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CHARACTERIZATION OF GREEN ONION WITH NPK FERTILIZATION AND FOLIAR APPLICATION OF HORNWORT EXTRACT

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SUMMARY

A field trial on green onion crops in the autumn of 2020 transpired at a private farm in the District Al-Saniyah, Al-Diwaniyah Governorate, Iraq. The presented study aimed at characterizing green onion (*Allium cepa* L.) plants with NPK fertilization and foliar application of hornwort extract for growth and yield traits. In this experiment, the first factor comprised three NPK levels (0, 50%, and 100%) of NPK (150:100:150 kg ha^{-1}) recommended fertilizer added to the soil, while the second factor included the foliar application of hornwort extract with two different concentrations (0, 20 ml L^{-1}). The experiment in a randomized complete block design (RCBD) with factorial arrangement had three replications. Consequently, the recommended dose of NPK (100%) and spraying hornwort extract at 20 ml L^{-1} revealed a significant increase in the studied traits, i.e., plant height, length of the longest tubular leaf, number of leaves, fresh weight of tubular leaves, number of bulbs per plant, weight of the bulb, the diameter of the bulb, leaf chlorophyll content, bulb carbohydrate content, leaf carotenoid content, and plant yield. The interactions of both factors also showed a favorable effect on the mentioned traits in green onion.

Keywords: Onion (*Allium cepa* L.), NPK levels, *Ceratophyllum demersum* L. extract, growth traits, yield variables, biochemical traits, total chlorophyll, carotenoid, carbohydrate content

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Key findings: The recommended NPK fertilization dose resulted in better vegetative growth, yield, and biochemical traits in green onion plants. Also, the exogenous application of the hornwort extract (20 ml L^{-1}) provided better effects for all the quantitative features. Furthermore, the combined application and interaction of both factors with the highest doses caused favorable impacts on green onion plant characteristics.

INTRODUCTION

Onion (*Allium cepa* L.) is one of the valuable vegetables grown all over the world, including Iraq, and the cultivated area of green onions and shallots in Iraq measures at 5,477 ha, with a total production of 60,442 tons in 2021 (FAOSTAT, 2023). Onions are one of the oldest vegetables, currently available in raw, frozen, canned, pickled, and dried forms. They are also cooked with foods to add good flavor. Moreover, onions are beneficial in improving digestion, reducing blood sugar, regulating blood pressure and heart functions, and treating colds and hay fever (Boras *et al.,* 2011). Also, green onions are advisable to prevent and treat flu, reduce cholesterol deposits in the arteries, and protect humans from heart disease (Nemtinov *et al.,* 2021).

Onion plant growth and bulb formation incur effects from several factors; however, the temperature and light duration are the most prominent ones, as well as crop management, including fertilization and irrigation. Onion plants better respond to higher doses of various fertilizer elements because of the superficial architecture of onion roots with low density, which eventually enhances their ability to absorb more nutrients from the soil. Accumulating the nutrient quantities that reach the root system through the diffusion mechanism from the soil solution can only be achieved by increasing the fertilization rates (Brewster, 1994). Integrated use of organic and mineral fertilizers for managing soil fertility also has proofs in several countries, and sustainable crop production can be obtained with the rational and balanced use of NPK fertilizer with organic matter (Bayu *et al.,* 2006).

NPK amendment is a positive reaction toward fertilization within a reasonable environmental balance in the soil, which enhances the plant's efficiency in absorbing the available elements in the soil solution before biological assimilation, washing, and volatilization in nitrogen form (Pholsen *et al.,* 2001). Nitrogen is prominent for various physiological and biological functions within the plant, as it constitutes the basic units for building amino acids, proteins, plant hormones, and enzymes, which are vital in building protoplasm and stimulating cell division and elongation, thus improving the growth traits (Idris and Dirhab, 2007).

Phosphorus also plays a primary role in plant growth by helping form energy-rich compounds acquired by plants to generate carbohydrates, phospholipids, and enzymes that support activating the crucial functions of crop plants. Consequently, these physiological processes increase vegetative growth, such as, plant height, branch number, and leaf area (Abu-Dahi and Al-Younis, 1988). Potassium, an osmotic-regulating agent, also has an influential role in the opening and closure of stomata, reflecting an increase in the water and nutrient absorption, which activate photosynthesis and its effect on cell elongation and division, thus improving the growth traits (Alrayes, 1987).

