EFFECT OF HUMIC ACID AND SALICYLIC ACID ON THE GROWTH, YIELD AND QUALITY IN ONION

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CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF HUMIC ACID AND SALICYLIC ACID ON THE GROWTH, YIELD AND QUALITY IN ONION**" submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE**, embodies the result of a piece of bona-fide research work carried out by **Khairun Nahar** bearing **Registration No. 13-05439** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has been duly acknowledged.

Dated: January 2022
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ABSTRACT

The field experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka from October 2019 to February 2020 to find the effect of humic acid and salicylic acid on the growth, yield and quality in onion. The experiment consisted of Factor A: Humic acid doses as H_0- 0 ppm, H_1- 15 ppm, H_2- 30 ppm and H_3- 45 ppm; Factor B: Salicylic acid doses as S_0- 0 ppm, S_1- 10 ppm, S_2- 20 ppm and S_3- 30 ppm. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. In the case of humic acid and salicylic acid, both H_3 and S_2 showed the best result individually with all aspects of growth and nutrition assimilation in onion. The treatment combination of H_2S_2 provided the highest bulb diameter (3.86 cm), bulb length (2.86 cm), bulb weight (39.50 gm), nitrogen content (2.31 %), phosphorus content (0.85 %), potassium content (1.44 %), sulphur content (0.49 %), total sugar (0.95 %), ascorbic acid content (9.70 mg/100g) and soluble solids (11.40 %) in the bulb of onion. The highest bulb yield (10.92 t ha^{-1}) was obtained from 45 ppm humic acid with 30 ppm salicylic acid treatment. So, the application of 45 ppm humic acid with 20 ppm salicylic acid would be the best option to maintain better growth, yield and quality in onion.

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ABBREVIATIONS AND ACRONYMS

N	:	Nitrogen
P	:	Phosphorus
K	:	Potassium
DAT	:	Days after transplanting
ANOVA	:	Analysis of variance
LSD	:	Least significant difference
df	:	Degrees of Freedom
C.V.%	;	Percentage of Coefficient of Variation
t	:	Ton
h	:	Hectare
pH	:	Potential hydrogen
ppm	:	Parts per million
RCBD	:	Randomized completely blocked design
S	:	Sulfur
CEC	:	Cation exchange capacity
meq	:	Milliequivalents

CHAPTER I

INTRODUCTION

The onion (*Allium cepa* L.) is a world-famous herbaceous bulb and spice crop from the Alliaceae family. Onions are used as vegetables as well as a condiment. The most edible component is the bulb, which is a modified organ with thicker fleshy scale leaves and a stem plate (Rashid and Islam, 2019). The onion is referred to as the "Queen of the Kitchen" because of its highly esteemed aroma, smell, and unique flavor (Griffiths, *et al.*, 2002). A volatile oil called allyl-propyl-di-sulfide is responsible for the onion's strong taste (Yawalkar, 1985). It has medicinal properties and offers significant nutritional value to the human diet (Sarker, *et al.*, 2017). Vitamin B and C, as well as iron and calcium, are abundant in onions. Onions contain steroidal saponins, which inhibit the absorption of cholesterol in the intestine (Ahmed, *et al.*, 2020). The fructans in onions are the primary storage carbohydrates (polysaccharides).

Onion originated in Central Asia, with a secondary origin in the Mediterranean area (Choudhary, 2018). China, India, Egypt, the United States, Pakistan, Turkey, and Iran are the world's top onion producers (FAO, 2018). Onion is the most extensively grown spice in Bangladesh, both in terms of area and yield (Ahmed, *et al.*, 2020). It covers around 1,85,269 acres in Bangladesh and produces about 19,53,800 tons of onions (BBS, 2020). Onion is grown in practically all of Bangladesh's districts but is mostly commercially grown in Faridpur, Rajshahi, Dhaka, Mymensingh, Cumilla, Jashore, Rangpur, Kushtia, Bogra, and Pabna (BBS, 2018). Onion is usually seeded from October to November, and harvested from February to March (Ahmed *et al.*, 2020). Due to unfavorable weather, a lack of summer tolerant varieties, and a lack of adequate cultural methods, onion growing during the Kharif season has several restrictions. In Bangladesh, the average onion output is roughly 10.55 t ha^{-1}. (BBS, 2020). However, this output does not meet the country's needs. Furthermore, neither the output nor the area under onion production in Bangladesh has risen.

Humic acid ($C_{187}H_{186}O_{89}N_9S_1$) is a naturally occurring organic polymer that may be extracted from humus in the soil, sediment, or water (Rahman, 2018). Humic acid promotes soil physical, chemical, and biological qualities and agricultural yield, especially in alkaline-calcareous and insufficiently fertile soils (Rajpar, *et al.*, 2011) while also reducing the negative effects of stress (Doran *et al.*, 2003). In addion, humic acid improves plant nutrient absorption (Sharif *et al.*, 2004), nitrogen use efficiency (Adani, *et al.*, 1998), assimilates minor and major nutrients, activates or inhibits enzymes, causes membrane permeability changes, resulting in protein synthesis and stimulating biomass development, all of which encourage plant growth (El-Ghamry, *et al.*, 2009). It is known that the humate moved from one region of the root system to another, allowing for more efficient iron absorption (Aso and Sakai, 1963) and also humic acids bind metal ions by generating stable complexes with ligands or via a simple cation exchange process. (MacCarthy, *et al.*, 1990). Finally humic compounds may also improve mineral absorption by stimulating microbial activity (Schnitzer, 1986).

Besides, salicylic Acid (SA) or ortho-hydroxyl-benzoic acid ($C_7H_6O_3$) and related compounds belong to a diverse group of plant phenolics (Hasan, 2018) and are found in extremely small levels in plants (Raskin, 1992). It is an endogenous growth regulator that regulates a variety of physiological processes in plants, including stomatal closure, ion absorption, ethylene biosynthesis inhibition, transpiration, and stress tolerance (Shakirove, *et al*., 2003). Foliar application of salicylic acid substantially influenced plant growth metabolism (Kalarani, *et al*., 2002). Under abiotic stress circumstances, salicylic acid plays an important function in plant water relations (Barkosky and Einhelling, 1993), photosynthesis, growth, and stomatal control, as well as creating a defensive mechanism against insect pests (Arfan, *et al.,* 2007). In salt-stressed plants, foliar application of salicylic acid enhanced net photosynthetic rate and proline content, which may have contributed to the improved growth characteristics (Khoshbakht and Asgharei, 2015). Salicylic acid-treated plants have higher chlorophyll content compared to untreated plants (Khoshbakht and Asgharei, 2015).

Taking the above facts, a field experiment entitled, was conducted during rabi season to fulfill the following objectives:

i. To investigate the growth and yield of onion affected by humic and salicylic acid concentration;

ii. To find out the quality in onion as affected by humic and salicylic acid concentration.

CHAPTER II

REVIEW OF LITERATURE

2.1. Effect of Humic acid

El –Shaboury and Sakara, (2021) experimented during the winter seasons of 2017-2018 and 2018-2019, at a private farm located in El-Sarou, Damietta governorate, Egypt, to test the role of garlic and onion extract in a foliar way on onion growth, yield, and quality as under soil addition of potassium humate and fulvate. The obtained results indicated that soil addition of 4 kg fed^{-1} potassium humate recorded the highest significant values for growth traits, yield and its components as well as N, P, K, Fe, Mn and Zn in leaves and bulb, also, recorded the highest significance in chemical and physical quality of the bulb. Based, on the same parameters, increased with the foliar application at the rate of 20 ml L^{-1} from plant extract. The combined application between 4 kg fed^{-1} potassium humate and foliar 20 ml L^{-1} plant extract was more prominent in enhancing the aforementioned traits. The addition of potassium humate 4 kg fed^{-1} increased available N, P, K $mg.kg^{-1}$ and porosity, while decreasing EC $ds.m^{-1}$ in the soil after harvesting.

