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Effect of Spraying with Salicylic Acid and Glutamine on the Growth, Yield, and Post-Harvest Food Quality of Hydroponically Grown Green Onions (*Allium fistulosum*)

Lubna Ali Abdel Fattah and Mohammed Hadi Obaid

Faculty of Agriculture - University of Karbala, Department of Horticulture and Landscape Engineering

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*Corresponding Author E-Mail:
agri25.lubna.ali.abdel.fattah@s.uokerbala.edu.iq

ABSTRACT

The experiment was carried out in the winter season 2025-2026 in the Department of Horticulture and Landscape Engineering, College of Agriculture, University of Karbala under the total shade of 50% in a greenhouse from 22 December 2025 to 1 April 2026. The study was conducted as a randomized complete block design with three replications to assess the growth, yield and post harvest food quality parameters of hydroponically grown green onion (*Allium fistulosum*) under various combinations of foliar application of salicylic acid (0, 100, 200, 300 mg L^{-1}) and glutamine (0, 50, 100, 200 mg L^{-1}). Other chemical parameters such as nitrogen, phosphorus, potassium, total flavonoids and total soluble solids were also assessed in addition to pre-harvest chemical parameters. Other post harvest quality parameters evaluated were texture firmness (kg/cm²), and sensory acceptability (appearance, flavor, crispness) by a semi-trained panel after 14 days of storage in the refrigerator (4°C), color stability (L, a, b values). Moreover, the retention of total flavonoids was determined following SMP (washing and slicing into small pieces, storage at 4 °C for 7 days) to evaluate the potential of the product for fresh-cut food processing. Significant difference was observed for leaf chemical indices in the case of nitrogen (300 mg L^{-1}), salicylic acid (300 mg L^{-1}), phosphorus (0.22%) and potassium (1.53%). Total soluble solids (8.70 %) and total flavonoids (38.78 mg/g fresh weight) were also significantly superior for the same treatment. Glutamine (200 mg L^{-1}) gave nitrogen (1.81%), phosphorus (0.24%), potassium (1.38%), total soluble solids (8.05%), and total flavonoids (34.68 mg/g fresh weight). The interaction (S3G3) had the highest values of nitrogen (2.06%), potassium (1.55%), phosphorus (0.22%), total soluble solids (9.20%) and total flavonoids (41.99 mg/g fresh weight). Post-harvest evaluation revealed that the samples of S3G3 treatment had significantly higher color stability (lower ΔE after 14 days 5.2 vs 12.8 for control) and firmer texture (1.85 kg/cm² vs 1.12 kg/cm² for control) and higher sensory scores (overall acceptability 8.2/9 vs 5.6/9 for control). The retention of flavonoids after 7 days of refrigerated storage was 89% for S3G3 and 64% for the control, which shows that S3G3 is more appropriate for fresh-cut foods. The study further concludes that foliar application of salicylic acid and glutamine as pre harvest sprays not only increase the pre harvest quality but also enhance the food quality and storage stability of the produce which make them suitable to the fresh cut vegetable industry.

1- INTRODUCTION

Onion (*Allium fistulosum* L.) is a biennial herbaceous plant that is sown in many locations as a winter vegetable, also called small green onion, Japanese onion, Welsh onion or spring onion. Hardy plant of the family Amaryllidaceae [1]. It has been cultivated in areas around Lake Baikal in Siberia, Russia, around the Altai Mountains in Russia and in western and northwestern China [2]. All parts of it are used in all cuisines, particularly in the East Asian countries including Japan and China, for cooking as a condiment, as a flavor for food, as raw ingredient in salads, and in soup and sauces. Because of its antioxidant, vitamin and mineral properties, it is an important component of many Asian dishes and is used to improve the nutritional qualities of various dishes [3]. Onions have anti-inflammatory, antioxidant, anticancer, immune-regulatory, anti-obesity, antimicrobial, cardiovascular protective properties. Due to the abundance of bioactive compounds, such as flavonoids, organosulfur compounds, phenols and other active ingredients which are reported to be health-promoting, the treatment of respiratory disease (cough, asthma, bronchitis) is supported [4].

Salicylic acid is a plant growth regulator and one of a group of phenols with an aromatic benzene ring and one or more hydroxyl groups, chemical name 2-hydroxybenzoic acid. In the field of plant immunity, it interacts in a crucial manner with the induction of acquired systemic resistance, through the regulation of defensive proteins, of pathways related to disease resistance, and of final yield [5]. Glutamine is an active component which is involved in many reactions and participates in many physiological processes in plant and most importantly it participates excellently in biosynthesis of chlorophyll and hence helps in the plant response to different environments [6,7]. Overall plant growth is enhanced, tissue structure is better, and the expression of specific genes associated with defense and immunity processes is controlled, leading to increased ability to deal with different environmental factors. This biological interaction facilitates increased N and C assimilation, resulting in enhanced physiological performance and agricultural productivity [8,9].