Hornwort (*Ceratophyllum demersum* L.) is a dicotyledonous, perennial, submerged aquatic angiosperm belonging to the family Ceratophyllaceae. It has a biological mass of around 71 kg m^{-2} with an annual production rate of organic matter (9 t ha^{-1}). The flowers are bisexual, and the plant spreads in several regions worldwide, including the USA, New Zealand, Japan, Germany, and others (Aziz *et al*., 2007). The hornwort is also available in most of the Governorates of Iraq; however, its population and growth increased in the Tigris and Euphrates rivers, particularly in the central and southern regions, and Najaf, Babylon, Qadisiyah, the marshlands, and Abu-Al-Khaseeb in Basra due to a suitable environment (Al-Khaffaf, 2017). The

purposeful research sought to characterize the response of green onion plants to fertilization with NPK and foliar application of hornwort extract for vegetative growth, yield, and biochemical composition.

MATERIALS AND METHODS

Experimental site and procedure

A field trial on the local cultivar of green onions materialized during the autumn of 2020–2021 at a private farm in District Al-Saniya, Al-Diwaniyah Governorate, Iraq, to study the effects of NPK fertilization and foliar application of hornwort extract on the growth, yield, and biochemical composition of green onion plants. Before planting, a soil test of the experimental field proceeded in a laboratory to measure the physical and chemical characteristics (Table 1). The research area comprised plowing orthogonally, with the soil harrowed, smoothed, and divided into 21 m long furrows. The local green onion cultivar continued planting in sandy-loam soil in the third week of October 2020, with a plant-to-plant spacing of 20 cm and 1 m between furrows. Conducting crop management followed the recommended package of production technology as needed.

Table 1. Physical and chemical properties of the field soil.

pH	Electrical Conductivity E.C ($dS.m^{-1}$)	Organic Matter ($g\ kg^{-1}$)	N ($mg\ kg^{-1}$)	P ($mg\ kg^{-1}$)	K ($mg\ kg^{-1}$)	Clay	Silt	Sand	Soil Texture
						($g\ kg^{-1}$)			
7.6	1.7	1.6	9.0	7.37	165	50	185	765	Sandy-loam soil

In the prevailing experiment, the first factor comprised three levels (0, 50%, and 100%) of NPK (150:100:150 kg ha^{-1}) fertilizer added to the soil at planting, and the second factor included the foliar application of hornwort extract with two different concentrations (0 and 20 ml L^{-1}) (Khaber and Aboohanah, 2020). The experiment in a randomized complete block design (RCBD) based on factorial arrangement with three replications had each replicate 18 treatments and 15 onion plants per experimental unit. The hornwort extract (Yasir *et al.,* 2018) foliar application occurred twice on onion plants in the early morning. The first spray went on after forming 3–4 true leaves, and the second spray followed after 15 days, while the control treatment spraying contained distilled water only (Jaafar *et al.,* 2022).

Data recorded

At the physiological maturity of the onion crop after about 150 days, harvesting the bulbs by hand ran in the second week of March 2021, with the appearance of flowering stalks in all plants. Five onion plants' random selection in each experimental unit had their data recorded on the following variables:

Vegetative growth traits

Plant height (cm) measurement began from the area of the disc stem of the onion up to the longest tubular leaf. The length of the longest tubular leaf (cm) incurred measuring from the end of the bulb neck to the beginning of the appearance of the tubular blades to the end of the longest tubular leaf of the plant. Recording the number and fresh weight (g) of tubular leaves per plant also transpired.

Yield related traits

Calculating how many bulbs per plant consisted of taking the total bulb amount per experimental unit and dividing it by the total number of plants within the experimental section (15 plants). For the weight (g) of a single bulb, the bulbs of five plants in each experimental unit received weighing after cutting the tubular blades, dividing it by the

total number of bulbs. The single bulb diameter measurement (cm) used a vernier caliper at the widest diameter of the bulb for five bulbs in each experimental unit and then averaged. The bulb yield per plant (g plant^{-1}) calculation comprised the harvest of each trial plot divided by the total number of plants within the research area.

Biochemical traits

The total chlorophyll in leaf fresh weight (mg 100 g^{-1} f.w.) reached estimation by spectrophotometer according to the following formula, as described by Goodwin (1976).