Forotaghe, *et al.* (2021) conducted a study on the effect of water shortage on onion growth and quality was evaluated under soil humic acid (HA) application. Three levels of irrigation namely: a_1; 80%, a_2; 70% and a_3; 60% of field capacity (FC) were supplied to plants in combination with two levels of HA namely: b_1; 0 and b_2; 100 mg/kg soil, in factorial and completely randomized design with four replications. According to the findings, irrigation and HA had a significant effect on leaf dry weight, vitamin C, calcium, total chlorophyll, and bulb flavonoids, but treatments did not affect onion fresh yield. The leaf biomass, as well as the leaf concentrations of potassium, calcium and zinc, were significantly decreased under the highest water deficit treatment (60% FC; a_3b_1 and a_3b_2) compared to control (a_1b_1) treatment. Leaf vitamin C and calcium concentration showed almost a similar response in which their highest levels were observed in a_1b_2 treatment, while the lowest amounts were recorded under higher water shortage (a_3b_1), and application of HA (a_3b_2) significantly increased these traits under higher water shortage. The amounts of bulb flavonoids and phenols were increased by deficit irrigation and the application of HA further increased their content under the highest deficit irrigation. Under water deficit conditions, the results showed that water deficiency inhibited onion plant development, but soil application of HA dramatically boosted growth and quality features such as leaf biomass, vitamin C, and minerals such as Ca, as well as bulb flavonoids.

Gemin, *et al*. (2021) carried out a study with onions about the influence of applications via root immersion in microalgae *Scenedesmus subspicatus* (Sc) and humic acid (HA) solutions, analyzing possible alterations of macro and micronutrients, total sugars, reducing sugar, free total amino acids, total soluble solids, soluble proteins and antioxidant capacity in the bulbs. Results showed that the treatments with microalgae with humic acid association were able to increase the content of N, carbohydrates and soluble proteins, also elevating antioxidant activity in onion bulbs.

Lestari and Dewi, (2020) conducted a study aimed to evaluate the effect of humic acid on vegetative growth, yield, oxalic acid and betacyanin content of red amaranth (*Amaranthus tricolor* L*)*. The concentration variation of humic acid was 0 mg L^{-1}, 5 mg L^{-1}, 20 mg L^{-1} or 35 mg L^{-1} and there were 5 replicates for each treatment. Results showed that humic acid of 20 mg L^{-1} applied through the leaves significantly increase plant height, leaf number, the fresh and dry weight of shoot and betacyanin content. They also reported that humic acid of 20 mg L^{-1} that was applied through the soil surface also significantly increased leaf number, both fresh and dry weight of shoot and root but reduced oxalate content.

Mohan, *et al.* (2020) studied the effect of humic and fulvic acid on yield and chemical quality in brinjal reported that the humic followed by fulvic acid application had increased the yield and chemical quality in brinjal.

Turhan, *et al.* (2020) experimented to investigate the influence of irrigation water salinity and humic acid on the nutrient contents of onion (*Allium cepa* L.). Results concluded that the highest content of K, Ca, and N in the bulbs was obtained by humic acid (HA) application under different salinity levels. Similarly, the soil application of humic acid (HA) positively was affected the P, Mg, Fe, Zn, B contents of the bulbs. While contents of Na, Mn, and Cu were not affected by soil application, Cl was decreased. The results showed that the application of HA could partially reduce the harmful effects of salt, so HA can be used as an alternative method to improve product performance in saline conditions.

Hafez and Geries, (2019) conducted two field experiments to study the effects of the application of nitrogen fertilizer, biofertilizers and organic compounds on the growth, yield and economic return of onion production in the 2014/2015 and 2015/2016 seasons. Based on the results, the best treatment in this study was N fertilization of onion plants with 100 kg N fed^{-1} (hectare = 2.38 feddan) and foliar application of humic acid at a rate of 1 kg fed^{-1} for giving the highest bulb yield with the highest net returns with a B: C ratio of 2.35.

Al-Fraihat, *et al.* (2018) experimented to investigate the effect of spraying humic acid at various concentrations (0, 500, 750 and 1000 mg L^{-1}) and frequency (G_1: at 21days after transplanting, G_2: two times sprays of Humic acid at 21 and 35 DAT and G_3: three times spray of Humic acid at 21, 35 and 45 DAT) on the growth of onion (*Allium cepa* L.) *cv.* Giza 20 during the two seasons of 2014/2015 and 2015/2016. Investigation results concluded that Foliar application of humic acid significantly increased all growth characters (i.e., Number of leaves, leaf length, leaf diameter, neck diameter, fresh weight of leaves, root length and number, bulb length and diameter and fresh weight of plants) compared to untreated control plants. They also reported that among different times of Humic acid applications, Triple spray of humic acid was better than double or single spray in terms of having a significantly higher number of leaves, leaf length, leaf diameter, neck diameter, fresh weight of leaves, root length and number, bulb length and diameter and fresh weight of plants. It is concluded that spraying onion with humic acid at 1000 mg L^{-1} resulted in higher growth and yield.

Hafez and Geries, (2018) carried out two field experiments to investigate the optimum nitrogen rate (80, 100 and 120 kg N fed^{-1}; Fed = 0.38 ha) and stimulative compounds, i.e., foliar spraying with water, as control, *Azotobacter spp*. and *Azospirillum spp*., yeast, compost tea and humic acid on vegetative growth, yield, quality, as well as storability of bulb yield of onion (*Allium cepa* L.) under North Delta conditions. The results showed that the vegetative growth was positively influenced, also yield its components, quality and storability of onion were related to the medium rate of nitrogen (100 kg N fed^{-1}). Furthermore, foliar spraying with humic acid at the rate of 1 kg fed^{-1} led to a significant increment in most of the vegetative growth characteristics, as well as total bulb yield and its components, bulb quality and storability of onion. Both 100 kg N fed^{-1} and spraying humic acid at the rate of 1 kg fed^{-1} significantly increased most vegetative growth characteristics, total and marketable bulbs yield fed^{-1}, bulb quality and storability of onion.

Rouphael and Colla, (2018) stated that the biostimulant effect of humic acid has resulted in improved seed germination, root and plant growth development, and are major constituents of organic fertilizers.

Doklega, (2017) conducted two experiments during 2013/2014 and 2014/2015 successive winter seasons to determine the effect of farmyard manure (FYM), sulfur (S), humic acid (H) fertilization and their interactions on growth, chemical composition, yield and quality of onion plants *cv.* Italian Red, at the Experimental Station of Agriculture College, Mansoura Univ., Egypt. Experiment results concluded that humic acid fertilizer at the rate of 15 kg fed^{-1}achieved highest values compared to other treatments in all estimated parameters in both seasons except crude fiber (%), bulb moisture (%) in both seasons and NO_3-N (ppm) in the second season. The interaction among $20m^3$ FYM, 200kg fed^{-1} sulfur and 15 Kg fed^{-1} humic acid gave significant increases in dry weight (g $plant^{-1}$), plant height (cm), chlorophyll a+b (mg g^{-1} FW), crude protein (%), total carbohydrates (%), TSS (%), Sulpher volatile oil (%) and total yield (t fed^{-1}), but NO_3-N (ppm) accumulation was decreased in both seasons.

Khan, (2017) evaluated the influence of humic substances (HSs) produced from coal, sunflower, and maize waste materials on onion yield by a field experiment at NARC, Islamabad. Onion was treated with four different HS rates: 0, 20, 30, and 40 kg ha^{-1} (variety: Red Swat). The application of plant-derived HSs, such as SFDHSs (sunflower derived humic acid) and MDHSs (maize derived humic acid), yielded the highest bulb yields of 25.1 and 24.5 t ha^{-1}, respectively, while CDHA (coal-derived humic acid) applied at a rate of 20 kg ha^{-1} yielded the highest bulb yield of 24.7 t ha^{-1}. The number of bulbs in each plot followed a nearly identical pattern. CDHA at 20 kg ha^{-1} produced the most bulbs per plot (28.3), followed by 25.5 and 24.6 bulbs per plot in SFDHSs and MDHSs, both treated at 30 kg ha^{-1} respectively.

Bettoni, *et al.* (2016) concluded that the intermediate dose of humic substances (HS) exerted greater increases on onion yield, productivity, carbohydrates and proteins levels in bulbs, mineral nutrient accumulation resulted especially when the highest doses of HS were added. From a nutritional point of view, higher sweetness (from 113 to 149 mg g^{-1} of soluble sugars in dry matter) and an improved P, K and Mg content of bulbs (4.00, 11.65 and 3.18 g kg^{-1}, respectively) in response to HS addition has been ascribed.

