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The Use of Poultry Manure, The Growth Regulator Brassinosteroids, and Ganoderma Lucidum to Study Their Effect on N, P, K Elements and Organic Matter in the Crop Soil Mid-Season and Pre-Harvest to Improve the Quality Characteristics of Purple Carrot Roots

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ABSTRACT

To study the effect of poultry manure, the growth regulator Brassinosteroids, and an aqueous extract of Reishi mushroom (Ganoderma Lucidum), a factorial experiment was carried out with three factors (3×3×3) with three replicates using a split-plot design within a randomized complete block design (RCBD) for the autumn growing seasons of 2024 and 2025. The first factor was decomposed poultry manure at three levels 0, 5000, and 10000 kg. ha-1. The second factor is spraying the plants with the growth regulator Brassinosteroids at three concentrations (0, 1, and 2 mg/L). The third factor is spraying the plants with reishi mushroom extract, prepared by hydro-extraction at three concentrations (0%, 5%, and 10%). The plants are sprayed twice: the first time, 10 days after thinning, when Brassinosteroids are sprayed, and then three days later, the reishi mushroom extract is sprayed. The second spraying is done twenty days after the first. Decomposed poultry manure is randomly distributed over the main plots before planting. The addition of poultry manure, the growth regulator Brassinosteroids, and an aqueous extract of Reishi mushroom increased the percentage of N, P, K, as well as organic matter in the crop soil mid-season and pre harvest. It also increased the levels of the amino acids arginine and threonine in the roots, thus improving the quality characteristics of purple carrots.

Objectives:The possibility of increasing the percentage of N, P, K elements and organic matter in the crop soil in the middle of the season and pre-harvest to improve the qualitative characteristics of the roots of the purple carrot plant by adding decomposed poultry manure to the soil and spraying with both the growth regulator Brassinosteroids and the aqueous extract of the reishi mushroom.

KEYWORDS: Purple carrots, Amino acids, Arginine, Threonine, Poultry manure, Reishi mushroom, Brassinosteroids..

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INTRODUCTION

Purple carrots (Daucus carota) are biennial plants with taproots, belonging to the Apiaceae family. They are genetically related to the common orange carrot but are distinguished by their purple color, which is attributed to their high antioxidant content. Purple carrots are an excellent source of dietary fiber, vitamin C, potassium, and manganese, as well as vitamins A and K, carbohydrates, and the natural antioxidants lutein and beta-carotene. It also contains phenolic compounds, such as anthocyanins, and essential amino acids like leucine, threonine, and arginine. Regular consumption of purple carrots is very healthy; they reduce carbohydrate intake, especially when consumed as fiber, which supports weight loss, and help prevent diabetes by slowing carbohydrate digestion. They also reduce the risk of certain cancers and cardiovascular diseases. It also helps reduce inflammation, is beneficial for the eyes, and stimulates blood circulation. (For the purpose of improving the qualitative characteristics of purple carrot roots, three factors were used: poultry manure, the growth regulator Brassinosteroids, and the aqueous extract of Reishi mushroom. Studies have shown that the use of organic fertilizer leads to plant productivity that is close to that obtained with chemical fertilization (1), as organic matter has a direct effect on the physical, chemical, and biological properties of the soil, and is responsible for the soil's exchange capacity. In addition to its effect on soil acidity, its regulatory capacity, and soil fertility, organic matter supplies plants with essential nutrients released from organic compounds during decomposition and provides microorganisms with energy and important elements for building their bodies. Furthermore, organic matter increases biological activity within the root zone due to its content of beneficial microbes that stimulate vital processes. In addition to being considered one of the natural amendments that play an important and effective role in improving the general properties of the soil (2,3,4). Excessive use of chemical fertilizers leads to an increase in the percentage of salts in the soil and exacerbates the problem of environmental pollution, especially when irrigating with saline water (5). Therefore, it has become necessary to search for environmentally clean and suitable alternatives, such as poultry manure. Poultry manure is a good organic fertilizer containing high levels of nitrogen (N), phosphorus (P), and potassium (K), which plants need. Poultry manure improves soil fertility and increases the soil's water retention capacity (6). Adding poultry manure to the soil significantly increased the soil's nutrient content of nitrogen (N), phosphorus (P), potassium (K), and zinc (Zn), and increased the yield of sweet potatoes. Moreover, (7) explained that organic matter prepared from poultry manure has a significant impact on the physical condition of the soil, such as increasing soil porosity, thus increasing aeration and water movement in clay soils, and conversely increasing the cohesion of sandy soils, thus increasing their water retention. Furthermore, the long-term use of poultry manure can alter the biological and chemical properties of the soil (8,9). Also, (10) found that adding poultry manure to carrot plants at a rate of 2500 kg/ha resulted in a significant increase in yield and root content of carbohydrates, carotenes, and calcium compared to mineral fertilization treatment. Brassinosteroids (BRs) are one of the plant hormones and were first discovered by the scientist Mitchell by examining the pollen grains of approximately 60 plant species (11). It was called Brassins (12,13). BRs are essential hormones in most plant physiological functions and are important for plant growth and development. They also regulate several cellular and physiological processes that occur in the plant. For example, cell division and elongation, biosynthesis of cell wall components, synthesis of DNA, RNA and 10 different proteins, distribution of nutrient media to plant organs, growth of pollen tube, differentiation of plant vascular system, formation of adventitious roots, flowering, seed production and germination, resistance to biotic and abiotic stresses, delaying aging and other processes (3,14). A study conducted by (15) involved spraying carrot leaves with a concentration of 0.5 mg/L of the growth regulator BRs. This resulted in an increase in plant height and the number of leaves, thus affecting root growth and development. A recent study by (16) showed that spraying BRs on carrot leaves increased plant growth rate and improved root quality. Concentrations of 0.1 and 0.2 mL/L of the growth regulator were used, and the 0.1 mL/L concentration was found to promote root growth, plant height, and leaf count, as well as increase sugar content in the roots (15). Ganoderma lucidum, also known as reishi mushroom, is used in traditional Asian medicine for its medicinal properties. In recent years, its potential benefits in agriculture have been studied. Research has shown that Ganoderma extracts can be used as a plant growth stimulant, improving the yield and quality of vegetables and fruits. Studies also indicate that it can enhance plant stress tolerance (17) and improve its ability to withstand drought, high temperatures, and diseases. Additionally, it can also be used as a natural pesticide. Numerous studies have investigated the effects of Ganoderma mushrooms on various crops. One such study (18) found that when using Reishi mushroom extracts as a material in the manufacture of biodegradable containers, which were evaluated for planting seeds of various vegetable plants, it affected the germination of 15 out of 17 plant species and improved seedling growth and quality, particularly for tomato seedlings.