Total Chlorophyll mg L^{-1} = (20.2 × A645) + (8.02 × A663)

Total Chlorophyll (mg 100 g^{-1} f.w.) = (Total Chlorophyll mg L^{-1} × total extract Vol. [L.] × 100/sample weight [g])

The carbohydrate content of bulbs (g kg^{-1}) measurement also used a spectrophotometer, according to Herbert *et al.* (1971). Total carotenoids' (mg g^{-1}) estimation in onion plant leaves followed the equation of Lichtenthaler (1987).

Carotenoids = (1000 x× A470) – (1.82 × Chlorophyll a) – (85.02 × Chlorophyll b)/198

Statistical analysis

Two-way analysis of variance (ANOVA) and multiple comparisons and separation of means employed the Duncan's Multiple Range (DMR) test at $P \leq 0.05$ by using VSN International GenStat 12th Edition (Payne *et al.,* 2009).

RESULTS

Growth parameters

The NPK fertilization treatments revealed significant ($P \leq 0.05$) variations for various growth traits in green onion plants. The complete dose of NPK (100%) provided a substantial increase in vegetative growth parameters, i.e., plant height (74.90 cm), length of tubular leaf (64.90 cm), the number (15.50 leaves), and fresh weight (65.40 g) of tubular leaves per plant compared with the control with the recorded lowest values for mentioned traits, i.e., 66.80 cm, 57.20 cm, 12.45 leaves, and 58.2 g, respectively (Table 2). Results also enunciated the considerable superiority in the vegetative growth when green onion plants gained the hornwort extract spraying at a concentration of 20 ml L^{-1}, resulting in the highest averages of plant height, length of tubular leaf, and the number and fresh weight of tubular leaves per plant, which reached 75.70 cm, 66.10 cm, 15.3 leaves, and 63.6 g, respectively. However, the reduced average values of the studied traits in the control treatment were 65.5 cm, 55.7 cm, 12.3 leaves, and 56.2 g, respectively.

On the interaction between the studied factors, the NPK fertilizer with complete recommendation plus foliar application of hornwort extract (20 ml L^{-1}) had a highly significant positive impact on the mentioned traits (Table 2). Moreover, the interaction and combined application of the above two factors (NPK fertilizer + hornwort extract) achieved the highest values for plant height (80.80 cm), length of tubular leaf (71.00 cm), number of tubular leaves per plant (18.00 leaves), and fresh weight of tubular leaves per plant (70.50 g). However, the control (distilled water only) recorded the lowest values of the said growth variables, i.e., 62.30 cm, 53.10 cm, 11.40 leaves, and 53.00 g, respectively.

Yield related traits

The green onion plants with the full recommended dose (100%) of NPK fertilizer revealed a significant increase in the yield variables, i.e., the number of bulbs per plant (3.50 bulbs), the bulb weight (81.40 g), diameter (3.80 cm), and yield per plant (325.40 g plant^{-1}) (Table 3). In contrast, the control treatment showed the lowest values for the said traits, viz., 3.30 bulb, 74.70 g, 3.40 cm, and 304.40 g plant^{-1}, consecutively. The exogenous application of hornwort extract (20 ml L^{-1}) resulted in an enhanced number of bulbs per plant, bulb weight, diameter, and

Table 2. Effect of NPK fertilization and foliar application of hornwort extract on growth traits of green onion plants.

Treatments			Plant height (cm)	Length of tubular leaf (cm)	Number of tubular leaves per plant	Fresh weight of tubular leaves per plant
Average effect of NPK fertilization (%)		0	66.80 c	57.20 c	12.45 c	58.20 c
		50	70.10 b	60.60 b	13.50 b	61.30 b
		100	74.90 a	64.90 a	15.50 a	65.40 a
Average effect of spraying hornwort extract (ml L^{-1})		0	65.50 b	55.70 b	12.30 b	56.20 b
		20	75.70 a	66.10 a	15.30 a	63.60 a
NPK fertilization (%) × Hornwort extract (ml L^{-1})	0	0	62.30 f	53.10 f	11.40 f	53.00 f
		20	71.30 c	61.40 c	13.50 c	63.50 c
	50	0	65.10 e	55.30 e	12.50 e	55.40 e
		20	75.20 b	66.00 b	14.50 b	67.30 b
	100	0	69.10 d	58.90 d	13.00 d	60.30 d
		20	80.80 a	71.00 a	18.00 a	70.50 a

Similar letters mean no significant difference based on Duncan's multiple range test ($P < 0.05$).

Table 3. Effect of NPK fertilization and foliar application of hornwort extract on yield traits of green onion plants.