Moustafa, *et al.* (2016) conducted two field experiments were imposed during the winter seasons of 2012 and 2013 to study the main and interaction effects of spraying humic acid (0, 500, 1000 and 1500 ppm), Salicylic acid (0, 500 and 1000 ppm) and copper (0, 200 and 400 ppm) on vegetative growth and bulbs yield and its components of onion plants *cv.* Giza 20. They reported that the main effect of spraying humic acid, salicylic acid and copper, irrespective of the concentration used, significantly, increased the number of leaves $plant^{-1}$ and plant height relative to the untreated control. The highest concentration of humic acid, salicylic acid and copper, positively and significantly, increased marketable and total bulbs yield. The second-order interaction of humic acid, salicylic acid and copper at the highest concentration was the most effective treatment which gave the best vegetative growth and highest total and marketable bulbs yield.

Hussein, *et al.* (2015) reported that the application of humic substances showed an increased yield of onion as well as greater accumulations of amino acids, sugars and vitamin C in bulbs.

Bakry, *et al.* (2014) carried out field experiments to mitigate the salinity effects on flax grown on moderate saline sandy soil and irrigated with moderate saline water at the experimental Station of the Faculty of Agriculture, Wadi El-Natrun district El-Behera Governorate, Egypt, for two successive winter seasons of 2012/2013 and 2013/2014. The results showed the positive responses of Giza-8 variety to the combined application of humic acid and proline and mitigated the salinity effects of soil and irrigation water and reflected on most of the studied characters. They also indicated that the highest seed yield, straw yield and oil yield was obtained at humic acid (50 kg fed^{-1}) with the foliar treatment of proline at the rate of (100 mg L^{-1}). The interaction of proline at (100 mg L^{-1}) with humic acid at the rate of (50 kg fed^{-1}) improved plant fresh and dry weight in all flax cultivars under salinity conditions. Fresh weight increased by 66.6%, 48.7% and 65.5% over controls for Opal, Giza-8 and Mayic varieties, respectively. The interaction of proline at (100 mg L^{-1}) with humic acid at the rate of (50 kg fed^{-1}) with Giza-8 variety gave the highest values of seed yield, straw yield and oil yield**.**

Bettoni, *et al.* (2014) found that humic acid enhanced chlorophyll concentration in onion plants.

Klein, *et al*. (2014) reported that humic acid has been shown to stimulate plant growth and yield by acting on mechanisms involved in physiological respiration by acting as an activator, photosynthesis, protein synthesis, water and nutrient uptake, cationic exchange capacity, enzyme activities and antioxidant.

Geries, (2013) revealed that foliar spraying of onion plants with humic acid markedly increased vegetative growth, bulb yield and its attributes, onion quality and chemical composition.

Kandil, *et al.* (2013) conducted two field experiments at Gemmeiza Agriculture Research Station Farm, Gharbeia Governorate, Agriculture Research Center, during 2010/2011 and 2011/2012 seasons to investigate the effect of nutrient foliar spraying such as amino and humic acids under nitrogen fertilizer levels on growth, yield and keeping the quality of onion bulbs *cv.* Giza 20. The obtained results showed that foliar spraying with humic acid resulted in the highest growth characters, total and marketable yields, total culls and bulb weight as well as TSS %, dry matter and total weight loss percentages at storage period compared with the control treatment. They also reported that foliar application of 18.5% HA, applied at 60 and 80 days after transplant, increased vegetative growth, bulb yield, quality and chemical composition of onion.

Traversa, *et al*. (2013) reported that humic acid positively influences physiological processes *viz.* cell respiration, photosynthesis, protein synthesis, water and nutrient uptake, and enzymatic activity of plants.

El-Nemr, *et al.* (2012) reported that foliar application of humic acid-enhanced nutrient uptake, plant growth, yield and quality in several plant species.

Osvalde, *et. al*. (2012) concluded that the different humic substances' application caused no changes in onion leaf Mn concentration, which also supports this outcome.

Sajid, *et al.* (2012) performed a field experiment at the Pakistan Agricultural Research Council (PARC) Mardan Station to study "Humic acids affect the bulb output of onion cultivars" during the winter of 2010-2011. Experiment results concluded that the growth and yield parameters of onion cultivars were significantly influenced by various levels of humic, as a cultivar, Parachinar Local showed more neck height (7.5 cm), plant height (80.9 cm), bulb weight (94.2 g), yield plot^{-1} (22.9 kg) and total yield ha^{-1} (36.1 tons) whereas 2 kg ha^{-1} of humic significantly increased neck height (7.6 cm), plant height (75.3 cm), bulb weight (96.4 g), yield plot^{-1} (22.4 kg) and total yield ha^{-1} (35.86 tons), a non-significant response was recorded for survival percentage.

El-Sayed Hameda, *et al*. (2011) reported that application of humic acid significantly increased photosynthetic pigments, vegetative growth, the nutritive value and assist in the transport and absorption of nutrients due to the formation of complexes and chelates, which leads to increased yield in several plants.

Rajpar, *et al.* (2011) conducted a field study to observe the growth, yield and oil content of three mustard varieties viz., S-9, P-78 and AH-2001 under varying levels of humic acid application to a poorly fertile and alkaline-calcareous soil. The humic acid was applied to the soil at the time of sowing @ 0, 3.17, 6.35, and 9.35 kg acre^{-1}. Field experiment results concluded that overall varieties, compared to control, the application of humic acid @ 6.35 kg acre^{-1} positively affected almost all the growth and yield parameters.

Silva, *et al.* (2011) reported that the largest accumulation of ^{13}C was detected in isotopic assays when humic acid was applied by foliar pulverization, suggesting that bulbs were preferred sinks for photo assimilates when compared to other treatments.

Ahmed, *et al.* (2010) stated that plants sprayed with humic acid had better storability than untreated ones.

Mahmoud and Hafez, (2010) reported that the vegetative growth parameters, potato yield and tuber size, weight and quality as well as nutritive value of potato tuber were significantly increased with increasing the level of Humic acid application from 0 up to 2 kg ha^{-1}.

Katkat, *et al*. (2009) stated that rapid increases in cell division and cell elongation in the meristematic region were found in plants spread with humic acid resulted in improving plant growth.

Rosa, *et al*. (2009) reported that root dry mass increased by more than three times with the application of humic substances in bean plants.

Nikbakht, *et al*. (2008) stated that the application of humic acid increased the uptake of N, P, K, Mg and Ca over the control.

Sangeetha and Singaram, (2007) conducted a field experiment during Kharif season 2003, to study the influence of lignite humic acid on the growth and yield of onion, in a sandy clay loam soil belonging to somaiyanur series (Typic Haplustalf). The experiment includes eight treatments in which lignite humic acid was applied (through the soil at 10 and 20 kg ha^{-1} and foliar spray at 0.1 % concentration) with the 75 and 100 percent recommended dose of inorganic fertilizers. Results concluded that combined application of the recommended dose of inorganic fertilizers (60:60:30 kg NPK ha^{-1}) and humic acid at 20 kg ha^{-1} significantly increased plant height, number of leaves/plant and root length of onion. The combined application of lignite humic acid at 20 kg ha^{-1} and recommended dose of inorganic fertilizers had conspicuously increased 11.31 % of bulb yield over inorganic fertilizers alone.

Abdel-Al, *et al.* (2005) found that foliar application of potassium humate on onion plants at different levels had a significant effect on growth characters and total yield and its components as well as chemical characters.

Cimrin and Yilmaz, (2005) reported that humic acid stimulates roots, increases both available plant nutrients and nutrient uptake from the soil, and improves the plants' resistance to biotic and abiotic stress factors. They also reported that the availability of phosphate and iron increased due to the humic application.

Cimrin and Yilmaz, (2005) reported that humic substances stimulate shoot and root growth and nutrient uptake of vegetable crops.

El-Desuki, (2004) reported that increasing humic acid application from 0 to 6 kg fed^{-1}, gradually and significantly, increased onion bulbs yield. He, also, added that the combined application of humic acid at 20 kg ha^{-1} together with the recommended dose of NPK recorded a higher bulb yield over the recommended NPK by 12%.

Feibert, *et al*. (2003) reported no positive response from soil and foliar humic substances application on the production of onions (*Allium cepa* L.).

Canellas, *et al*. (2002) reported that the involvement of humic acid in accelerating root development, increasing root hair proliferation, producing smaller but more ramified secondary roots, and improving root initiation might explain why humic acid spraying improves onion growth characteristics.

Boyhan, *et al.* (2001) reported that the percentage of marketable short-day onions after 4.5 months of storage was increased in 1 out of 2 years by a humic acid product applied as a transplant dip and foliar spray.

Akinremi, *et al.* (2000) stated that humic substances stimulate shoot and root growth and nutrient uptake of vegetable crops.