MATERIALS AND METHODS

To study the effect of fertilization with poultry manure, spraying with the growth regulator Brassinosteroids (BRs) and Reishi mushroom extract, and their interactions on the quality and yield of purple carrot roots, the experiment was conducted in one of the fields of the College of Agricultural Engineering Sciences/University of Baghdad, Al-Jadriya, during the autumn growing seasons of 2024 and 2025 at station (A), where the Flooding process took place. After a week, the weeds were controlled, then the soil was turned over, followed by a second plowing. The field was divided, and raised beds were made. Poultry manure was added and mixed with the soil in the experimental units. The decomposed poultry manure was distributed randomly on the main plots, and the combination of spraying agents with both BRs and Reishi mushroom (of equal importance) was distributed on the sub-plots within the main plots. Subsequently, the drip irrigation system was implemented, and then the seeds were sown in an experimental unit area of 1 x 2 m2, planted in three rows with a distance of 20 cm between rows and a distance of 5 cm between plants. After planting, thinning, and weeding were carried out.

Factors studied:

1- The first factor is poultry manure at three levels (0, 5000, and 10000 kg. ha-1). These levels are added to the soil before planting.
2- The second factor is the growth regulator Brassinosteroids, sprayed at three concentrations (0, 1, and 2 mg/L). The first spraying is applied one month after planting, and the appearance of three true leaves. The second spraying is applied 20 days after the first.
3- The third factor is the aqueous extract of the Reishi mushroom (Ganoderma lucidum), sprayed at three concentrations (0%, 5%, and 10%). The first spraying is applied three days after the (BRs) growth regulator application, and the second spraying is applied 20 days after the first.

The studied properties:

1- Percentage of nitrogen in the soil
2- Percentage of phosphorus in the soil
3- Percentage of potassium in the soil
4- Percentage of organic matter in the soil
5- Arginine concentration (PPM) in purple carrot roots
6- Threonine concentration (PPM) in purple carrot roots

The nitrogen content was estimated using the Micro Kjeldahl method, following the approach of (19). The percentage of phosphorus in the radicals was estimated using ammonium molybdate and measured with a spectrophotometer at a wavelength of 882 nm, according to the (20) method. Potassium was determined using a flame photometer according to the method proposed by (21). The organic matter content in the soil was estimated using the Loss on Ignition (LOI) method. Measurement of the amino acids arginine and threonine: The amino acids were extracted according to the method presented by the scientist (22).

Table (1) Effect of adding poultry manure, spraying with (BRs) and Reishi mushroom, and their interaction on the nitrogen % in the soil mid-season and pre-harvest for purple carrot plants for the autumn season of 2024 (values above) and for the autumn season of 2025 (values below)

		Mid-season				Pre-harvest			
P	B	G			P * B	G			P * B
		G_1	G_2	G_3		G_1	G_2	G_3	
P_1	B_1	7.18 6.73	9.55 9.15	10.70 9.60	9.14 8.50	6.73 5.27	9.15 7.69	9.60 8.27	8.50 7.07
	B_2	7.38 7.38	9.79 9.55	11.94 11.10	9.05 9.34	6.58 5.90	9.29 7.90	10.10 9.15	9.34 7.65
	B_3	10.20 9.37	11.16 11.90	13.20 12.10	11.52 11.12	9.55 7.470	9.37 10.21	12.10 10.44	10.34 9.37
P_2	B_1	10.95 10.11	12.22 11.40	13.30 11.50	12.16 11.00	10.11 8.24	11.40 9.43	11.50 9.58	11.00 9.09
	B_2	10.79 10.69	12.17 10.71	12.30 12.32	11.75 11.24	10.19 8.70	10.51 8.83	11.32 10.62	10.64 9.38
	B_3	10.57 11.07	12.20 11.77	13.50 12.07	12.09 11.63	10.07 9.32	11.77 10.01	12.07 10.67	11.33 10.00
P_3	B_1	10.03 10.40	12.40 11.90	13.20 12.03	11.88 11.44	9.40 8.73	11.53 10.05	11.90 10.38	10.94 9.72
	B_2	10.90 10.44	11.77 11.67	13.55 11.83	12.07 11.31	10.44 8.95	10.77 10.18	11.83 10.22	11.01 9.78
	B_3	10.97 10.53	11.50 11.80	13.93 12.87	12.93 11.73	10.00 9.60	10.53 10.33	12.27 10.92	10.73 10.28
LSD		1.78 1.72			1.32 0.96	1.72 1.699			0.96 0.96
P * G						P * G			
P		G_1	G_2	G_3	Average P	G_1	G_2	G_3	Average P
P_1		8.10 8.63	9.89 9.40	11.72 10.93	9.90 9.65	7.70 7.02	9.40 7.79	10.93 9.28	9.34 8.03
P_2		11.50 11.06	12.22 11.32	12.43 11.50	12.01 11.29	11.06 9.19	11.32 9.43	11.50 9.85	11.29 9.49
P_3		11.62 11.29	12.48 11.47	12.48 11.54	12.19 11.43	11.29 9.65	11.47 9.87	11.54 9.87	11.43 9.79
LSD		1.32 0.96			1.29 0.66	0.96 0.96			0.66 0.85
B * G						B * G			
B		G_1	G_2	G_3	Average B	G_1	G_2	G_3	Average B
B_1		10.56 10.04	11.05 10.04	11.54 10.86	11.06 10.31	10.04 8.30	10.04 8.41	10.86 9.19	10.31 8.63
B_2		10.33 9.97	11.77 10.23	11.78 11.69	11.29 10.63	9.97 8.31	10.23 8.52	11.69 9.98	10.63 8.94
B_3		10.08 10.32	12.36 11.98	12.91 11.99	11.78 11.43	10.32 8.60	11.98 10.28	11.99 10.38	11.43 9.75
G						G			
G		G_1	G_2	G_3		G_1	G_2	G_3	
Average G		10.33 10.11	11.73 10.75	12.07 11.51		10.11 8.41	10.75 9.07	11.51 9.58	
LSD		0.53 0.58				0.58 0.56			

