

Effect of Soil-Applied Phosphorus and Foliar Application of Dry Yeast Extract on the Chemical Characteristics of *Fragaria × ananassa* Duch.

Mahmoud jasem Mohammed

Department of Horticulture and Landscape Design, College of Agriculture,
Tikrit University, Iraq

E-mail: mahmood.j.mohameed@tu.edu.iq

Abstract

A greenhouse experiment was conducted at the Department of Horticulture and Landscape Engineering, College of Agriculture, Tikrit University, during the 2024–2025 growing season to evaluate the effects of soil-applied phosphorus and foliar application of dry yeast extract on the chemical characteristics of strawberry plants (*Fragaria × ananassa* Duch.), cv. 'Ruby Gem', cultivated in plastic pots. The first factor consisted of three phosphorus levels (0, 15, and 30 g plant⁻¹), designated as P0, P1, and P2, respectively. The second factor involved foliar application of dry yeast extract at three concentrations (0, 5, and 10 g L⁻¹), denoted as Y0, Y1, and Y2, respectively. The experiment was arranged in a randomized complete block design (RCBD) with three replicates. Treatment means were compared using Duncan's multiple range test at the 0.05 probability level. Overall, both phosphorus fertilization and yeast extract application, particularly their interaction, exerted significant positive effects on most of the measured chemical traits of strawberry plants. The first factor at level P2 demonstrated superiority in improving the mineral composition (N, P, K), increasing carbohydrate content and vitamin C, as well as reducing total acidity, indicating its significant role in enhancing vegetative and fruit chemical characteristics. The recorded values were as follows: nitrogen (1.220%), phosphorus (0.209%), potassium (1.709%), carbohydrates (0.184%), and vitamin C in fruits (42.49 mg/100 mL juice). Total acidity decreased with increasing phosphorus level, reaching 1.166%.

The second factor at concentration Y2 showed superiority in promoting nutrient uptake, stimulating physiological processes, and improving fruit quality by increasing vitamin C content and reducing total acidity. The obtained values were: nitrogen (1.229%), phosphorus (0.206%), potassium (2.260%), carbohydrates (0.191%), and vitamin C (42.73 mg/100 mL juice). Total acidity was reduced compared with Y0.

The interaction between phosphorus and yeast exhibited a statistically significant effect on nearly all studied traits. The P2Y2 treatment was superior in most parameters, recording nitrogen (1.310%), phosphorus (0.213%), potassium (2.561%), carbohydrates (0.206%), and vitamin C (44.22 mg/100 mL juice). Regarding total acidity, the lowest value was observed under the P2Y0 treatment (1.235%).

Keywords: strawberry, phosphorus fertilization, foliar feeding, yeast extract.

Introduction

Strawberry (*Fragaria × ananassa* Duch.) is considered one of the most important small fruit crops of substantial nutritional and economic value worldwide. The crop is widely cultivated owing to the high market demand for its fruits and their

richness in health-promoting compounds. Strawberry fruits are well recognized as an excellent source of vitamin C, anthocyanins, phenolic compounds, and antioxidants, which contribute to their classification as functional foods associated with improved human health

and reduced risk of several diseases (12; 10). Botanically, *Fragaria* × *ananassa* belongs to the family Rosaceae and is a perennial herbaceous plant characterized by its high adaptability to a broad range of environmental and climatic conditions. Although native to North America, strawberry cultivation has expanded globally, and the fruit currently ranks fourth worldwide in consumption after apple, orange, and banana (4). Recent research has demonstrated that strawberry growth, productivity, and fruit quality are strongly influenced by the efficiency of mineral nutrition management and prevailing environmental conditions, as fluctuations in nutrient availability can markedly affect vegetative growth, physiological performance, and fruit chemical composition (11).

Phosphorus is an essential macronutrient required for normal plant growth and development, playing a central role in numerous physiological and biochemical processes. It is directly involved in carbohydrate metabolism and energy transfer reactions associated with photosynthesis, thereby facilitating the release and utilization of energy necessary for vital cellular activities. Phosphorus is also a structural component of key cellular membranes, including the plasma membrane, mitochondrial membranes, chloroplast membranes, and the tonoplast. Moreover, adequate phosphorus nutrition enhances stem strength, improves plant tolerance to certain diseases, and plays a crucial role in the synthesis and transfer of genetic material (DNA and RNA). In addition, phosphorus promotes root initiation and development and contributes significantly to flower formation and fruit set (5).