Muscolo, *et al.* (1999) found that humic acids have a favorable influence on plant growth and productivity, which they attribute to their hormone-like activities in cell respiration, photosynthesis, oxidative phosphorylation, protein synthesis, and numerous enzymatic processes.

Nardi, *et al*. (1996) reported that the application of humic acid is capable to regulate hormonal levels in plants, increasing essential nutrient uptake and stimulate growth root and whole plant.

Castro, *et al.* (1988) reported a 17% yield increase of large tomato fruits with the application of humic acid compared to the control treatment in micro irrigated culture.

Rauthan and Schnitzer, (1981) reported that the humic acid treatment increased the uptake of K, N, P, Fe, and Zn thereby improving the nutritional status of the plant.

2.2. Effect of Salicylic acid

Chattoo, *et al.* (2020) conducted an experiment during rabi-2017-18, and 2018-2019 at the experimental field of the Division of Vegetable Sciences of, SKUAST-Kashmir. The experiment results indicated that significant improvement in vegetative, growth yield and quality parameters were found as compared to control application. Foliar application of salicylic acid at 30 and 120 days after transplanting recorded maximum plant height (81.55 cm), number of leaves plant^{-1} (12.95), average Bulb weight (98.70 gm), maximum polar diameter (6.38 cm), equatorial diameter (7.16 cm), total bulb yield (322.81 q ha^{-1}), neck thickness (0.46 cm), and also same treatment registered maximum quality attributes like dry matter content (15.31), soluble solid content (11.92 ^{0}Brix), Pyruvic Acid (µmol g^{-1}) content (7.66 mg 100 g^{-1}) besides lowest storage losses were also recorded with the same treatment (9.15%).

Nangare, *et al.* (2018) carried out a field experiment at Scheme for Research on Onion Storage, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri during the rabi season of 2015-16 to study the effect of salicylic acid on onion (*Allium cepa* L.) cv. N-2-4-1. The experiment was laid out in a Factorial Randomized block design with two replications consisting of two factors, Factor-A (03) with levels of concentration and water spray and Factor-B (07) with seven levels of time of applications. The result indicated that, there was a significant influence of the foliar application of salicylic acid on growth parameters *viz.*, plant height (68.28-76.45 cm), number of leaves per plant (13.15-15.30), neck thickness (0.84-1.07) and a higher level of chlorophyll content (0.58-0.75 mg 100 g^{-1} FW) as compared to water spray. The foliar application of salicylic acid at a lower concentration (100 mg L^{-1}) gives significantly maximum plant height, several leaves per plant, total chlorophyll content, bulb diameter, the average weight of the bulb, total bulb yield, marketable bulb yield as compared to a higher dose (150 mg L^{-1}) and water spray. Three foliar sprays at 30, 45 and 60 DAT were beneficial for vegetative growth, yield, quality and storability of onion *cv.* N 2-4-1 than either single or two sprays of salicylic acid.

Shelke, *et al.* (2018) carried out an experiment to find out the influence of salicylic acid on the growth, yield and quality in onion *cv.* Akola safed during rabi season of the academic year 2016-2017, at Chilli and Vegetable Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The results of the present investigation indicated that, polar diameter (cm), equatorial diameter (cm), TSS (^{0}Brix), ascorbic acid content (mg 100^{-1} g) in onion bulbs were recorded maximum, wherein the treatment combination consisting of two applications of salicylic acid at 30 and 60 DAT along with salicylic acid @ 100 mg L^{-1}. As regards to the influence of treatment combination on storage parameters viz., physiological loss in weight, sprouting and rotting loss were concerned, they depicted numerically minimum values in the treatment combination consisting of two applications of salicylic acid at 30 and 60 DAT with salicylic acid @ 100 mg L^{-1}.

Ali, (2017) performed a field experiment during the two consecutive winter seasons of 2015-2016 and 2016-2017 at the Farm of the Faculty of Agriculture, Assiut University (New Valley Branch), to investigate the effect of foliar spray with bio-stimulant namely yeast extract (0, 1, 2 and 3 %), and two antioxidants; i.e., salicylic acid and ascorbic acid at 200 ppm of each, besides control treatment on plant growth, yield and its components as well as bulb quality of garlic *cv*. Sids-40 under newly reclaimed soil of New Valley-Egypt. Results showed that the interaction between foliar spray with yeast extract at 3 % and sprayed plants with salicylic acid at 200 ppm was the best interaction treatment for increasing plant growth traits, i.e., plant height, leaf area $plant^{-1}$ both fresh and dry weight/plant, bulbing ratio, mineral contents (N, P, K and S in leaves and bulb) and biochemical concentration in leaves (total carbohydrates and salicylic acid) after 135 days from planting time, total yield fed^{-1} and bulb parameters as well as bulb quality (total carbohydrates and salicylic acid contents) at harvesting time, while the interaction between yeast extract at 3% and sprayed plants with ascorbic acid at 200 ppm gave the highest values of ascorbic acid content in leaves and bulb at 135 days after planting and harvesting time respectively in both seasons. The increases in total yield were about 166.9 and 165.1 % for the interaction treatment between the plants which sprayed with yeast extract at 3 % and salicylic acid at 200 ppm; 148.9 and 151.3 % for the interaction treatment between the same rate of yeast extract and sprayed plants with ascorbic acid at 200 ppm over control treatment in the 1^{st} and 2^{nd} seasons, respectively.

Sathiyamurthy, *et al.* (2017) carried out an experiment to study the effect of salicylic acid on the yield and quality of onion at the Department of Vegetable Crops, Horticulture College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during the three consecutive seasons of 2012-2013, 2013- 2014 and 2014-2015. Foliar application of Salicylic acid (AR grade) at the rate of 250 mg L^{-1} of water at different day intervals were used to study the difference in plant height (cm), the number of leaves, neck thickness, polar diameter (cm), equatorial diameter (cm), average bulb weight (g), percentage of A-grade bulb (above 5.5 cm), B-grade bulb (4.5 to 5.5 cm), C-grade bulb (3.5 to 4.5 cm), % of doubles, total yield (t ha^{-1}) and marketable yield (t ha^{-1}) of onion. The result showed that significant increases in vegetative growth and yield of onion were observed due to the application of salicylic acid. Foliar application of salicylic acid at 30 days after sowing (DAS), second spray at 30 days after transplanting (30 DAT) and third spray at 45 days after transplanting (DAT) recorded a significant increase in most growth and yield characters *viz.*, plant height (62.7 cm), number of leaves $plant^{-1}$ (11.6), neck thickness (8.62 mm), polar diameter (6.69 cm), equatorial diameter (4.33 cm), total yield (26.5 t ha^{-1}) and marketable yield (24.7 t ha^{-1}) with 36.5 % of A-grade bulb and total dry matter content (5.52 t ha^{-1}) compared to other treatments. The least percentage of doubles (0.74%) and total storage loss (22.2 %) was also observed in the aforementioned treatment. These results suggest that foliar application of salicylic acid may improve the growth and yield of onion.

Koppad, *et al.* (2017) conducted an experiment at the University of Agricultural Sciences, Dharwad during the rabi season of 2014-15 to enhance the production of onion through assessing the impact of salicylic acid. Experiment results concluded that plant height (68.98cm), no. leaves (8.35), collar thickness (15.56 mm), avg. bulb weight (69.32 gm), equatorial (62.72 mm) bulb diameter, polar (54.04 mm) diameter, lower % of bolters (3.06 %) and doubles (2.50 %), marketable yield (39.22 t ha^{-1}) and total yield (41.75 t ha^{-1}) were recorded in the foliar application of SA at 30 days after sowing and second spraying at 30 days after transplanting and the third spray at 45 days after transplanting.

Al-khafagi, *et al.* (2016) conducted a field experiment in the agricultural season 2011-2012 in the vegetable field of the Department of Horticulture and Landscape Gardening, College of Agriculture, the University of Baghdad to observe the impact of each salicylic acid and urea phosphate on the growth and seed yield of onion plant *var.* Texas Early Grano. The spraying of 100 mg L^{-1} salicylic acid treatment offered the best outcomes in terms of umbel diameter (7.789 cm) and setting percent (78 %). They also determined that the combined impact of 100 mg L^{-1} salicylic acid and 2.5 gm L^{-1} salicylic acid had substantial outcomes in all criteria, such as lowering the number of days required for seed maturity (210.3 days) and germination vigor (80.33 %).