The results in Table (1) indicate that adding poultry manure led to a significant increase in the nitrogen content of the soil mid-season and pre-harvest, as treatments P3 and P2 were significantly superior and had the highest percentage in mid-season at the P3 level 12.19 and 11.43% for the two seasons respectively, compared to the control treatment P1, which gave the lowest percentage 9.90 and 9.65% for both seasons respectively. In the pre-harvest stage, the percentages were 11.43% and 9.79% for the two seasons, respectively, compared to the control treatment P1, in which the lowest percentages were 9.43% and 8.03% for both seasons, respectively. Furthermore, the B3 treatment significantly exceeded soil nitrogen levels at mid-season and pre-harvest for both seasons, where the highest levels at mid-season reached 11.78% and pre-harvest 11.43%, respectively. Compared to the control treatment B1, which gave the lowest percentages of 11.06% and 10.31% for the two seasons, respectively, and at the pre-harvest stage, it reached 11.43% and 9.75% for the two seasons, respectively, compared to the control treatment P1, in which the lowest percentage was 10.31% and 8.63% for the two seasons, respectively. The treatment using the aqueous extract of the Reishi mushroom G3 was significantly superior to the control treatment G1 in providing the highest mid-season nitrogen content for both seasons, reaching 12.07% and 11.51%, respectively, compared to the control treatment G1, which gave the lowest contents of 10.33% and 10.01% for both seasons, respectively. The same treatment was also significantly superior to the control treatment G1 in providing the highest pre-harvest soil nitrogen content, reaching 11.51% and 9.58% for both seasons, respectively, compared to the control treatment G1, which gave the lowest contents of 10.11% and 8.41% for both seasons, respectively. The results of the interaction between organic fertilizer and (BRs) P3B3 show the highest percentages of nitrogen in the soil mid-season, amounting to 12.93% and 12.73% for both seasons, respectively, compared to the control treatment P1B1, which gave the lowest percentages, 9.14% and 8.5% for both seasons, respectively. At the pre-harvest stage, the percentages reached 12.93% and 11.73% for both seasons, respectively, compared to the control treatment P1, in which the lowest percentage was 9.14 and 8.50% for both seasons, respectively. The interaction between the two treatments, P3G2 in the first season and P3G3 in the second season, also showed a significant superiority in the percentage of nitrogen in the soil and gave the highest increase of 12.43 and 11.54% compared to the control treatment, which gave the lowest rate of 8.10% and 8.63%, respectively. Also, pre-harvest, the interaction between the two treatments P3G3 in both seasons showed a significant superiority in the percentage of nitrogen in the soil pre-harvest and gave the highest increase of 11.54 and 9.87% compared to the control treatment, which gave the lowest rate of 7.70 and 7.02%, respectively. The mid-season interaction treatment B3G3 was significantly superior in soil nitrogen percentage in both seasons, which gave the highest increases of 12.91% and 11.99%, compared to the control treatments, which showed the lowest rate of 10.56% and 10.01%, respectively. Similarly, the same treatment B3G3 gave a significant superiority in soil nitrogen percentage pre-harvest in both seasons, and gave the highest increases of 11.99% and 10.38%, compared to the control treatments B1G1which showed the lowest increases of 10.04% and 8.30%, respectively. The results of the triple interaction treatment P3B3G3 in both seasons also showed a significant superiority in the percentage of nitrogen in the leaves in both seasons and gave the highest rate 13.93% and 12.87%, respectively, compared to the control treatment, which gave the lowest rates 7.18% and 6.73%, respectively, in both seasons. Likewise, the results of the same treatment P3B3G3 in both seasons showed a significant increase in the percentage of nitrogen in the soil pre-harvest and gave the highest rate 12.27% and 10.92%, respectively, compared to the control treatments, which gave the lowest rates 6.73% and 5.27%, respectively, for both seasons.

Table (2) Effect of adding poultry manure, spraying with (BRs) and Reishi mushroom, and their interaction on the phosphorus % in the soil mid-season and pre-harvest for purple carrot plants for the autumn season of 2024 (values above) and for the autumn season of 2025 (values below)

		Mid-season				Pre-harvest			
P	B	G			P * B	G			P * B
		G_1	G_2	G_3		G_1	G_2	G_3	
P_1	B_1	1.860 2.220	1.900 2.300	2.267 2.247	2.042 2.256	1.130 1.550	1.403 1.490	1.597 1.693	1.377 1.578
	B_2	1.900 2.090	1.800 2.250	2.250 2.617	1.787 2.319	1.047 1.630	1.547 1.417	1.637 1.887	1.413 1.644
	B_3	1.820 2.017	2.057 2.207	2.240 2.427	2.109 2.217	1.323 1.727	1.667 1.847	2.013 1.923	1.868 1.832
P_2	B_1	2.100 2.257	2.267 2.327	2.500 2.683	2.286 2.422	1.627 1.847	1.643 1.903	1987 2.030	1.752 1.927
	B_2	2.100 2.230	2.233 2.387	2.900 2.760	2.411 2.459	1.483 1.583	1.513 1.510	1.840 1.753	1.912 1.608
	B_3	2.200 2.610	2.600 2.930	3.100 3.207	2.435 2.916	1.817 1.843	2.017 2.300	2.097 2.530	1.977 2.224
P_3	B_1	2.300 2.637	2.900 2.747	3.000 3.260	2.767 2.882	1.210 2.167	1.957 2.083	2.257 2.477	1.808 2.242
	B_2	2.000 2.647	2.100 2.797	3.100 3.310	2.400 2.918	1.407 2.043	1.440 2.117	2.223 2.813	1.687 2.324
	B_3	2.150 2.663	2.450 2.847	3.500 3.063	2.700 2.858	1.447 2.187	1.763 2.190	2.523 2.053	1.878 2.143
LSD		0.493 0.341			0.258 0.219	0.424 0.399			0.236 0.236
P * G						P * G			
P		G_1	G_2	G_3	Average P	G_1	G_2	G_3	Average P
P_1		1.993 2.362	2.308 2.469	2.713 2.690	2.338 2.507	0.986 1.636	1.144 1.734	1.258 2.034	1.129 1.801
P_2		2.033 2.729	2.433 2.992	2.867 3.142	2.444 2.754	1.646 2.152	1.688 2.348	2.308 2.700	1.880 2.400
P_3		2.633 2.918	2.633 2.937	2.933 3.202	2.733 3.019	1.699 2.332	1.870 2.430	2.173 2.448	1.914 2.403
LSD		0.258 0.219			0.121 0.193	0.236 0.236			0.157 0.186
B * G						B * G			
B		G_1	G_2	G_3	Average B	G_1	G_2	G_3	Average B
B_1		2.542 2.738	2.789 2.758	2.833 3.030	2.721 2.842	1.418 2.073	1.502 2.107	2.027 2.367	1.649 2.182
B_2		2.200 2.483	2.300 2.639	3.344 3.373	2.615 2.832	1.642 1.948	1.981 2.094	2.289 2.676	1.671 2.239
B_3		2.307 2.630	2.786 3.003	3.247 3.087	2.780 2.907	1.529 2.019	1.678 2.362	1.816 2.469	1.674 2.283
LSD		0.258 0.219			N.S N. S	0.236 0.236			N.S N. S
G						G			
G		G_1	G_2	G_3		G_1	G_2	G_3	
Average G		2.349 2.617	2.625 2.767	3.141 3.164		1.463 1.980	1.654 2.154	2.010 2.471	