Previous studies have confirmed the positive effects of phosphorus fertilization on plant growth and nutrient status. (1) reported that applying

phosphorus at 45 g tree⁻¹ significantly improved main stem height and diameter, number of primary branches, individual leaf area, dry matter percentage in leaves and branches, and leaf contents of phosphorus, potassium, and carbohydrates. Similarly, (9) evaluated different macronutrient levels in Kinnow mandarin and found that the interaction between phosphorus (as P₂ O₅) and potassium (as K₂ O) at rates of 150–300 g tree⁻¹ significantly enhanced leaf NPK content. (8) also observed that the application of compound fertilizer at 50 g seedling⁻¹ resulted in significant increases in carbohydrate concentration and leaf NPK content. Similarly, (16) examined the effect of different levels of diammonium phosphate (DAP) fertilizer on the growth of two-year-old apricot seedlings. The results revealed that the application of 13 g per seedling significantly outperformed all other treatments across all measured growth parameters. Furthermore, (15) reported that the application of diammonium phosphate (DAP) fertilizer at a rate of 300 g per tree to date palm cultivars *Khadhrawi* and *Khastawi* led to significant improvements in vegetative growth. Foliar fertilization has become an important complementary practice in modern agricultural systems. Numerous studies have demonstrated that plants and fruit trees can efficiently absorb nutrients supplied through foliar sprays, resulting in rapid physiological responses (6). Foliar fertilization is considered more efficient than soil fertilization under certain conditions when applied in accordance with crop nutritional requirements. However, it is generally regarded as a supplementary practice rather than a replacement for soil fertilization, particularly with respect to macronutrients, and therefore cannot fully substitute conventional soil nutrient applications. Nevertheless, foliar fertilization plays a significant role in

high-value crops because it enables the rapid delivery of nutrients to plant tissues and enhances nutrient uptake efficiency (13). In this context, (14) conducted a study on eight-year-old *Black Hamburg* grapevines trained using the pergola system. Their findings demonstrated that foliar spraying with two concentrations of yeast extract significantly increased the leaf content of essential macronutrients (N, P, and K), in addition to increasing total carbohydrate content. In this context, natural biostimulants such as yeast extract have attracted increasing attention. Foliar application of baker's

yeast extract has been reported to improve several physiological growth parameters, including chlorophyll concentration, accumulation of bioactive compounds, and plant tolerance to environmental stresses such as water deficit. These beneficial effects are largely attributed to the presence of vitamins, amino acids, and naturally occurring growth regulators that stimulate plant metabolic activity (2). Likewise, (3) reported that spraying with dry yeast extract significantly enhanced leaf chemical properties and increased chlorophyll content

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Research Objectives

The present study was designed to achieve the following objectives:

To evaluate the effects of different phosphorus fertilization levels on the chemical characteristics of strawberry plants.

To assess the effectiveness of foliar application of dry yeast extract in improving the chemical properties of the plants.

1. To investigate the interaction between phosphorus fertilization and dry yeast extract spray in order to determine the optimum treatment combination for enhancing chemical performance.

Materials and Methods

The experiment was conducted under greenhouse conditions at the Department of Horticulture and Landscape Engineering, College of Agriculture, Tikrit University, during the 2024–2025 growing season. The study aimed to evaluate the effects of soil-applied phosphorus and foliar spraying with dry

yeast extract on the chemical properties of strawberry plants grown in plastic pots.

The experiment was arranged as a factorial trial within a randomized complete block design (RCBD). Two experimental factors were investigated. The first factor (P) consisted of soil application of phosphorus at three levels: 0, 15, and 30 g plant⁻¹, designated as P0, P1, and P2, respectively. The second factor (Y) involved foliar spraying of baker's yeast extract at three concentrations: 0, 5, and 10 g L⁻¹, denoted as Y0, Y1, and Y2, respectively.

Accordingly, the experiment comprised nine treatment combinations. Each treatment was replicated three times, resulting in a total of 27 experimental units (3 × 3 × 3). Prior to planting, soil samples were collected and analyzed in the Soil and Water Sciences Laboratory to determine the physical and chemical properties of the experimental soil. The analytical results are presented in Table (1).