Pradhan, *et al.* (2016) conducted a field experiment under the All India Network Research Project on Onion and Garlic operating at College of Horticulture (OUAT), Sambalpur, Odisha India during the winter season of 2013–14 to study the efficacy of exogenous application of salicylic acid (SA) on growth and yield in onion *var*. Agrifound Light Red. Exogenous treatment of SA resulted in considerably improved vegetative development in terms of plant height (68.18 to 71.08 cm), collar thickness (16.90 to 18.51 mm), and leaf chlorophyll content (31.53 to 33.01 SPAD) compared to the untreated control. They also found that spraying SA three times was more effective than spraying it twice in terms of bulb diameter (polar: 65.60 to 67.94 mm and equatorial: 49.10 to 49.80 mm), bulb weight (59.50 to 69.25 g), marketable bulb yield (180.91 to 183.10 q ha^{-1}), and total bulb yield (180.91 to 183.10 q ha^{-1}) and total bulb yield (266.99 to 290.91 q ha^{-1}). As a result, the application of SA at 30 DAS, 30 DAT, and/or 45 or 60 DAT boosted not only vegetative growth but also bulb production in onion variety ALR.

Semida, *et al.* (2016) conducted two field experiments consecutively in 2013/2014 and 2014/2015 to study the effect of 1 and 2 mM SA on growth, yield, plant water relations, chlorophyll *a* fluorescence, osmoprotectants and water use efficiency (WUE) in onion plants under four levels of irrigation. Experiment results concluded that foliar application of SA enhanced drought stress tolerance in onion plants by improving photosynthetic efficiency and plant water status as evaluated by membrane stability index and relative water content. These results were positively reflected by improving plant growth, productivity and WUE under drought stress conditions.

Khadr, (2015) clarified that, spraying garlic plants with salicylic acid at 50 ppm after 45, 60, and 75 days of seed sowing gave the highest mean values of plant height, total fresh and dry weights, fresh weight and number of leaves and leaf area $plant^{-1}$. In addition, the highest mean values of total marketable and exportable bulbs yield, average fresh and dry bulb weight, N, P, K, Ca, chlorophyll a, b, total chlorophyll, and carotenoid contents were attained.

Pacheco, *et al.* (2013) found that salicylic acid significantly affected the number of inflorescences in the marigold plant.

Javaheri, *et al.* (2012) concluded that in tomatoes, the fruit yield enhanced significantly when the plants were sprayed with lower concentrations of salicylic acid.

Loutfy, *et al.* (2012) stated that SA increased total soluble sugars accumulation and this might be contributing as a solute for the osmotic regulation and/or a substrate for the protein and polysaccharide syntheses and thereby for the growth of whole plants.

Hayat, *et al.* (2010) reported that salicylic acid stimulates dry mass production through enhancement of cell division and cell enlargement and chlorophyll accumulation which is reflected in the vegetative growth of onion plants.

Shraiy and Hegazi, (2009) revealed positive effects of SA application on total soluble proteins., phenol, total soluble carbohydrates and sugars in pea (*Pisum Sativum* L.).

Vlot, *et al.* (2009) reported that the influence of salicylic acid as a flowering promoter and its effect on changing the synthesis of many plant hormones such as jasmonic acid.

Hussein, *et al*. (2007) conducted a pot experiment in which they sprayed salicylic acid on the foliage of wheat plants irrigated with Mediterranean seawater and reported increased productivity as a result of improvements in plant height, number and area of green leaves, stem diameter, and dry weight of stem, leaves, and plant as a whole. Furthermore, the plants that were treated with SA exhibited a higher proline content.

Sahu, *et al.* (2007) evaluated the influence of different salicylic acid concentrations on laboratory-produced wheat plants' growth, pigment content, and antioxidant activity. According to the findings, larger concentrations of SA treatment affected root and shoot development in the early stages of growth. With the administration of SA, the activities of catalase (CAT), ascorbate peroxidase (APX), and guaiacol-specific peroxidase (POX) decreased in both root and leaf tissues, with the drop becoming more significant as SA concentrations increased. Although larger quantities of salicylic acid (5 and 10 mM) decreased CAT activity, the activities of APX and POX were unaffected. With the addition of SA, superoxide dismutase (SOD) activity increased. SA has no influence on the activity of these enzymes in vitro at low doses. In both root and leaf tissues, a high concentration of SA enhanced the levels of H_2O_2 and malondialdehyde.

Amin, *et al*. (2007) carried out two field experiments at the National Research Center (Research and Production Station, Nubaria) during the two successive seasons of 2005/2006 and 2006/2007 to study the effect of indole-3-butyric acid (25, 50 and 100 mg L^{-1}) and salicylic acid (50, 100 and 200 mg L^{-1}) as well as their combinations on vegetative growth, photosynthetic pigments content of leaves, yield and its quality and some biochemical constituents of onion plants. They also reported that spraying salicylic acid caused a significant increase in most growth characters, photosynthetic pigments content leaves^{-1}, yield and its quality, total soluble sugars, total free amino acids, total phenols and total indoles. The lower and moderate concentrations (50 and 100 mg L^{-1}) were more effective than the higher ones (200 mg L^{-1}). The combination between indole-3-butyric acid and salicylic acid concentrations showed a significant increase in most growth characters, yield and its quality, total soluble sugars, total free amino acids, total phenols and total indoles of onion plants in comparison with the individual effect of salicylic acid concentrations or untreated plants, especially the combinations between indole-3-butyric acid at 100 mg L^{-1} and salicylic acid at 50 or 100 mg L^{-1} which were more effective than other combinations in this respect.

Eraslan, *et al.* (2007) reported that exogenous application of salicylic acid, enhanced growth, physiological processes and antioxidant activity of carrot plants grown under salinity stress.

Shakirova, *et al.* (2007) revealed the positive effect of salicylic acid on growth and yield can be attributed its influence on other plant hormones. They also reported that salicylic acid altered the auxins, cytokinins and ABA balances in wheat and increased the growth and yield under both normal and saline conditions.

Gharib, (2006) reported that exogenous application of SA boosted photosynthetic activity and cell division, increasing the number of leaves plant^{-1}.

Abdel-Wahed, *et al*. (2006) found that foliar application of salicylic acid at a low dose of 1 µM and 2 µM resulted in a significant increase in total sugars, crude protein, oil and total carotenoids content of yellow maize grains, while, the high doses (3 µM) significantly decreased it.

Martin, *et al.* (2005) reported that different plant species including ornamental plant *Sinningia speciosa* flowered much earlier as compared to the untreated control, when they received an exogenous foliar spray of salicylic acid.

Helgi and Rolfe, (2005) reported that foliar spray of low concentration of salicylic acid promotes and influences the growth, development, differentiation of cells, and tissues of plants and enhanced the plant's growth parameters.

Semida, *et al*. (2017) reported that foliar application of salicylic acid enhanced drought stress tolerance in onion plants by improving photosynthetic efficiency and plant water status that resulted in yield recovery under drought stress.

Lucas and Lee, (2004) reported that salicylic acid application augmented uptake of ions, control stomata functions and gravity sensing and pathogenesis.

Bardisi, (2004) found that spraying garlic plants with SA recorded maximum values of N, P and K uptake by leaves and bulb and N, P and K total uptake by plant.

El-Mergawi and Abdel-Wahed, (2004) reported that a low dose of salicylic acid (2.5 µM) resulted in a significant increase in total carbohydrate content. While the high doses (5 and 10 µM) significantly decreased it.

Blokhina, *et al*. (2003) reported that the stimulative effect of SA and AA on fresh and dry weight of eggplant shoots may be due to their involvement as antioxidant defense, regulation of photosynthesis and growth.

Fariduddin, *et al.* (2003) showed that salicylic acid significantly impacted the dry weight, photosynthetic rate, carboxylation efficiency, activities of nitrate reductase, the number of pods and finally the seed yield in the mustard plant.

Khan, *et al.* (2003) reported that SA is an endogenous growth regulator with phenolic nature, which participates in the regulation of several physiological processes in crop plants such as stomata closure, ion uptake, inhibition of ethylene biosynthesis and transpiration.

Singh and Usha, (2003) reported that the ability of SA to promote Rubisco activity under water stress may be responsible for the increase in yields of wheat genotypes with SA treatment.

Zaghlool, *et al.* (2001) found that the combined effect of salicylic acid and naphthalene acetic acid markedly increased the seed yield of *Phaseolus vulgaris* L.

Shehata, *et al*. (2001) reported that phenols content in maize leaves significantly increased by acetyl-salicylic acid application (20 and 40 µM).