LSD	0.172 0.110		0.145 0.133	

The results in Table (2) indicate that adding poultry manure led to a significant increase in soil phosphorus content mid-season and pre-harvest. Specifically, P3 significantly exceeded, reaching its highest-level mid-season, 2.733% and 3.019% for the two seasons, respectively, compared to the control treatment, 2.338% and 2.507% for the two seasons, respectively. Pre-harvest, phosphorus levels reached 1.914% and 2.403% for the two seasons, respectively, compared to the control treatment P1, which had the lowest levels of 1.129% and 1.801% for the two seasons, respectively. Treatment B did not significantly increase soil phosphorus levels at mid-season or pre-harvest in either season. However, treatment G3 significantly exceeded the control treatment (G1), which produced the highest increases in soil phosphorus percentage at mid-season: 3.141% and 3.164% for both seasons, compared to the control treatment G1, which produced the lowest percentages: 2.349% and 2.617% for both seasons, respectively. At the pre-harvest stage, the increase was 2.010% and 2.471% for both seasons, respectively, compared to the control treatment G1, which produced the lowest percentages of 1.463% and 1.980% for both seasons, respectively. The results of the interaction between organic fertilizer and (BRs) spraying show that in the first season, treatment P3B1 and in the second season, treatment P3B2 were superior in giving the highest mid-season phosphorus levels in the soil, reaching 2.767% and 2.918% respectively, compared to the control treatment P1B1, which gave the lowest levels 2.042% and 2.256%, respectively. Likewise, the combination P2B3 in the first season and P3B2 in the second season significantly exceeded in terms of the percentage of phosphorus in the soil pre-harvest, giving the highest percentage of 1.977 and 2.324% respectively, compared to the control treatment P1B1, which gave the lowest percentage for both seasons, 1.377 and 1.578% respectively. The interaction treatment P3G3 also showed a significant increase in the percentage of phosphorus in the soil at mid-season, giving the highest percentage of 2.933 and 3.202% in both seasons, compared to the control treatment, which gave the lowest percentage of 1.993 and 2.362%, respectively. Also, the interaction in the combination P2G3 showed a significant increase in the percentage of phosphorus in the soil pre-harvest, giving the highest percentage of 2.308 and 2.700% in both seasons, compared to the control treatment, which gave the lowest percentage of 0.986 and 1.636%, respectively. The treatment B3G3 in mid-season also gave a significant superiority in the percentage of phosphorus in the soil and gave the highest percentage of 3.141 and 3.164% for both seasons, compared to the control treatment, which gave the lowest percentages of 2.349% and 2.617%, respectively. Likewise, the treatment B2G3 significantly increased the percentage of phosphorus in the soil pre-harvest and gave the highest percentages of 2.289% and 2.676% for both seasons, compared to the control treatment B1G1, which gave the lowest percentages of 1.418% and 2.073%, respectively. The results of the triple interaction treatment P3B3G3 in the first season and P3B2G3 in the second season showed a significant increase in the percentage of phosphorus in the soil at mid-season, giving the highest percentages 3.500% and 3.310%, respectively, compared to the control treatment, which gave 1.860% and 2.220% for both seasons, respectively. Likewise, the results of the triple interaction treatment P3B3G3 in the first season and P3B2G3 in the second season showed a significant increase in the percentage of phosphorus in the soil pre-harvest and gave the highest percentages of 2.523% and 2.813%, respectively, compared to the control treatments, which gave the lowest percentages 1.130% and 1.550% for both seasons, respectively.

Table (3) Effect of adding poultry manure, spraying with (BRs) and Reishi mushroom, and their interaction on the potassium % in the soil mid-season and pre-harvest for purple carrot plants for the autumn season of 2024 (values above) and for the autumn season of 2025 (values below)

Mid-season						Pre-harvest			
P	B	G			P * B	G			P * B
		G_1	G_2	G_3		G_1	G_2	G_3	
P_1	B_1	5.133 5.400	5.303 5.533	5.800 6.300	5.412 5.744	1.247 1.270	1.427 1.433	1.487 1.537	1.387 1.413
	B_2	5.467 5.700	5.833 6.167	6.533 6.533	5.944 6.133	1.307 1.153	1.523 1.393	1.410 1.507	1.413 1.350
	B_3	5.933 6.267	6.233 6.833	6.900 7.233	6.356 6.778	1.537 1.307	1.243 1.527	1.463 1.627	1.414 1.487
P_2	B_1	5.300 5.400	5.400 5.700	6.300 6.433	5.667 5.844	1.420 1.460	1.357 1.430	1.470 1.797	1.416 1.562
	B_2	5.333 5.667	6.067 6.233	6.433 6.533	5.944 6.144	1.297 1.263	1.533 1.353	1.687 2.073	1.506 1.563
	B_3	6.033 6.133	6.333 6.633	7.133 7.333	6.500 6.700	1.327 1.377	1.400 1.410	1.360 1.347	1.362 1.378
P_3	B_1	5.767 6.000	5.867 6.033	7.000 7.133	6.211 6.389	1.413 1.417	1.340 1.377	1.197 1.227	1.317 1.340
	B_2	5.300 5.567	5.483 5.667	5.633 5.700	5.472 5.644	1.347 1.427	1.350 1.407	1.300 1.343	1.332 1.392
	B_3	6.633 6.700	6.600 6.800	7.233 7.400	6.822 6.967	1.390 1.473	1.490 1.630	1.707 1.683	1.529 1.496
LSD		0.691 0.645			0.376 0.348	0.446 0.456			NS NS
P * G						P * G			
P		G_1	G_2	G_3	Average P	G_1	G_2	G_3	Average P
P_1		5.568 5.833	5.965 6.267	6.189 6.556	5.904 6.219	1.210 1.390	1.348 1.444	1.407 1.550	1.388 1.461
P_2		6.022 6.089	6.033 6.233	6.256 6.367	6.104 6.230	1.314 1.367	1.363 1.398	1.506 1.539	1.394 1.434
P_3		5.950 6.133	6.244 6.367	6.311 6.500	6.169 6.333	1.383 1.439	1.327 1.471	1.668 1.618	1.459 1.509

LSD	0.376 0.348			N.S N. S	0.245 N. S			N.S N. S
B * G					B * G			
B	G_1	G_2	G_3	Average B	G_1	G_2	G_3	Average B
B_1	5.490 5.656	5.811 6.078	5.989 6.244	5.763 5.993	1.440 1.471	1.374 1.413	1.504 1.531	1.440 1.472
B_2	5.489 5.800	5.672 5.867	6.200 6.256	5.787 5.974	1.350 1.432	1.402 1.451	1.599 1.557	1.450 1.480
B_3	6.389 6.533	6.500 6.789	6.989 7.122	6.626 6.815	1.311 1.492	1.418 1.449	1.777 1.589	1.502 1.507
LSD	0.376 0.348			0.217 0.201	0.245 N. S			N.S N. S
G					G			
G	G_1	G_2	G_3		G_1	G_2	G_3	
Average G	5.789 5.996	5.994 6.244	6.392 6.540		1.403 1.465	1.363 1.448	1.627 1.559	
LSD	0.217 0.201				0.141 N. S			