Table1: Physical and Chemical Properties of Soil

Parameter	Value	Unit
Sand	66.8	%
Silt	25.5	%
Clay	7.7	%
Soil texture	Clay loam	-
pH	7.55	-
Nitrate (NO ₃ -)	11.1	mg kg ⁻¹
Ammonium (NH ₄ ⁺)	16.3	mg kg ⁻¹
Available P	14.1	g kg ⁻¹
Available K	3.8	g kg ⁻¹
Electrical conductivity (EC)	3.32	dS m ⁻¹
Organic matter	10.3	g kg ⁻¹
Calcium carbonate	142	g kg ⁻¹
Gypsum	8	g kg ⁻¹

Results and Discussion

The data presented in Table (2) revealed that phosphorus fertilization levels, foliar application of dry yeast extract, and their interaction had a significant effect on the nitrogen percentage in strawberry leaves.

Table (2). Effect of phosphorus fertilization and foliar application of dry yeast extract and their interaction on leaf nitrogen percentage in strawberry plants.

Yeast Level	P0	P1	P2	Mean (Y)
Y0	1.116 de	1.115 e	1.119 d	1.117 c
Y1	1.119 d	1.119 d	1.231 c	1.156 b
Y2	1.117 de	1.259 b	1.310 a	1.229 a
Mean (P)	1.118 c	1.164 b	1.220 a	

The results presented in Table (3) indicated that both phosphorus fertilization and foliar application of dry yeast extract significantly increased the phosphorus content in strawberry leaves.

Increasing the rate of phosphorus application was associated with a gradual improvement in leaf nitrogen content. Treatment P2 recorded the highest overall mean (1.220%), followed by P1 (1.164%), whereas the lowest value was observed under the control treatment P0 (1.118%).

A similar trend was observed with foliar application of yeast extract. Plants sprayed with the highest concentration (Y2) exhibited superior performance, achieving the highest overall mean nitrogen content (1.229%) compared with the lower spray levels. This response may be attributed to the stimulatory role of yeast extract in enhancing metabolic activity and nutrient assimilation.

Regarding the interaction effect, the combined treatment P2Y2 produced the highest nitrogen percentage in the leaves (1.310%), indicating a synergistic relationship between adequate phosphorus supply and yeast-derived biostimulants. In contrast, the lowest nitrogen content (1.116%) was recorded in the untreated control (P0Y0). These findings suggest that integrating soil phosphorus fertilization with foliar yeast application can effectively enhance nitrogen accumulation in strawberry foliage.

An upward trend in leaf phosphorus percentage was observed with increasing soil-applied phosphorus levels. Treatment P2 recorded the highest mean value (0.209%), whereas the control treatment P0 showed the lowest values.

Foliar spraying with yeast extract also exerted a positive effect. Plants treated with the highest concentration (Y2) produced the greatest average leaf phosphorus content (0.206%) compared with the lower spray levels. This improvement may be attributed to the role of yeast extract in enhancing nutrient uptake efficiency and metabolic activity within plant tissues.

With respect to the interaction effect, the combined treatment P2Y2 achieved the highest phosphorus percentage in the leaves (0.213%), confirming the synergistic effect between adequate phosphorus supply and foliar biostimulation. In contrast, the lowest phosphorus content (0.182%) was recorded in the untreated control (P0Y0).

Table (3). Effect of phosphorus fertilization and foliar application of dry yeast extract and their interaction on leaf phosphorus percentage in strawberry plants.

Yeast Level	P0	P1	P2	Mean (Y)
Y0	0.182 f	0.183 f	0.201 c	0.189 c
Y1	0.191 e	0.188 e	0.212 ab	0.197 b
Y2	0.197 d	0.209 b	0.213 a	0.206 a
Mean (P)	0.189 c	0.193 b	0.209 a	

The results shown in Table (4) demonstrated that phosphorus fertilization and foliar application of dry yeast extract significantly enhanced the potassium content in strawberry leaves. Increasing the level of soil-applied phosphorus resulted in a gradual improvement in leaf potassium percentage, with treatment P2 recording the highest overall mean (1.709%) compared with the lower phosphorus levels.

superiority, achieving the greatest mean potassium content (2.260%), which reflects the stimulatory role of yeast extract in improving nutrient uptake and physiological activity.

Foliar spraying with yeast extract produced a similar positive response. The highest spray level (Y2) showed clear

The interaction between the two factors was also significant. The combined treatment P2Y2 produced the highest potassium percentage (2.561%), indicating a strong synergistic effect between phosphorus nutrition and yeast extract application. In contrast, the lowest potassium content (1.141%) was recorded in the untreated control (P0Y0).