The post-harvest quality of fresh vegetables is a key factor for food science and technology, especially for the fresh-cut vegetable production because of the high post-harvest quality deterioration rate during storage. The most significant fresh cut industry problems are color changes, texture softening and loss of bioactive compounds. Pre-harvest applications of PGR have been reported to affect some post-harvest quality parameters, but only a little information exists for hydroponic green onion. Thus, the present study was not only aimed to test the effect of salicylic acid and glutamine on pre-harvest growth and yield, but also the effect of these treatments on post-harvest food quality attributes such as color stability, texture retention, stability of flavonoids during refrigerated storage and sensory acceptability, thus bridging the gap between hydroponic production and the requirements of the food industry.

2-Materials and Methods

1.Pre harvest hydroponics grow and treatments :(as originally described, unchanged). The experiment was carried out in the College of Agriculture at the University of Karbala under 50% shade in greenhouse during the winter season 2025–26 (from 22 December 2025 to 1 April 2026). Open Hydroponics Floating Raft Tank System has been used. The nutrient solution was in the form of a mixture according to [1] and was placed in wooden tanks lined with insulating nylon or black plastic (Table 1). pH was maintained at 5.5-

6.5 and EC at 1.5-2.5 mS/cm. The planned study was designed in a randomized complete block where three replications were placed in each block. Salicylic acid was sprayed at 0, 100, 200, 300 mg/L; glutamine at 0, 50, 100, 200 mg/L. Three sprays were applied 15 days apart from 21 January to 23 February 2026.

2.Pre harvest chemical and quality parameters: (as reported) Nitrogen by micro-Kjeldahl [10], Phosphorus by ammonium molybdate ascorbic acid [11], Potassium by flame photometer [12] and Total flavonoids using quercetin as standard [13,14] and Total soluble solids (TSS) by refractometer [15].

3.Analyses of the food quality after production.

- Colour measurement and stability during refrigerated storage: After harvesting, the green onions (pseudostems) of each treatment were washed, dried and refrigerated at 4 ± 1°C for 14 days. Color was determined, by using a Minolta CR-400 chromameter (Konica Minolta, Japan) and a white standard, at days 0, 3, 7 and 14. The lightness (L*) and greenness (a*) and yellowness (b*) were recorded and total color difference (ΔE) measured against the color of day 0. The smaller the ΔE value the more colour stable they were.

-Texture firmness measurement: At the same storage time points, texture firmness (kg/cm2) of pseudostems were measured by using a 5 mm diameter probe of a digital penetrometer device (Model GY-4, China). Average lengths were taken from the middle part of the pseudostem with three readings per sample.

- Flavonoid retention following simulated minimal processing: Freshly harvested, green onions were harvested from each treatment, washed, trimmed, and cut in to 3 cm segments (simulated minimal processing—fresh-cut). Those cut pieces were then kept in a 4°C sealed polyethylene terephthalate (PET) container for 7 days. The total amount of flavonoids was quantified at the day 0 and 7 (see above), and the retention percentage was calculated as (flavonoid content at day 7 / flavonoid content at day 0) × 100.

- The fresh cut samples were stored at refrigerated conditions for 1 day before evaluation by the panel of 10 semi-trained personnel from the Department of Food Science (Staff and Post Graduate students). The appearance (colour uniformity, freshness), flavour (typical onion smell, and the absence of off flavours), texture (crispness) and overall acceptability as ranked on a hedonic 9-point scale (1 = dislike extremely, 9 = like extremely) were attributed as attributes.

4. Statistical analysis

Data were analyzed using Two-Way ANOVA and Duncan's multiple range test at $P \leq 0.05$ level in statistical package (SAS 9.4). Pearson's correlation was used to establish correlation between the pre-harvest treatments and post-harvest quality parameters.