The results in Table (3) indicate that the addition of poultry manure (P) did not lead to a significant increase in potassium, either in the mid-season or pre-harvest for both seasons. The spraying treatment B3 was significantly superior in the percentage of potassium in the purple carrot soil in the mid-season and gave the highest percentage, 6.626 and 6.815 % for both seasons, compared to the control treatment B1, which gave the lowest percentage of 5.763 and 5.993 % for both seasons, respectively. The pre-harvest treatment with (BRs) was not significant for either season. The treatment G3 significantly exceeded the control treatment G1, which gave the highest percentage of potassium, 6.392% and 6.540% for both seasons, respectively, compared to the control treatment G1, which gave the lowest percentages of 5.789% and 5.996% for both seasons, respectively. Also, the treatment G3 was significantly superior in the first season pre-harvest and gave the highest percentage (1.627%). In the second season, it was not significant compared to the control treatment G1, which gave the lowest percentage, 1.403%. The results of the interaction in the combination P3B3 showed a significant superiority in the percentage of potassium in the soil at mid-season and gave the highest percentage, reaching 6.822% and 6.967% for both seasons, respectively, compared to the control treatment P1B1, which gave 5.412% and 5.744%, respectively. The interaction treatment PB was not significant pre-harvest in both seasons. The interaction treatment P3G3 also showed a significant superiority in the percentage of potassium in the soil at mid-season, giving the highest percentage of 6.311% and 6.500% for both seasons, respectively, compared to the control treatment, which gave the lowest percentage of 5.568% and 5.833% for both seasons, respectively. Likewise, the treatment P3G3 was significantly superior in the first season in the percentage of potassium in soil pre-harvest, giving the highest increase of 1.668%, and it was not significant in the second season compared to the control treatment, which gave the lowest percentage of 1.210%, respectively. The interaction treatment B3G3 also gave a significant superiority in the percentage of potassium in the soil mid-season, giving a percentage of 6.989 and 7.122% for both seasons, compared to the control treatment, which gave a lower percentage of 5.490 and 5.656% for both seasons, respectively. Likewise, B3G3 significantly exceeded the percentage of potassium in the soil pre-harvest and gave the highest percentage in the first season, reaching 1.777%, compared to the control treatment B1G1, which gave the lowest percentage of 1.440%. It was not significant in the second season. The results of the triple interaction treatment P3B3G3 showed a significant superiority in the percentage of potassium mid-season and gave the highest percentage of 7.233% and 7.400% for both seasons, respectively, compared to the control treatment, which gave 5.133% and 5.400% for both seasons, respectively. Similarly, the results of the triple interaction treatment P3B3G3 in the first season and P2B2G3 in the second season were significantly superior in terms of the percentage of potassium in the soil pre-harvest, giving the highest percentage of 1.707% and 2.073%, respectively, compared to the control treatment, which gave the lowest percentage of 1.247% and 1.270% for both seasons respectively.

Table (4) Effect of adding poultry manure, spraying with (BRs) and Reishi mushroom, and their interaction on the organic matter (%) in the soil mid-season and pre-harvest for purple carrot plants for the autumn season of 2024 (values above) and for the autumn season of 2025 (values below)

		Mid-season				Pre-harvest			
P	B	G			P * B	G			P * B
		G_1	G_2	G_3		G_1	G_2	G_3	
P_1	B_1	3.820 3.567	3.833 3.917	4.007 4.067	3.887 3.850	2.830 3.077	3.003 3.073	3.000 3.287	2.944 3.146
	B_2	3.700 4.030	3.997 3.977	4.507 4.557	4.065 4.184	3.187 3.157	3.403 2.917	3.460 3.693	3.350 3.295
	B_3	3.837 3.993	3.947 3.893	4.653 4.683	4.146 4.190	2.683 3.153	3.000 3.123	3.843 3.887	3.176 3.388
P_2	B_1	3.447 3.520	4.357 4.437	3.450 3.517	3.751 3.824	2.687 2.720	2.857 3.457	3.303 2.907	2.949 3.028
	B_2	3.433 3.473	4.537 4.500	3.833 3.900	3.934 3.958	2.860 2.827	2.903 3.597	3.620 3.323	3.128 3.249
	B_3	3.610 4.270	3.820 3.650	4.220 3.923	3.883 3.948	2.530 3.453	3.007 2.763	3.433 3.133	2.990 3.117
P_3	B_1	3.477 4.873	3.667 3.700	4.823 3.543	3.989 4.039	2.663 3.977	2.827 3.353	3.810 2.810	3.100 3.380
	B_2	3.533	3.640	4.413	3.862	2.677	3.117	3.670	3.154

		3.600	3.717	4.480	3.932	2.863	3.070	3.723	3.219
	B_3	3.917 3.990	4.720 4.777	5.020 5.117	4.552 4.628	3.300 3.287	3.883 3.860	4.213 4.037	3.799 3.762
LSD		0.708 0.717			0.469 0.464	0.491 0.685			0.299 0.410
		P * G				P * G			
P		G_1	G_2	G_3	Average P	G_1	G_2	G_3	Average P
P_1		3.700 3.754	3.701 3.780	4.068 4.196	3.856 3.910	2.922 3.000	2.993 3.273	3.151 3.121	3.022 3.131
P_2		3.922 3.963	4.056 4.296	4.289 4.336	4.089 4.198	2.958 3.129	3.278 3.604	3.434 3.622	3.223 3.452
P_3		4.201 4.354	4.409 4.464	4.603 4.580	4.304 4.467	3.262 3.376	3.276 3.428	3.516 3.657	3.351 3.487
LSD		0.469 0.464			0.426 0.413	0.299 0.410			0.248 0.328
		B * G				B * G			
B		G_1	G_2	G_3	Average B	G_1	G_2	G_3	Average B
B_1		3.644 3.709	3.952 4.018	4.040 4.087	3.876 3.938	2.840 3.001	2.987 3.258	3.167 3.294	2.998 3.184
B_2		3.656 3.701	4.124 4.018	4.251 4.312	4.010 4.148	2.908 2.949	3.580 3.580	3.344 3.800	3.277 3.401
B_3		4.028 4.084	4.056 4.107	4.498 4.574	4.194 4.255	3.139 3.298	3.138 3.249	3.688 3.819	3.321 3.455
LSD		0.469 0.464			0.225 0.230	0.299 0.410			0.162 0.228
		G				G			
G		G_1	G_2	G_3		G_1	G_2	G_3	
Average G		3.776 3.831	4.044 4.185	4.263 4.324		2.962 3.082	3.235 3.335	3.399 3.346	
LSD		0.225 0.230				0.162 0.228			