CHAPTER III

MATERIALS AND METHODS

3.1. Experimental site

The present study was conducted on the Horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. The location of the site is $23^{0}74^{/}$ N latitude and $90^{0}35^{/}$ E longitude. A map of the experimental location is presented in Appendix I.

3.2. Experimental time frame

The field experiment was conducted during the period of October 2019 to February 2020.

3.3. Climatic condition in the experimental site

The experimental area is situated in the sub-tropical climate zone, characterized by heavy rainfall from April to September and scanty rainfall during the rest of the year. The monthly average temperature, humidity, rainfall and sunshine hour during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix II.

3.4. Soil characteristics in the experimental site

The initial soil samples from 0-15 cm depth were collected from the experimental site. The collected soil was air-dried, grind and passed through a 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka for soil physical and chemical properties. The physio-chemical properties of the soil are presented in Appendix-III. The soil of the experimental site belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28) and the general soil type is deep red-brown terrace soils (Appendix III).

3.5. Plant materials

BARI Piaz-1 is a high-yielding variety that was used as a plating material in this experiment. The seeds were collected from the BARI, Joydebpur, Gazipur.

3.6. Treatments of this experiment

The experiment consisted of two factors as follows:

Factor A: Four levels of Humic Acid

i. H_0 = 0 ppm (Control)

ii. H_1 = 15 ppm

iii. H_2 = 30 ppm

iv. H_3 = 45 ppm

Factor B: Four levels of Salicylic Acid

i. S_0 = 0 ppm (Control)

ii. S_1 = 10 ppm

iii. S_2 = 20 ppm

iv. S_3 = 30 ppm

There were in total 16 (4×4) treatment combinations such as H_0S_0, H_0S_1, H_0S_2, H_0S_3, H_1S_0, H_1S_1, H_1S_2, H_1S_3, H_2S_0, H_2S_1, H_2S_2, H_2S_3, H_3S_0, H_3S_1, H_3S_2 and H_3S_3.

3.7. Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Two factors were considered *viz.* humic acid level and salicylic acid level for the present study. The experimental area was first divided into three blocks. Therefore total no. of plots was 48. Thereafter 16 treatment combinations were assigned to each block as per the design of the experiment. The size of the unit plot was 2.0 m x 1.5 m. The spacing between the two blocks and the two plots was kept at 1.5 and 1.0 meters, respectively. (Appendix. IV)

3.8. Seedbed preparation

The land which was selected for raising seedlings was fine textures and well-drained. The land was opened and dried for 10 days. The seedbed was made on October 22, 2019, for raising seedlings and the size of the seedbed was 3 x 1 m^2 with a height of about 20 cm. To get a good tilth, the soil was thoroughly plowed and turned into loose friable and dry masses. Cowdung was applied at a rate of 15 t ha^{-1} to the prepared seedbed. Polythene was used to cover the seedbed for two days after the application of Furadan 3G at 20 kg ha^{-1}. Onion seeds were soaked in water overnight (12 hours) and sprouted on a piece of moist cloth in the sunshade for one day.

3.9. Seed treatment and seed sowing

Seeds were treated by Vitavax-200 @ 5g/1kg seeds to protect against seed-borne diseases. On October 24, 2019, the seeds were sown in the seedbed. The seeds were covered with a thin layer of sandy soil after sowing.

3.10. Raising of seedlings

Light watering, weeding, and mulching were done several times. No chemical fertilizers are applied for the raising of seedlings. When the seedlings of the seedbeds attained a height of about 10 cm, the thinning operation was done. Healthy and 30 days old seedlings were transplanted into the main field.

3.11. Land preparation

On November 16, 2019, a disc plough in direct sunlight was used to open the experimental area. The area was next prepared by plowing and cross plowing with a power tiller, followed by laddering to get a proper tilth. The ground was leveled, the corners contoured, and the clods were broken up. The field was cleared of weeds, crop leftovers, and stables. At the end of the plowing, the base dose of manures and fertilizers was administered. The plots were made according to the design and layout. To protect the young plants from mole cricket, ants, and cutworm, the soil was sprayed with Sevin 50 WP @ 5 kg ha^{-1}.

3.12. Manures and Fertilizers application

The following doses of manures and fertilizers were applied to each plot for bulb production: Cowdung 10 t ha^{-1}, Urea 220 kg ha^{-1}, TSP 125 kg ha^{-1}, MOP 180 kg ha^{-1} and Gypsum 180 kg ha^{-1} (BARI, 2016). After opening the land, a basal dose of well-decomposed cow dung 10 t ha^{-1} was applied. The total amount of TSP, ½ MP and full gypsum was applied at the final land preparation. Total urea and ½ MP were applied in two installments. The first installments were applied 30 days after transplanting, second installments were applied 45 days after transplanting as a top dressing. The fertilizer was thoroughly mixed with the soil.

3.13. Transplanting of seedlings

Healthy and disease-free uniform-sized 30 days old seedlings were uprooted from the seedbeds and transplanted to the main field on 23 November 2019 as per layout and maintaining a spacing of 20 cm ×15 cm. The seedlings were watered immediately after transplanting. Some seedlings were also transplanted adjacent to the experimental area to be used for gap fillings.

3.14. Application of humic acid and salicylic acid

Humic acid and Salicylic acid in different concentrations were prepared and sprayed at 30, 70 and 90 days after transplanting (DAT) according to the treatments.

3.15. Intercultural operations

After transplanting of seedlings, intercultural operations were done whenever required for getting better growth and development of the plants. So, the seedlings were always kept under careful observation.

3.15.1. Gap filling

Gap filling was done using healthy and stout seedlings within the first week whenever it is required from the extra seedlings.

3.15.2. Weeding and mulching

Weeding was performed whenever it is required to keep the plots free from weed infestation and to minimize crop-weed competition for resources. Mulching was accomplished by breaking the surface crust to provide better aeration and to conserve soil moisture whenever needed.

3.15.3. Irrigation and Drainage

Irrigation was given by watering can once a week after 15 days of transplantation of seedlings and continued up to one month before harvesting where final irrigation was flood irrigation. Adequate drainage facilities were provided in the plots to provide adequate growth and development.

3.15.4. Plant protection

Preventive measures were taken against soil-dwelling insects during the final land preparation. Soil was treated with Furadan 5G @ 25kg ha^{-1} to provide protection from Cutworm (*Agrotis ipsilon)*. To provide protection to the crops from purple blotch of onion caused by (*Alternaria porri*), Rovral 50WP was used 3 times at 10 days interval.

3.15.6. Removal of escape

Bolting was discouraged by pinching off the flower bearing stalks whenever they appeared during the flowering stage of the crop.

3.15.7. Harvesting

Crops were harvested at ninety four days after transplanting when the maximum number of plants showed the maturity sign by being yellow out most of the leaves, drying of pseudostem, being thin and drying the outer scale. Bulbs were pulled out from the soil manually and prior to that light irrigation was given to the plots to pull them out easily.

3.15.8. Storage of bulbs

After each harvest, the bulbs were dried in the shade in the field for one day. The bulbs were cured for 7 days in a room at room temperature (29.6 ± 2.6^0C) and then kept in a well-ventilated room.

3.16. Data collection

Ten plants were randomly selected from each plot to record data in such a way that the border effect was avoided. The following data was recorded from the sample plants during the study period.

Data were collected on the following parameters:

A. Growth and yield parameters

- Plant height (cm)
- Number of leaves plant^{-1}
- Bulb length (cm)
- Bulb diameter (cm)
- Weight of single bulb (g)
- Yield (t ha^{-1})

B. Quality parameters

- Total Nitrogen content (%)
- Total Phosphorus content (%)
- Total Potassium content (%)
- Total Sulfur content (%)
- Sugar content (%)
- Ascorbic acid content (mg/100g)
- Total soluble solids (%)

3.17. The procedure of recording data

3.17.1. Plant height (cm)

The height of the randomly selected ten plants was measured of each plot after 30 days after transplanting (DAT), and continued to 50 DAT, 70 DAT and at harvest. The height was measured in centimeters (cm) from the ground level to the tip of the longest leaf and the average height of ten plants was calculated in centimeters.

3.17.2. Number of leaves plant^{-1}

The number of leaves plant^{-1} was calculated from randomly selected ten plants from each replication and the mean was recorded. The number of leaves plant^{-1} was measured from each unit plot after 30 days after transplanting (DAT), and continued to 50 DAT, 70 DAT and at harvest.

3.17.3. Bulb length (cm)

After harvesting the length of the bulb was measured with a scale from the neck to the bottom of the bulb of ten randomly selected plants from each plot and their average was taken in centimeters.

