics of the growing season, reducing the time before flowering and fruiting, and increasing the productivity of garden strawberry plants. The most pronounced effect on the characteristics of the growing season, such as the number of whiskers from the plant and the number of triple leaves in the second week of cultivation, was demonstrated by the drug with a high potassium content VerdeGrow. VerdeBloom, which contains a significant concentration of phosphorus, most effectively improved the characteristics of the flowering period. The combination of all three synthetic fertilisers under study had the highest positive effect on the productivity of garden strawberries.

In the course of the work, it was shown that the effectiveness of compost is also quite high and comparable to the use of VerdeMicro. Trichodermin concentrations of 1, 0.5, and 0.25 ml per three square metres eliminated the effects of fungal infections on strawberry plants for most of the varieties. At the same time, the practice of mulching also showed a significant positive effect on the growth characteristics of garden strawberries. Abamectin in amounts of 6, 3, and 1 mg per three square metres was effective for controlling insect pests. The use of fluazifop-p-butyl in amounts of 60 and 30 microgrammes per three square metres reduced the negative impact of plant pests. At the same time, at a concentration of 90 microgrammes per site, this drug reduced the growth characteristics of most of the strawberry varieties under study. The findings show that the use of organic fertilisers, natural farming practices, and the use of a reduced amount of herbicides and insecticides facilitates high productivity of garden strawberry plants. The obtained data allow adjusting the approach to growing this type of plant towards greater environmental friendliness and productivity. The effectiveness of using combinations of these factors requires further investigation.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Анотація. Метою цього дослідження було оцінити ефективність вирощування суниці за використання регуляторів pH, синтетичних та органічних добрив, практики мульчування та застосування фунгіцидів, інсектицидів і гербіцидів. Рівень pH ґрунту регулювали шляхом внесення сульфату алюмінію та вапняку у кількості 200 та 900 г на три квадратних метри відповідно. Для перевірки дії добрив використовували синтетичні препарати з різними макро- і мікроелементами, а також органічний компост. Оцінювали ростові характеристики вегетаційного періоду, включаючи показники цвітіння та плодоношення. Результати показали, що зниження pH ґрунту позитивно впливає на ефективність вирощування досліджуваних рослин. Застосування добрив з високим вмістом калію збільшувало швидкість проходження вегетаційного періоду, а препарати, багаті на фосфор, позитивно впливали на характеристики періоду цвітіння. Застосування компосту забезпечило збільшення продуктивності суниці, порівнянне з використанням синтетичних добрив. Доведено, що мульчування знижує ризик розвитку грибкових інфекцій у рослин та підвищує показники росту. Застосування гербіциду було значно ефективнішим для пригнічення росту рослин-шкідників та покращення ростових характеристик суниці. Показано, що застосування методів органічного землеробства та знижених концентрацій гербіцидів та інсектицидів дозволяє досягти високої ефективності вирощування суниці

Ключові слова: ростові характеристики; органічне землеробство; синтетичні добрива; мульчування; плодово-ягідні культури