The results in Table (4) indicate that adding poultry manure led to an increase in the percentage of organic matter in the soil mid-season. Treatment P3 exceeded and gave the highest percentage of organic matter, 4.304% and 4.467% for both seasons, respectively. compared to the control treatment P1, which gave the lowest percentages of 3.856% and 3.910% for both seasons, respectively. P3 also had significant superiority over the control treatment P1 pre-harvest of 3.351% and 3.487% for both seasons, respectively, compared to the control treatment P1, which gave the lowest percentages of 3.022% and 3.131% for both seasons, respectively. Furthermore, treatment B3 significantly increased the percentage of organic matter in the soil mid-season, and gave the highest percentage of 4.194% and 4.255% for both seasons, respectively, compared to the control treatment B1, which gave the lowest percentages of 3.876% and 3.938% for both seasons, respectively. Besides, the treatment B3 significantly increased the percentage of organic matter pre-harvest by 3.321% and 3.455% for both seasons, respectively, compared to the control treatment B1, which gave the lowest percentages of 2.998% and 3.184% for both seasons, respectively. The treatment G3 significantly exceeded the control treatment G1 in terms of the percentage of organic matter in the mid-season, reaching the highest percentage of 4.263% and 4.324% for both seasons, respectively, compared to the control treatment G1, which gave the lowest percentages of 3.776% and 3.957% for both seasons, respectively. However, treatment G3 also significantly exceeded the control treatment G1 pre-arvest, resulting in a higher percentage of organic matter in the soil, 3.399% and 3.346% for both seasons, respectively, compared to the control treatment G1, which gave the lowest percentages of 2.962% and 3.082% for both seasons, respectively. The interaction results for treatment P3B3 also showed a significant increase in the percentage of organic matter mid-season, with the highest percentages of 4.552% and 4.628% for both seasons, respectively, compared to the control treatment P1B1, which gave the lowest percentages of 3.887% and 3.850% for both seasons, respectively. Additionally, P3B3 showed a significant increase in the percentage of organic matter in soil pre-harvest, with the highest percentages of 3.799% and 3.762% for both seasons, respectively, compared to the control treatment P1B1, which gave 2.944% and 3.146%, respectively. The interaction treatment P3G3 showed a significant increase in the first season and a non-significant increase in the second season in the percentage (%) of organic matter in soil, and gave the highest percentage in the first season, which reached 4.303%, compared to the control treatment, which gave the lowest percentage of 3.700%, respectively. The interaction treatment B3G3 also gave a significant superiority in the percentage of organic matter in soil at mid-season, giving the highest percentage of 4.498% and 4.574% for both seasons, compared to the control treatment, which gave the lowest percentage of 3.644% and 4.087% for both seasons, respectively. B3G3 also gave a significant superiority in the percentage of organic matter in soil pre-harvest in both seasons, giving the highest percentage of 3.688% and 3.819% for both seasons, compared to the control treatment B1G1, which gave the lowest percentage of 2.840% and 3.001%, respectively. The results of the triple interaction treatment P3B3G3 showed a significant superiority in the percentage of organic matter in the soil at mid-season and gave the highest percentages of 5.020% and 5.117% in both seasons, respectively, compared to the control treatment, which gave 3.820% and 3.567% in both seasons, respectively. The same triple interaction treatment P3B3G3 also resulted in a significant increase in the percentage of organic matter in the soil pre-harvest in both seasons, with the highest percentages of 4.213% and 4.037% in both seasons, respectively, compared to the control treatment, which gave the lowest percentages 2.830% and 3.077% in both seasons, respectively.

Table (5) Effect of adding poultry manure, spraying with (BRs), and Reishi mushroom and their interaction on the root content of Arginine for purple carrot plants for the autumn season of 2024 - 2025

		Mid-season				Pre-harvest			
P	B	G			P * B	G			P * B
		G_1	G_2	G_3		G_1	G_2	G_3	
P_1	B_1	8.16	8.55	9.25	8.65	8.25	8.77	9.33	8.78
	B_2	9.12	10.33	10.80	10.08	9.21	10.40	10.65	10.08
	B_3	9.78	11.20	11.69	10.89	9.88	11.29	11.66	10.94
P_2	B_1	8.72	10.00	10.99	9.90	9.14	10.10	11.08	10.10
	B_2	10.15	10.64	11.33	10.70	10.25	10.98	11.44	10.89
	B_3	12.06	12.89	13.45	12.80	12.11	12.80	13.52	12.80
P_3	B_1	9.47	11.80	12.30	11.19	9.56	11.88	12.38	11.27
	B_2	12.65	13.23	13.59	13.16	12.75	13.25	13.55	13.18
	B_3	13.07	13.90	14.22	13.73	13.16	13.99	14.20	13.78
LSD					0.71		1.25		0.67
		P * G				P * G			
P		G_1	G_2	G_3	Average P	G_1	G_2	G_3	Average P
P_1		9.02	10.03	10.58	9.88	9.08	10.15	10.54	9.93
P_2		10.31	11.18	11.92	11.14	10.50	11.29	12.01	11.27
P_3		11.73	12.98	13.37	12.69	11.82	13.04	13.22	12.70
LSD			0.71		0.48		0.67		0.36
		B * G				B * G			
B		G_1	G_2	G_3	Average B	G_1	G_2	G_3	Average B
B_1		8.78	10.12	10.85	9.92	8.95	10.25	10.93	10.04
B_2		10.64	11.40	11.91	11.32	10.74	11.54	11.88	11.39
B_3		11.64	12.66	13.12	12.47	11.72	12.69	13.21	12.53
LSD			0.71		0.43		0.67		0.43
		G				G			
G		G_1	G_2	G_3		G_1	G_2	G_3	
Average G		10.35	11.39	11.96		10.47	11.50	11.98	
LSD			0.43				0.43		

The results in Table (5) showed that the addition of poultry manure led to a significant increase in the root content of arginine for both seasons, as the treatment P3 were significantly superior in both seasons to the control treatment and gave the highest value of 12.69 and 12.70 mg/100g FW respectively, compared to the control treatment P1, which gave the lowest value of 9.88 and 9.93 mg/100g FW for both seasons respectively. Additionally, treatment B3 resulted in a significant increase in the root arginine content of purple carrot plants by giving the highest levels of 12.47 and 12.53 mg/100g FW, respectively, compared to the control treatment B1, which gave the lowest levels of 9.92 and 10.04 mg/100g FW for both seasons, respectively. The treatment with spraying aqueous extract of Reishi mushroom G3 also led to a significant superiority in the root content of arginine acid for the carrot plant for both seasons, as the highest average reached 11.96 and 11.98 mg/100g FW respectively, compared to the control treatment G1, which gave the lowest average of 10.35 and 10.47 mg/100g FW for both seasons respectively. The results of the bilateral interaction P3B3 showed a significant superiority in the root content of arginine acid for the purple carrot plant in both seasons, giving the highest percentage of 13.73 and 13.78 mg/100g FW, respectively, compared to the control treatment P1B1, which gave the lowest rate of 8.65 and 8.75 mg/100g FW for both seasons, respectively. The interaction treatment P3G3 was also significantly superior in both seasons in terms of the root content of arginine acid, giving the highest value of 13.37 and 13.22 mg/100g FW, respectively, compared to the control treatment, which gave 9.02 and 9.08 mg/100g FW for both seasons, respectively. The interaction treatment B3G3 was significantly superior in both seasons in the root content of arginine in purple carrot plants, giving the highest values of 13.12 and 13.21 mg/100g FW, respectively, compared to the control treatment, which gave 8.78 and 8.95 mg/100g FW for both seasons, respectively. The results of the triple interaction treatment P3B3G3 also showed a significant increase in root arginine content in both seasons, with the highest values of 14.22 and 14.20 mg/100g FW, respectively, compared to the control treatment, which gave the lowest values of 8.16 and 8.25 mg/100g FW for both seasons, respectively.