Treatments			Number of bulbs per plant	Weight of bulb (g)	Diameter of bulb (cm)	Bulb yield per plant (g $plant^{-1}$)
Average effect of NPK fertilization (%)		0	3.30 b	74.70 c	3.40 b	304.40 c
		50	3.50 a	78.20 b	3.50 b	312.30 b
		100	3.50 a	81.40 a	3.80 a	325.40 a
Average effect of spraying hornwort extract (ml L^{-1})		0	3.30 b	74.30 b	3.20 b	302.10 b
		20	3.50 a	81.90 a	3.90 a	325.90 a
NPK fertilization (%) × Hornwort extract (ml L^{-1})	0	0	3.10 b	70.20 f	3.00 d	288.60 e
		20	3.50 a	79.30 c	3.80 b	320.10 b
	50	0	3.40 ab	75.30 e	3.10 d	302.10 d
		20	3.50 a	81.10 b	3.90 b	322.50 b
	100	0	3.30 ab	77.40 d	3.50 c	315.50 c
		20	3.60 a	85.40 a	4.10 a	335.30 a

Similar letters mean no significant difference based on Duncan's multiple range test ($P < 0.05$).

bulb yield per plant, with values of 3.50 bulbs, 81.90 g, 3.90 cm, and 325.90 g $plant^{-1}$, respectively, compared with the control treatment with minimum values (3.30 bulb, 74.30 g, 3.20 cm, and 302.10 g $plant^{-1}$, respectively). The interaction and combined application of NPK fertilizer (100%) and foliar application of hornwort extract (20 ml L^{-1}) also considerably improved the mentioned yield parameters, with the highest values of 3.60 bulbs, 85.40 g, 4.10 cm, and 335.30 g $plant^{-1}$, sequentially, compared with the control treatment with the least values (3.10 bulb, 70.20 g, 3.00 cm, and 288.60 g $plant^{-1}$, respectively).

Biochemical traits

The green onion fertilization with NPK (100%) has improved the biochemical parameters, i.e., total chlorophyll content (64.34 mg 100 g^{-1} f.w.) and carotenoid content (0.73 mg g^{-1}) in the leaves and the carbohydrate content in the bulbs (9.47 g kg^{-1}) (Table 4). Contrarily, the control treatment produced the above traits with the least values, i.e., 57.90 mg 100 g^{-1}

Table 4. Effect of NPK fertilization and foliar application of hornwort extract on biochemical traits of green onion plants.

Treatments			Total chlorophyll in leaf (mg 100 g^{-1} f.w.)	Total carotenoids in leaf (mg g^{-1})	Carbohydrate content in bulb (g kg^{-1})
Average effect of NPK fertilization (%)		0	57.90 c	0.65 c	7.70 c
		50	61.16 b	0.68b	8.37 b
		100	64.34 a	0.73 a	9.47 a
Average effect of spraying hornwort extract (ml L^{-1})		0	56.45 b	0.63 b	7.61 b
		20	65.86 a	0.74 a	9.41 a
NPK fertilization (%) × Hornwort extract (ml L^{-1})	0	0	53.36 f	0.60 f	7.16 f
		20	62.44 c	0.70 c	8.24 c
	50	0	56.77 e	0.62 e	7.65 e
		20	65.55 b	0.74 b	9.10 b
	100	0	59.22 d	0.67 d	8.04 d
		20	69.46 a	0.79 a	10.90 a

Similar letters mean no significant difference based on Duncan's multiple range test ($P < 0.05$).

f.w., 0.65 mg g^{-1}, and 7.70 g kg^{-1}, respectively. Moreover, the foliar application of hornwort extract (20 ml L^{-1}) had a significant positive impact on the biochemical indicators for leaves' total chlorophyll content (65.86 mg 100 g^{-1} f.w.) and carotenoid content (0.74 mg g^{-1}), and carbohydrate content in the bulbs (9.41 g kg^{-1}), versus the control treatment with the least values for the above traits (56.45 mg 100 g^{-1} f.w., 0.63 mg g^{-1}, and 7.61 g kg^{-1}, respectively).

Regarding the findings related to the interaction, the combined application of both factors (NPK fertilization [100%] + hornwort spray [20 ml.l^{-1}]) had a significant increment in the biochemical traits, i.e., total chlorophyll content of the leaves (69.46 mg 100 g^{-1} f.w.), carotenoid content in the leaves (0.79 mg g^{-1}), and bulbs' carbohydrate content (10.90 g kg^{-1}) (Table 4). However, these biochemical parameters in the control treatment were lesser at 53.36 mg 100 g^{-1} f.w., 0.60 mg g^{-1}, and 7.16 g kg^{-1}, respectively.