3.17.4. Bulb diameter (cm)

After harvesting the diameter of the bulb was measured at the middle portion of ten randomly selected plants with the help of a slide caliper from each plot and their mean value was taken in centimeter.

3.17.5. Weight of single bulb (g)

Bulb of 10 individual plants was taken and weighted after harvest by electric balance and their average weight was calculated and expressed in gram (g).

3. 17.6. Yield (t ha^{-1})

All bulbs were collected from each replication of each treatment combination. Bulb weight per plot was measured by an electric balance and then the average was expressed as bulb yield per plot in kilogram (kg). Plot yield of harvested fresh bulb was converted to per hectare yield and it was expressed in a ton (t).

3.17.7. N, P, K and S contents in bulb

Dried bulbs were used for the determination of N, P, K and S contents.

3.17.7.1. Total Nitrogen

Total nitrogen content in bulbs was determined by the micro Kjeldahl method following concentrated sulfuric acid digestion, distillation and titration (Black, 1965). One gram of oven-dry sample was taken into micro Kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100:10:1), and 6 ml H_2SO_4 were added. The flasks were swirled and heated 200^0C and added 3 ml H_2O_2 and then heating at 360^0C was continued until the digest was clear and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al*., 1982).

Then 20 ml digest solution was transferred into the distillation flask, then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add a sufficient amount of 10N-NaOH solutions in the container connecting with the distillation apparatus. Water running through the condenser of the distillation apparatus was checked. The operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally, the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink. The amount of N was calculated using the following formula:

$$\% N = (T-B) \times N \times 0.014 \times 100/W$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

W= Sample weight in grams

3.17.7.2. Total phosphorus, potassium and sulfur

Dried bulbs were digested with concentrated HNO_3 AND $HClO_4$ mixture as described by Piper (1942) for the determination of total phosphorus and potassium content. Total phosphorus content in the extract was determined by the Vanado-molybdate yellow color method as described by Jackson (1973). Total potassium content was determined by Atomic Absorption Spectrophotometer. Available sulfur was determined by the Calcium chloride extraction method.

3. 17.8. Analytical Methods

For biochemical analysis, a composite sample of onion was prepared the sample was homogenized with distilled water. The homogenized solution was centrifuged and filtered to remove solid materials. The filtrate was then used for estimation of ascorbic acid, organic acid and sugar.

Determination of Sugar

Sugar contents were estimated as per the method described by Somogyi, (1952).

Reducing sugar

At first 10 ml of the prepared extract was taken in a 50 ml conical flask. Then 10 ml of each Bertrand A (40g of $CuSO_4.5H_2O$ dissolved in water and diluted to 1 liter) and Bertrand B (200g of sodium-potassium tartrate and 150g of NaOH dissolved in water and diluted to 1 liter) solutions were added to it. After that, the flask was placed on a hot plate (sand bath), boiled for 3 minutes and kept overnight for cooling. The supernatant was decanted and discarded very carefully be keeping precipitation. The precipitation was washed repeatedly until the blue color was present. Then 10 ml of Bertrand C [50g $Fe_2(SO_4)_3$ and 115 ml of conc. H_2SO_4 was added and diluted to 1 liter] was added to dissolve precipitation (Cu_2O). Finally, the solution was titrated with 0.3% $KMnO_4$ solution. Reducing sugar was calculated by comparing tabulated values. Before the calculation of reducing sugar factor of 0.3 %, $KMnO_4$ was determined.

Total sugar

10 ml of the extract was taken into a 100 ml conical flask and 2-3 drops of 4N HCI were added to it. Then the flask was boiled for 3 minutes on a hot plate for hydrolysis. After cooling the extract was neutralized with 2 N NaOH solutions to remove HCI.

Then to the neutral extract, 10 ml of both Bertrand A and Bertrand B solutions were added and continued procedure as reducing sugar method.

Determination of ascorbic acid

Ascorbic acid was determined as per the procedure described by Pleshkov, (1976).

Free ascorbic acid

10 ml prepared extract was taken in a conical flask. To the extract, 5 ml of 5% KI, 2 ml of 1% starch solution and 2 ml of glacial acetic acid were added. Finally, the sample solution was titrated with 0.00 l N KIO_3 solution.

Free ascorbic acid was quantified as per Pleshkov, (1976) using the formula:

Ascorbic acid content (mg/l00g) = [(T.F. V. 1000(v. W)]

Where,

T= Titrated volume of KIO_3 (ml)

F= 0.088 mg of ascorbic acid per ml of 0.001 N KIO_3

V= Total volume of the extract (ml)

v= Volume of the extract taken for titration (ml), and

W= weight of sample taken (g)

Total ascorbic acid

10 ml of the prepared extract was passed through cation exchange resin (CG-IR-120). The column was washed repeatedly with distilled water for collecting the extract, similarly, as free ascorbic acid, 5 ml of Kl (5%), 2 ml of starch solution (1%) and 2 ml of glacial acetic acid were added to it. It was then titrated with 0.001 N KlO_3 solution, finally, total ascorbic acid was measured as per the procedure described above (Pleshkov, 1976)

Measurement of total soluble solids (TSS, %)

A Brix refractometer (Model RHB 32 ATC) was used to measure TSS. One onion sample was collected from each of the treatments. Onion samples were cut with a sharp knife and inside was a squeeze with the needle for sample juice. A drop of onion juice was placed on the transparent glass and it was covered by the upper glass. Brix refractometer was directly showed the TSS as a percentage.

3.18. Statistical analysis

The collected data on various parameters under study were statistically analyzed using the STATISTIX-10 computer package programmed. The means for all the treatments were calculated and analysis of variance for all the characters was performed by the F-variance test (Gomez and Gomez, 1984). The significance of the difference between means was evaluated by Least Significance Difference (LSD) and the probability level 5% for the interpretation of results.

CHAPTER IV

RESULTS AND DISCUSSIONS

4.1. Growth and yield parameters of onion

4.1.1. Plant height (cm)

Humic acid has a significant impact ($P<0.05$) on plant height (Table 1). The tallest plant (53.99 cm) resulted from the H_3 (45 ppm humic acid) treatment, which was statistically equivalent to the H_2 (30 ppm humic acid) treatment (52.06 cm), while the smallest plant (48.17 cm) resulted from the H_0 (control) treatment. Increases in humic acid significantly improved plant height up to a certain point. The increase in plant height due to the humic the acid application might have been attributed to the better rooting and absorption of nutrients by plants and also due to the auxin activity of humic acid on plant growth. Kandil, *et al.* (2013) reported that foliar application of 18.5% HA, applied at 60 and 80 days after transplant, increased vegetative growth, bulb yield, quality and chemical composition of onion. Forotaghe, *et al.* (2021), Lestari and Dewi, (2020), and Turhan, *et al.* (2020) supported the findings of this experiment and reported that humic acid application increase the nutrient absorption in the plant which cause cell elongation as a result of increased plant height.

Different levels of salicylic acid showed a statistically significant variation ($P<0.05$) in plant height (Table 2). The tallest plant (54.02 cm) resulted from the S_2 (20 ppm salicylic acid) treatment, which was statistically equivalent to the plant height (51.78 cm) obtained by S_3 (30 ppm salicylic acid) treatment, while the smallest plant (48.41 cm) resulted from the S_0 (control) treatment. Nangare, *et al.* (2018) supported the findings of this experiment and reported that the balance of internal levels of natural auxins caused by salicylic acid is primarily responsible for sustaining physiological activities in the plant system, resulting in improved growth and increased plant height. These findings are in close agreement with Sathiyamurthy, *et al.* (2017) reported that foliar application of salicylic acid at 30 days after sowing (DAS), second spray at 30 days after transplanting (30 DAT) and third spray at 45 days after transplanting (DAT) recorded a significant increase in most growth and yield characters *viz.,* plant height (62.7 cm), number of leaves plant^{-1} (11.6), neck thickness (8.62 mm), polar diameter (6.69 cm), equatorial diameter (4.33 cm), total yield (26.5 t ha^{-1}) and marketable yield (24.7 t ha^{-1}) with 36.5 % of A-grade bulb and total dry matter content (5.52 t ha^{-1}) compared to other treatments.

The combined effect of humic acid and salicylic acid indicated a significant variation ($P<0.05$) in plant height (Table 3). The tallest plant height (57.67 cm) was found in H_3S_2 (45 ppm humic acid with 20 ppm salicylic acid) treatment which showed statistically similar plant height with H_1S_2, H_2S_2, H_2S_3, H_3S_1 and H_3S_3 treatments, whereas the smallest plant height (44.07 cm) was found in H_0S_0 (control) treatment.