Table (6) Effect of adding poultry manure, spraying with (BRs), and Reishi mushroom and their interaction on the root content of Threonine for purple carrot plants for the autumn season of 2024 - 2025

		Mid-season				Pre-harvest			
P	B	G			P * B	G			P * B
		G_1	G_2	G_3		G_1	G_2	G_3	
P_1	B_1	10.447	10.657	11.440	10.848	10.497	10.770	11.557	10.941
	B_2	11.200	12.327	13.040	12.189	11.290	12.440	13.107	12.279
	B_3	12.017	13.537	14.123	13.226	12.120	13.463	14.083	13.222
P_2	B_1	10.983	12.147	13.257	12.129	11.053	12.240	13.320	12.204
	B_2	12.387	12.820	13.923	13.043	12.497	12.780	13.897	13.058
	B_3	14.753	15.450	16.297	15.500	14.390	15.387	16.250	15.342
P_3	B_1	11.670	14.137	15.017	13.608	11.753	14.193	15.090	13.679
	B_2	15.217	16.037	16.133	15.796	15.297	16.027	16.143	15.822
	B_3	15.360	16.350	16.407	16.039	15.463	16.403	16.490	16.119
LSD			1.226		1.037		1.200		1.013
		P * G				P * G			

P	G_1	G_2	G_3	Average P	G_1	G_2	G_3	Average P
P_1	11.221	12.173	12.868	12.087	11.302	12.224	12.916	12.147
P_2	12.708	13.472	14.492	13.557	12.647	13.469	14.489	13.535
P_3	14.082	15.508	15.852	15.147	14.171	15.541	15.908	15.207
LSD	1.037			1.055	1.013			1.030
B * G					B * G			
B	G_1	G_2	G_3	Average B	G_1	G_2	G_3	Average B
B_1	11.033	12.313	13.238	12.195	11.101	12.401	13.322	12.275
B_2	12.934	13.728	14.366	13.676	13.028	13.749	14.382	13.720
B_3	14.043	15.112	15.609	14.921	13.991	15.084	15.608	14.894
LSD	1.037			0.318	1.013			0.312
G					G			
G	G_1	G_2	G_3		G_1	G_2	G_3	
Average G	12.670	13.718	14.404		12.707	13.745	14.437	
LSD	0.318				0.312			

The results in Table (6) showed that the addition of poultry manure led to a significant increase in the root content of threonine acid for both seasons, as the treatment P3 was significantly superior in both seasons to the control treatment and gave the highest value of 15.147 and 15.207 mg/100g FW respectively compared to the control treatment P1, which gave the lowest value of 12.087 and 12.147 mg/100g FW for both seasons respectively. Moreover, treatment B3 resulted in a significant increase in the threonine content of purple carrot roots, with the highest levels of 14.921 and 14.894 mg/100g FW, respectively, compared to the control treatment B1, with the lowest levels of 12.195 and 12.275 mg/100g FW for both seasons, respectively. Furthermore, treatment G3 also led to a significant superiority in the root content of threonine acid of purple carrot for both seasons, reaching the highest percentage of 14.404 and 14.437 mg/100g FW, respectively, compared to the control treatment G1, which gave 12.670 and 12.707 mg/100g FW for both seasons, respectively. The results of bilateral interaction P3B3 showed a significant superiority in the root content of threonine in both seasons, giving the highest percentage of 16.039 and 16.119 mg/100g FW, respectively, compared to the control treatment P1B1, which gave the lowest average of 10.848 and 10.941 mg/100g FW for both seasons, respectively. The interaction treatment P3G3 was also significantly superior in both seasons in the root content of threonine acid, giving the highest values of 15.852 and 15.908 mg/100g FW, respectively, compared to the control treatment, which gave 11.221 and 11.302 mg/100g FW, respectively. Whereas, the interaction treatment B3G3 was also significantly superior in both seasons in the root content of threonine acid, giving the highest value of 15.609 and 15.608 mg/100g FW, respectively, compared to the control treatment, which gave 11.033 and 11.101 mg/100g FW, respectively. Moreover, the results of triple interaction treatment P3B3G3 showed a significant superiority in both seasons in the threonine content of the roots, which gave the highest average of 16.407 and 16.490 mg/100g FW, respectively, compared to the control treatment, which gave the lowest value of 10.447 and 10.497 mg/100g FW, respectively.

DISCUSSION

The reason for the superiority of either single, bilateral or triple treatments over the control treatment in the percentage of nitrogen, phosphorus, potassium and organic matter in the soil in the mid-season and pre-harvest, as shown in Tables (1, 2, 3 and 4), may be attributed to the fact that poultry manure is rich in nutrients such as N, P, and K in addition to organic matter (23,24,25). When added to the soil, it acts as a slow-release source of these elements, improving their availability to plants throughout the growing season (26). Furthermore, adding poultry manure to the soil significantly increases its organic matter content, which is the basis for increasing soil fertility (27). Organic matter improves soil structure and increases its capacity to retain water and nutrients (28,29). It also enhances microbial activity in the soil and breaks down organic nitrogen in poultry manure, making it easily absorbed (30). Similarly, the phosphorus and potassium present in organic manure become slowly available, reducing their loss and ensuring their sustainability in the root zone (31,32). This gradual decomposition of nutrients corresponds to the noticeable mid-season increase in soil fertility. The indirect effect of Brassinosteroids and the aqueous extract of reishi mushroom on soil fertility via foliar spraying does not mean that the effect is limited to the leaves alone; rather, the plant reacts hormonally and physiologically when its leaves are sprayed and changes its root behavior. This effect is known as the rhizosphere effect, i.e., the effect of the root zone on the surrounding soil (33,34). Therefore, the roots become more active and secrete compounds that affect their surrounding environment in the soil (35). This explains the increase in the nitrogen, phosphorus, potassium, and organic matter content in the soil (36). Brassinosteroids stimulate the activity of enzymes involved in the metabolism of these elements. This stimulation not only increases nutrient uptake by the plant but can also contribute to the stabilization of these elements in the root zone (37,38), thus reducing their loss from the soil. This indirect effect of Brassinosteroids has contributed to an increased concentration of nutrients in the plant biomass and, consequently, in the soil surrounding the roots (39). The effect of Reishi mushroom extract (Ganoderma lucidum) and its polysaccharides, triterpenes, and phenols may be due to the enhancement of microbial activity (40,41), which may lead to the decomposition of organic matter in poultry manure, resulting in the release of more nitrogen, phosphorus, and potassium in forms that are easily absorbed by plants (42,43). Furthermore, these microbes can contribute to the formation of stable organic compounds in the soil, increasing the total organic matter content and improving soil fertility throughout the growing season (44). This microbial interaction leads to increased nutrient availability mid-season. In summary, the effects of the three studied factors show that poultry manure added to the soil adds nutrients and organic matter, and reishi mushroom extract enhances the activity of microbes to burn this fuel and convert it into available energy and nutrients. Brassinosteroids improve the roots to draw these nutrients in larger quantities and with higher efficiency (addition - breakdown - absorption), leading to a significant accumulation of nutrients and organic matter in the soil, which was measured mid-season. Therefore, the interactions between