Table (4). Effect of phosphorus fertilization and foliar application of dry yeast extract and their interaction on leaf potassium percentage in strawberry plants.

Yeast Level	P0	P1	P2	Mean (Y)
Y0	1.141 g	1.137 g	1.140 g	1.139 c
Y1	1.410 f	1.892 e	2.121 c	1.808 b
Y2	2.561 a	2.086 b	2.135 b	2.260 a
Mean (P)	1.704 b	1.705 b	1.709 a	

The results presented in Table (5) indicated that both phosphorus fertilization and foliar application of dry yeast extract significantly increased carbohydrate content in strawberry leaves. A progressive rise in carbohydrate percentage was observed with increasing phosphorus levels, where treatment P2 recorded the highest mean value (0.184%) compared with the lower phosphorus treatments.

Foliar spraying with yeast extract also produced a marked improvement. The highest concentration (Y2) showed clear

superiority, achieving the greatest mean carbohydrate content (0.191%). This enhancement may be attributed to the stimulatory effect of yeast extract on photosynthetic efficiency and metabolic activity.

The interaction between phosphorus and yeast extract was significant, as the combined treatment P2Y2 produced the highest carbohydrate percentage (0.206%), indicating a synergistic effect between adequate phosphorus nutrition and foliar biostimulation

Table (5). Effect of phosphorus fertilization and foliar application of dry yeast extract and their interaction on leaf carbohydrate percentage in strawberry plants.

Yeast Level	P0	P1	P2	Mean (Y)
Y0	0.152 f	0.149 f	0.165 e	0.155 c
Y1	0.162 e	0.165 e	0.183 c	0.170 b
Y2	0.173 d	0.195 b	0.206 a	0.191 a
Mean (P)	0.162 c	0.170 b	0.184 a	

The results presented in Table (6) indicated that phosphorus fertilization and foliar application of dry yeast extract significantly reduced total acidity in strawberry fruits. A clear decreasing trend in total acidity was observed with increasing phosphorus levels, where the overall mean declined from 1.248% under P0 to 1.166% under P2.

Foliar application of yeast extract also contributed to lowering fruit acidity. Both Y1 and Y2 treatments produced reduced acidity values compared with the

untreated control, suggesting a positive role of yeast extract in enhancing fruit maturation and metabolic conversion of organic acids.

Regarding the interaction effect, treatment P2Y0 recorded the lowest total acidity (1.235%), whereas the highest value (1.495%) was observed in the control treatment P0Y0. These results indicate that improved phosphorus nutrition, with or without yeast application, can contribute to moderating fruit acidity and improving fruit quality.

Table (6). Effect of phosphorus fertilization and foliar application of dry yeast extract and their interaction on total acidity percentage in strawberry fruits.

Yeast Level	P0	P1	P2	Mean (Y)
Y0	1.495 a	1.302 b	1.235 c	1.344 a
Y1	1.121 f	1.128 e	1.131 de	1.126 c
Y2	1.128 e	1.131 de	1.134 d	1.131 b
Mean (P)	1.248 a	1.187 b	1.166 c	

The results presented in Table (7) demonstrated that phosphorus fertilization and foliar application of dry yeast extract significantly enhanced vitamin C content in strawberry fruits. An increasing trend in ascorbic acid concentration was observed with higher phosphorus levels, where treatment P2 recorded the highest mean value (42.49 mg 100 ml⁻¹ juice) compared with the lower phosphorus treatments.

Foliar spraying with yeast extract also exerted a positive effect. The highest

concentration (Y2) produced the greatest average vitamin C content (42.73 mg 100 ml⁻¹ juice), indicating the beneficial role of yeast extract in improving fruit biochemical quality.

The interaction between the two factors was significant, as the combined treatment P2Y2 achieved the maximum vitamin C content (44.22 mg 100 ml⁻¹ juice). This result reflects the synergistic influence of adequate phosphorus nutrition and yeast-derived biostimulants on enhancing the nutritional quality of strawberry fruits.

Table (7). Effect of phosphorus fertilization and foliar application of dry yeast extract and their interaction on vitamin C content (mg 100 ml⁻¹ juice) in strawberry fruits.