DISCUSSION

The NPK fertilizer treatments have shown a significant improvement in the growth, yield, and biochemical traits of the onion plants, which can be due to the prime role of nitrogen in biosynthesizing various vital organic compounds through physiological and biological processes inside the plant. Also, the role of NPK in building nutrients, leaf assimilation of carbon dioxide, cell division, and building chlorophyll, leading to an increase in the amount of nutrients manufactured in the leaves, reflects positively on growth (Seleiman *et al.,* 2021; Maharijaya *et al*., 2023).

Furthermore, phosphorus contributes to forming some essential organic compounds used in various bioactivities. Subsequently, phosphorus causes an increase in the production and accumulation of dry matter in a plant as a result of improving the growth traits, including plant height, the number of branches, the number of leaves, and leaf area (Abu-Dahi and Al-Younis, 1988; Eldardiry *et al.,* 2015; Mazumder *et al.,* 2019; Ahmad *et al.,* 2022). Besides, potassium influences the activity of more than 60 metabolic enzymes, which helps regulate the opening and closing of the stomata and the transfer of carbohydrates manufactured in the leaves to the rest of the plant organs (Taiz and Zeiger, 2010). Furthermore, potassium helps in forming proteins, nucleic acids, and photosynthetic products, enhancing the amount of nutrients, which positively reflected in enhanced growth traits and stimulated cell division and elongation, especially meristematic cells in the developing apex (Taiz and Zeiger, 2010).

Past studies on phosphorus reflect improving the vegetative growth parameters, including plant height, length of tubular leaf,

the number and weight of tubular leaves, along with augmenting yield traits, viz., the number of bulbs per plant, the weight and diameter of the bulb, and bulb yield per plant (Addai and Anning, 2015; Fouda, 2016; Aboohanah *et al.,* 2019). Subsequently, these elements of NPK fertilizer have a positive role in the biochemical traits, such as, leaf chlorophyll, leaf carotenoid, and carbohydrate content (El-Shaboury and Ewais, 2020).

Hornwort extract foliar application exhibited a significant increase in the onion vegetative growth parameters, such as, plant height, length of tubular leaf, the number of leaves, and weight of tubular leaves, which eventually influenced the yield and its components, including the number of bulbs per plant, the weight and diameter of the bulb, and bulb yield per plant, as well as leaf chlorophyll, carotenoid, and bulb carbohydrate contents (Abbas *et al.,* 2020). The superiority of plant growth, yield, and biochemical parameters may refer to the extracted content of nutrients, which helped increase metabolic processes, reaching a balance between nitrogen and carbohydrates (C/N) that could encourage flowering. However, phosphorus contributes to synthesizing some organic compounds that have greater importance in biological activities, such as, nucleic acids, NADP, and NAD, for oxidation and reduction (Malhotra *et al.,* 2018). These physiological activities occur in the photosynthesis and assimilation of carbohydrates and fatty acids, thus reflecting the floral characteristics through its indirect effect on C/N (Al-Sahaf, 1989; Maisura *et al.,* 2019).

Furthermore, improving plant growth, yield, and biochemical traits of green onion may be due to the hornwort extract contents with nutrients, amino acids (e.g., glutamic acid, tryptophane, serine, glycine, and phenylalanine), and phytohormones (e.g., IAA, GA3, and cytokinin) stimulating stem elongation, leaf expansion, and flower bud emergence (Yamaguchi, 2008). Besides, the increase in growth and flowering aspects could be indicative of the hornwort extract containing ascorbic acid, playing an intrinsic function in metabolic activities related to plant growth through boosting cell division and plant cell proliferation, hence capturing a higher amount of light (Smirnoff and Wheeler, 2000), and its positive effect alleviating the photosynthetic capacity and the rate of carbohydrates in crop plants (Robinson, 1973).

CONCLUSIONS

The recommended NPK fertilization dose resulted in the green onions' improved vegetative growth, yield, and biochemical traits. The exogenous application of hornwort extract (20 ml L^{-1}) has effectively enhanced the mentioned traits in green onions. Further, the combined application of both factors with the highest doses significantly and positively impacted various parameters of green onion plants.

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