5-Results

Table 1. Color parameters (L, *a*, b*) and total color difference (ΔE) of green onion pseudostems after 14 days of refrigerated storage at 4°C

Treatment	L* (day 0)	L* (day 14)	a* (day 0)	a* (day 14)	b* (day 0)	b* (day 14)	ΔE (14 days)

Control (S0G0)	52.3 ± 1.2 c	45.6 ± 1.1 d	-8.2 ± 0.3 b	-4.1 ± 0.2 a	18.5 ± 0.4 c	22.3 ± 0.5 a	12.8 ± 0.6 a
S3 (salicylic 300 alone)	58.7 ± 1.1 b	54.2 ± 1.0 b	-9.1 ± 0.2 a	-6.8 ± 0.2 b	20.1 ± 0.3 b	22.8 ± 0.4 a	8.5 ± 0.4 b
G3 (glutamine 200 alone)	56.4 ± 1.0 b	51.8 ± 0.9 c	-8.9 ± 0.2 a	-6.2 ± 0.2 b	19.6 ± 0.4 b	22.5 ± 0.4 a	9.2 ± 0.5 b
S3G3 (combination)	61.2 ± 0.9 a	58.5 ± 0.8 a	-9.5 ± 0.2 a	-8.1 ± 0.2 c	21.3 ± 0.3 a	22.1 ± 0.3 a	5.2 ± 0.3 c
LSD (0.05)	1.8	1.6	0.4	0.3	0.6	0.7	0.9

Values are mean ± SD (n=3). Different letters within a column indicate significant differences (P<0.05).

It was concluded that the S3G3 treatment resulted in a significant retention of the lightness of the product (smaller decrease in L*) and change in color (ΔE = 5.2) than the control (ΔE = 12.8), demonstrating that pre-harvest treatment allowed a more stable product color during post harvest period.

Table 2. Texture firmness (kg/cm^2) of green onion pseudostems during refrigerated storage at 4°C

Treatment	Day 0	Day 3	Day 7	Day 14
Control (S0G0)	1.12 ± 0.05 c	0.85 ± 0.04 c	0.62 ± 0.03 c	0.41 ± 0.02 d
S3 (salicylic 300 alone)	1.58 ± 0.06 b	1.32 ± 0.05 b	1.10 ± 0.04 b	0.88 ± 0.03 b
G3 (glutamine 200 alone)	1.45 ± 0.05 b	1.20 ± 0.04 b	0.98 ± 0.04 b	0.75 ± 0.03 c
S3G3 (combination)	1.85 ± 0.05 a	1.68 ± 0.05 a	1.52 ± 0.04 a	1.35 ± 0.04 a
LSD (0.05)	0.09	0.08	0.06	0.05

Values are mean ± SD (n=3). Different letters within a column indicate significant differences (P<0.05).

Treatment with both compounds resulted in a significant increase in firmness throughout the period of storage, and the decrease in firmness after 14 days was just 27% of original value while in the control it was 63%.

Table 3. Total flavonoid content (mg/g fresh weight) and retention percentage after 7 days of refrigerated storage under simulated fresh-cut conditions

Treatment	Flavonoids day 0 (fresh)	Flavonoids day 7 (stored, cut)	Retention (%)
Control (S0G0)	24.81 ± 0.30 d	15.88 ± 0.25 d	64.0 ± 1.2 d
S3 (salicylic 300 alone)	38.78 ± 0.35 b	32.91 ± 0.30 b	84.9 ± 1.0 b
G3 (glutamine 200 alone)	34.68 ± 0.28 c	28.44 ± 0.26 c	82.0 ± 1.1 c
S3G3 (combination)	41.99 ± 0.32 a	37.37 ± 0.30 a	89.0 ± 0.9 a

LSD (0.05)	0.51	0.48	1.8

Values are mean ± SD (n=3). Different letters within a column indicate significant differences (P<0.05).

The addition treatment had greatest retention of flavonoids after one week in refrigerator (89%) which was significantly higher than the control (64%) indicating that the treatment was more suitable for fresh-cut produce applications.

Table 4. Sensory evaluation scores (9-point hedonic scale) of fresh-cut green onion samples after 1 day of refrigerated storage

Treatment	Appearance	Flavor (aroma)	Texture (crispness)	Overall acceptability
Control (S0G0)	5.8 ± 0.6 c	5.2 ± 0.5 c	5.5 ± 0.6 c	5.6 ± 0.5 d
S3 (salicylic 300 alone)	7.2 ± 0.5 b	7.0 ± 0.4 b	7.4 ± 0.5 b	7.3 ± 0.4 b
G3 (glutamine 200 alone)	6.8 ± 0.5 b	6.6 ± 0.5 b	6.9 ± 0.5 b	6.8 ± 0.5 c
S3G3 (combination)	8.4 ± 0.4 a	8.0 ± 0.4 a	8.2 ± 0.4 a	8.2 ± 0.4 a
LSD (0.05)	0.8	0.7	0.8	0.7

Values are mean ± SD (n=10 panelists). Different letters within a column indicate significant differences (P<0.05).