P3 × B3 × G3 recorded the highest values, indicating the effectiveness of these treatments in enhancing soil fertility. The values of nitrogen, phosphorus, potassium, and soil organic matter at mid-season were significantly higher than before harvest, as shown in Tables 1, 2, 3, and 4. The decrease in soil nitrogen, phosphorus, potassium, and organic matter levels pre-harvest may be attributed to several factors, including:

1. Carrot plants undergo two stages of growth: vegetative growth and root formation (carrot) development, during the second half of the growing season. These stages represent peak nutrient demand (45,46).
2. Plants treated with Brassinosteroids and reishi mushroom extract developed strong root systems and significant vegetative growth, indicating a greater need for nutrients. Consequently, these plants absorb large amounts of nitrogen for protein synthesis, chlorophyll, phosphorus (for energy transport), and potassium (for regulating osmotic pressure and transporting sugars) from the soil. This intensive uptake exceeds the rate of nutrient addition from compost decomposition, resulting in a lower net soil concentration.
3. Depletion of nutrient sources: Although poultry manure provides a slow release of nutrients, the plant's uptake rate in later stages of growth may exceed the release rate from the organic fertilizer. This leads to a gradual depletion of available nitrogen, phosphorus, and potassium stocks in the soil. Studies show that soil fertility can decline after a period of intensive cultivation unless the depleted nutrients are replenished (47,48).
4. Decomposition and Consumption of Organic Matter: The organic matter in poultry manure is rapidly consumed by active microbes thanks to the effects of Brassinosteroids and reishi mushroom extract. The microbes utilize the carbon in the organic matter as an energy source and absorb nutrients, a process called mineralization (49,50). By the end of the season, most of the easily decomposed organic matter has been mineralized and consumed, resulting in a record low in soil organic matter. This does not signify soil degradation; rather, it means that the organic matter has successfully fulfilled its purpose and been converted into plant material (51).
5. Effects of Brassinosteroids and Reishi Mushroom Extract in Later Stages: While Brassinosteroids and Reishi mushroom extract enhance nutrient uptake and microbial activity in the early and middle stages, their effect on nutrient dynamics may change as the season progresses. In the later stages, these factors may have already led to maximum uptake of available nutrients, contributing to lower residual levels in the soil. This reflects the dynamics of the nutrient cycle, as shown in Tables 1, 2, 3, and 4. As for the effect on the properties of the amino acids threonine and arginine in the roots, as shown in (Table 5 and 6) and their significant increase as a result of adding poultry manure, this may be due to it being a rich source of organic nitrogen (52), which is the basis for the manufacture of protein and amino acids. Through the microbial decomposition of poultry manure in the soil, and the improvement of the microbiological environment, the activity and mass of soil microorganisms (nitrogen-fixing and decomposing bacteria) increase. This nitrogen is converted into mineral forms (ammonium and then nitrate) that are available to the plant over the long term. This prevents leaching loss and provides sustainable and balanced nutrition (53,54). This improves nutrient cycling and increases the efficiency of root uptake of nitrogen and other essential elements for protein synthesis and amino acids, such as sulfur and magnesium (55). As for the role of Brassinosteroids, in the significant increase of the amino acids arginine and threonine, it comes through its function as a hormonal signal that regulates the expression of the main genes and enzymes in nitrogen metabolism. Research indicates that it activates the nitrate reductase (NR) gene and the nitrite reductase (NiR) genes, which are the two enzymes responsible for reducing nitrate (NO_3^-) absorbed from the soil to nitrite (NO_2^-) and then to ammonium (NH_4^+), which is the first and crucial step for nitrogen to enter the cycle of protein and amino acid synthesis (56). Moreover, Brassinosteroids also stimulate the synthesis of the GS/GOGAT enzyme: this enzyme system is the main pathway for incorporating ammonium into the glutamate structure, which in turn acts as an amino group donor for the synthesis of protein and all other amino acids (57). The third factor, Reishi mushroom extract (G), may have a significant effect on increasing total protein and amino acids due to its role as a biostimulant and growth promoter. The extract contains beta-glucans, triterpenoids, and organic acids that act as biostimulants (58,59,40). It stimulates the activity of enzymes involved in nitrogen and carbon metabolism, thus increasing the efficiency of converting absorbed nitrogen into protein compounds (60). It also enhances stress resistance by improving the overall health of the root biosystem (61), where Reishi mushroom extract reduces stress on the plant, enabling it to direct energy and resources towards biosynthesis (anabolism) such as protein and amino acid synthesis, rather than catabolism or defense. Interactions and Synergies: The significant increase in protein and amino acid levels when treatments were applied in a binary or triple interaction indicates synergistic effects between the factors. Organic fertilizer (P) provided the raw material (nitrogen), while Brassinosteroids acted as a regulator activating the enzymatic mechanism for processing this raw material, and reishi mushroom extract (G) supported and protected the efficiency of this mechanism. This synergy resulted in a net increase in total protein and amino acid synthesis in the roots in both binary and triple interactions.

CONCLUSIONS

The use of single factors (decomposed poultry manure at 10,000 kg/ha), the growth regulator Brassinosteroids at a concentration of 2 mg/L, and a 10% aqueous extract of Reishi mushroom) led to good results in increasing the concentration of nitrogen, phosphorus, and potassium, in addition to organic matter, and improving the qualitative characteristics of purple carrot roots, represented by the amino acids arginine and threonine. Furthermore, the interaction between decomposed poultry manure (10,000 kg/ha) and (BRs) at a concentration of 2 mg/L, the interaction between decomposed poultry manure (10,000 kg/ha) and a 10% aqueous extract of Reishi mushroom, and the interaction between (BRs) at a concentration of 2 mg/L and a 10% aqueous extract of Reishi mushroom also produced positive results, and gave results greater than the single factors in outperforming the single factors. Besides, using the combination of three treatments – 10,000 kg/ha of decomposed poultry manure, Brassinosteroids at a concentration of 2 mg/L, and a 10% aqueous extract of Reishi mushroom gave greater results than single and double treatment of this combination in creating an effective effect on the soil content of elements N, P, K, and organic matter, and significantly improved the qualitative characteristics of purple carrot roots in both seasons, specifically the amino acids arginine and threonine.

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