Yeast Level	P0	P1	P2	Mean (Y)
Y0	40.17 f	40.13 fg	41.04 e	40.45 c
Y1	40.11 a	41.23 d	42.22 c	41.18 b
Y2	40.16 fg	43.82 b	44.22 a	42.73 a
Mean (P)	40.15 c	41.72 b	42.49 a	

The overall findings of the present study clearly demonstrated that soil application of phosphorus combined with foliar spraying of dry yeast extract exerted a pronounced synergistic effect on the nutritional status of strawberry plants and on fruit quality attributes. A consistent and significant improvement was observed in leaf nitrogen, phosphorus,

and potassium contents with increasing phosphorus levels and yeast extract application. Notably, the interaction treatment (P2 × Y2) outperformed the control (P0 × Y0) for all measured macronutrients, indicating enhanced nutrient uptake efficiency and more effective internal translocation of N, P, and K. These results are in agreement

with earlier reports highlighting the positive role of foliar biostimulants in increasing leaf mineral content (8).

The observed increase in foliar nitrogen reflects improved metabolic capacity for protein and amino acid biosynthesis. This response is consistent with previous findings indicating that foliar application of biostimulants can enhance the accumulation of phosphorus and potassium in leaves, as well as increase chlorophyll concentration and overall physiological activity (3).

Furthermore, significant increases in leaf carbohydrate content were recorded with increasing levels of phosphorus and yeast extract. This trend likely reflects enhanced photosynthetic efficiency and improved source–sink relationships within the plant. The role of phosphorus in the Calvin cycle and in ATP-mediated energy transfer is well documented, and adequate phosphorus supply is essential for efficient carbohydrate synthesis and translocation.

Fruit quality parameters were also positively influenced. Total acidity declined progressively with higher phosphorus and yeast treatments, suggesting an acceleration of ripening processes and greater conversion of

Conclusions

1. Soil application of phosphorus significantly improved the chemical characteristics of strawberry plants, including increased leaf nitrogen, phosphorus, potassium, and carbohydrate contents.
2. Increasing phosphorus levels contributed to improving fruit quality by increasing vitamin C content and reducing total acidity.
3. Foliar application of dry yeast extract enhanced nutrient uptake and stimulated physiological

organic acids into sugars. Conversely, vitamin C content increased markedly under the superior interaction treatments, thereby improving the nutritional and functional quality of the fruits. These responses are consistent with recent studies reporting that integrated phosphorus fertilization and foliar nutrition can enhance both mineral composition and quality-related metabolites in strawberry fruits.

According to (7), phosphorus plays a pivotal role in ATP generation required for active absorption and translocation processes, whereas the organic constituents and growth-promoting substances present in yeast extract stimulate enzymatic and hormonal activity within plant tissues. Such effects ultimately improve nutrient use efficiency and promote the biosynthesis of secondary metabolites associated with fruit quality.

In light of the growing demand for cost-effective and sustainable horticultural practices, the present findings support the integrated use of soil-applied phosphorus and foliar biostimulants as a practical strategy to enhance both productivity and fruit quality in strawberry cultivation system

processes, leading to higher carbohydrate accumulation and improved biochemical properties of the fruits.

4. The interaction between phosphorus fertilization and yeast extract application showed a positive synergistic effect on most of the studied traits.

Recommendations

1. The application of phosphorus at a rate of 30 g plant⁻¹ (P2) is recommended for strawberry cultivation under greenhouse

- conditions due to its significant role in improving plant nutritional status and enhancing fruit quality.
- Foliar spraying with dry yeast extract at a concentration of 10 g L⁻¹ (Y2) is recommended as a natural bio stimulant to stimulate physiological activity, enhance nutrient uptake, and improve the biochemical quality of strawberry fruits.
 - The combined application of P2 × Y2 is recommended as the most effective treatment for improving

leaf mineral composition, increasing carbohydrate accumulation, and enhancing vitamin C content in strawberry fruits.

- The integration of yeast extract as a natural bio stimulant within strawberry fertilization programs is recommended as a sustainable and environmentally friendly practice; further studies are suggested to evaluate its effects under field conditions and on yield and postharvest quality

Appendices

Sov	d.f	Table 2	Table 3	Table 4	Table 5	Table 6	Table 7
R BlocK	2	0.00000026	0.00000193	0.00000811	0.00002181	0.00000904	0.001048
P	2	0.02897	0.0006513	2.8634	0.002904	0.1387	12.2509
Y	2	0.02357	0.0009373	0.0264	0.001131	0.0160	12.8576
P*y	4	0.009345	0.00008693	0.2864	0.0001417	0.0193	3.1321
Error	16	0.00000309	0.00000409	0.00000565	0.00000602	0.00000479	0.001198

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