Pre-harvest treatments not only increased the yield and bioactive compounds, but also increased the consumer's acceptance of the fresh-cut product as revealed by the highest sensory scores obtained with the combination treatment.

6-Discussion

The pre-harvest data (Tables 2-6) indicated that salicylic acid alone at 300 mg/L of the plants and glutamine alone at 200 mg/L of the plants together significantly raised the leaf nitrogen, phosphorus, potassium, total flavonoids, and total soluble solids. Earlier studies [16,17,18,] had shown similar results and this can be explained by following mechanisms such as increased mobilization of nutrients, osmotic adjustment, and secondary metabolism.

This is a novel study because of the post harvest quality evaluation. The results show that pre-harvest foliar treatments had a carry over effect upon post-harvest quality attributes. The S3G3 treatment resulted in reduced colour deterioration (lower DeltaE) after a period of refrigerated storage. This may be attributed to the antioxidant activity of salicylic acid and glutamine which can decrease the activity of polyphenol oxidaze (PPO) and thus prevent the oxidative browning phenomenon while maintaining the chlorophyll pigments. Colour is considered a key quality parameter of the freshcut vegetable industry, browning being one of the major shelf-life limitation [19,20]

The enhanced texture firmness retention of treated samples (Table 8) is possibly due to the effect of salicylic acid on the maintenance of cell wall integrity and minimisation of cell wall degradation during storage. Glutamine helps protein synthesis, and could stimulate expression of cell wall strengthening enzymes. Firmness is desirable in minimal processing as it will minimize mechanical damage during cutting, washing and package processing [21,22].

It is of significant importance to the food industry that the significantly higher retention of flavonoids after 7 days of refrigerated storage (89% in S3G3 vs 64% in control, Table 9) was found. Flavonoids are oxygen- and temperature-sensitive, which they must be to be stable in storage, and is an indicator of overall antioxidant capacity. The antioxidant enzyme activities (such as superoxide dismutase, catalase) and lipid peroxidation have been reported to be increased and decreased by pre-harvest treatments, respectively, suggesting a more stable cellular environment, which is now reflected to have been induced in the present study in the apple. Higher retention equal better nutritional quality of fresh-cut products over shelf-life for consumers.

An sensory evaluation (Table 10) corroborated the better physicochemical properties of the treated samples could be detected by the panelists. The appearance (brighter green color), flavor (stronger typical onion aroma), and crispness scores reflect that pre-harvest treatments neither affect the organoleptic qualities of onions, but they seem to improve them. This is one of the most important points to find out for the food industry as their success or failure lies in the acceptance of the consumer.

To conclude, salicylic acid and the glutamine were not only effective in enhancing pre-harvest yield and bioactive content of managed hydroponic green onions but also proved highly beneficial in developing post-harvest quality attributes of hydroponic green onions for fresh-cut processing (color stability, texture retention, flavonoid stability and sensory acceptability). Based on these findings, it has been possible to develop scientifically sound potential use of C. albicans and Bt. endotoxins for adding value to the end product in hydroponic crops.

7-Conclusion

From the results obtained in this study, the writer infers that Japanese green onion is potentially possible to grow through hydroponic system in Iraq. With regard to food science and industrial uses the following conclusions are drawn:

1. The application of salicylic acid 300 mg/L, glutamine 200 mg/L or both significantly increased the pre-harvest quality indicators (N, P, K, total flavonoids and TSS).

2. Enhancing post harvest quality attributes such as colour stability ($\Delta E = 5.2$ after 14 days), the texture firmness (1.35kg/cm² after 14 days) and retention of flavonoids (89% after 7 days of refrigerated storage under simulated fresh cut conditions) was the most effective increase that occurred in the treatments.

3. Sensory evaluation also showed that fresh-cut green onions with the highest overall acceptability (8.2/9) were the ones from S3G3 treatment.

These improvements enables production for fresh-cut vegetable industry, minimising the losses at post production and extending shelf-life.

Hence, the use of salicylic acid together with glutamine in hydroponic system is suggested for increasing the hydroponic productivity alongside increasing the food quality of the green onions for fresh-cut applications.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Data Availability

All data supporting the findings of this study are available within the manuscript.

Ethical Approval

This study did not involve human participants or animals. All experimental procedures were conducted in accordance with institutional and laboratory biosafety guidelines.

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