4.1.2. Number of leaves plant^{-1}

Different levels of humic acid showed significant variation ($P<0.05$) in the number of leaves plant^{-1} (Table 1). The highest number of leaves plant^{-1} (10.16) resulted from the H_3 (45 ppm humic acid) treatment, while the lowest number of leaves plant^{-1} (8.12) resulted from the H_0 (control) treatment. Humic acid application improves plant root formation, increases nutrient absorption which results in more leaf numbers in plants. The greater number of leaves, the greater the photosynthetic area which may result in higher bulb yield. Lestari and Dewi, (2020) supported the findings of this experiment and reported that humic acid application through the leaves significantly increases plant height, leaf number, the fresh and dry weight of shoot and betacyanin content. They also reported that humic acid application through the soil surface also significantly increased leaf number, both fresh and dry weight of shoot and root but reduced oxalate content.

The number of leaves on Plant^{-1} varied significantly ($P<0.05$) depending on the amount of salicylic acid application (Table 2). The highest number of leaves plant^{-1} (10.11) resulted from the S_2 (20 ppm salicylic acid) treatment, while the lowest number of leaves plant^{-1} (8.14) resulted from the S_0 (control) treatment. Onion leaves are storage organs of the food materials and they get translocated into the bulbs at the time of maturity. Hence the number of leaves plays a major role in bulb yield and quality. Chattoo, *et al.* (2020), Nangare, *et al.* (2018) and Gharib, (2006) supported the outcomes of this experiment and reported that the exogenous application of SA had an effect on increased photosynthetic activity and cell division which enhances the number of leaves plant^{-1}.

The combined effect of humic acid and salicylic acid indicated a significant variation ($P<0.05$) in the number of leaves plant^{-1} (Table 3). The highest number of leaves plant^{-1} (11.47) was found in H_3S_3 (45 ppm humic acid with 30 ppm salicylic acid) treatment which showed a statistically significant difference with all other treatment combinations, whereas the lowest number of leaves plant^{-1} (7.06) was found in H_0S_0 (control) treatment.

4.1.3. Bulb diameter (cm)

The humic acid showed a significant variation ($P<0.05$) in bulb diameter (cm) (Table 1). The highest bulb diameter (3.58 cm) resulted from the H_3 (45 ppm humic acid) treatment which showed statistically similar results with H_2 (30 ppm humic acid) treatment, while the lowest bulb diameter (3.33 cm) resulted from the H_0 (control) treatment. The application of humic acid increases the nutrient availability in soil which might have improved the vegetative growth and accelerated the photosynthesis in plants and translocation of photosynthates in storage organ of bulb resulting in an increased diameter and weight of bulb. Hafez and Geries, (2018) supported the findings of this experiment and reported that foliar spraying with humic acid led to a significant increment in most of the vegetative growth characteristics, as well as total bulb yield and its components, bulb quality and storability of onion.

Different levels of salicylic acid showed a statistically significant variation ($P<0.05$) in the bulb diameter of onion (Table 2). The highest bulb diameter (3.59 cm) resulted from the S_2 (20 ppm salicylic acid) treatment which showed statistically similar results with S_3 (30 ppm salicylic acid) treatment, while the lowest bulb diameter (3.33 cm) resulted from the H_0 (control) treatment. Experiment results concluded that increases in salicylic acid application increase bulb diameter up to a certain point. This increase might be due to stimulating dry mass production through enhancement of cell division and cell enlargement and chlorophyll accumulation which is reflected in the vegetative growth of onion plants. Al-khafagi, *et al.* (2016) supported the findings of this experiment and reported that the spraying of 100 mg L^{-1} salicylic acid treatment offered the best outcomes in terms of umbel diameter (7.789 cm) and setting percent (78 %) of onion.

The combined effect of humic acid and salicylic acid indicated a significant variation ($P<0.05$) in bulb diameter (cm) of onion (Table 3). The highest bulb diameter (3.86 cm) was found in H_3S_2 (45 ppm humic acid with 20 ppm salicylic acid) treatment which showed a statistically significant difference with all other treatment combinations, whereas the lowest bulb diameter (3.14 cm) was found with H_0S_0 (control) treatment.

4.1.4. Bulb length (cm)

Different levels of humic acid caused a significant difference (P<0.05) in bulb length (cm) (Table 1). The highest bulb length (2.66 cm) resulted from the H_3 (45 ppm humic acid) treatment which showed statistically similar results (2.57 cm) with H_2 (30 ppm humic acid) treatment, while the lowest bulb length (2.45 cm) resulted from the H_0 (control) treatment. The application of humic acid increased the N availability and uptake, which is an important constituent of nucleic acids that might have promoted cell division resulting in increased vegetative growth. Hussein, *et al.* (2015) and Forotaghe, *et al.* (2021) all found similar results and reported that foliar application of humic acid significantly increased all growth characteristics (i.e., Number of leaves, leaf length, leaf diameter, neck diameter, fresh weight of leaves, root length and number, bulb length and diameter and fresh weight of plants) compared to untreated control plants.

Bulb length (cm) varied significantly (P<0.05) depending on the amount of salicylic acid application (Table 2). The highest bulb length (2.67 cm) resulted from the S_2 (20 ppm salicylic acid) treatment which showed statistically significant variation with all other treatments. The lowest bulb length (2.44 cm) resulted from the S_0 (control) treatment. The present study indicated the beneficial impact of salicylic acid (SA) on crop growth, which might be due to the involvement of salicylic acid (SA) in the regulation of several physiological processes in plants such as stomata closure, ion uptake, inhibition of biosynthesis and transpiration. Sathiyamurthy, *et al.* (2017), Shelke, *et al.* (2018) supported the findings of this experiment and reported that polar diameter (cm), equatorial diameter (cm), TSS (^{0}Brix), ascorbic acid content (mg 100^{-1} g) in onion bulbs were recorded maximum, wherein the treatment combination consisting of two applications of salicylic acid at 30 and 60 DAT along with salicylic acid @ 100 mg L^{-1}.

The combined effect of humic acid and salicylic acid indicated a significant variation (P<0.05) in bulb length (cm) of onion (Table 3). The highest bulb length (2.86 cm) was found in H_3S_2 (45 ppm humic acid with 20 ppm salicylic acid) treatment which weighted a statistically significant difference with all other treatment combinations, whereas the lowest bulb length (2.32 cm) was found with H_0S_0 (control) treatment.

4.1.5. Weight of single bulb (g)

Weight of a single bulb varied statistically significantly ($P<0.05$) depending on humic acid levels (Table 1). The highest bulb weight (34.09 gm) was obtained with H_3 (45 ppm humic acid) treatment which showed statistically different results from all other treatments. The lowest bulb weight (26.42 gm) was obtained with H_0 (control) treatment. The application of humic acid increases the nutrient availability in soil which might have improved the vegetative growth and accelerated the photosynthesis in plants and translocation of photosynthates in storage organ of bulb resulting in an increased diameter and weight of bulb. Geries (2013) reported that foliar spraying on onion plants with humic acid promoted vegetative growth, bulb yield and characteristics, onion quality, and chemical composition significantly. Forotaghe, *et al.* (2021) found similar results and reported that foliar application of humic acid significantly increased all growth characters (i.e., Number of leaves, leaf length, leaf diameter, neck diameter, fresh weight of leaves, root length and number, bulb length and diameter and fresh weight of plants) compared to untreated control plants.

Different levels of salicylic acid showed a statistically significant variation ($P<0.05$) in the bulb weight of onion (Table 2). The S_2 (20 ppm salicylic acid) treatment produced the highest bulb weight (34.26 gm), which was statistically different from all other treatments. The S_0 (control) treatment yielded the lowest bulb weight (26.27 gm). The increased bulb weight in the present study by application of SA might be due to the better utilization of photosynthates and increased allocation of photosynthates towards the economic parts, the bulb in onion. Nangare, *et al.* (2018) reported that the foliar application of salicylic acid at a lower concentration (100 mg L^{-1}) gives significantly maximum plant height, several leaves per plant, total chlorophyll content, bulb diameter, the average weight of the bulb, total bulb yield, marketable bulb yield. Findings of this experiment are in close agreement with Pradhan, *et al.* (2016) reported that exogenous treatment of SA resulted in considerably improved vegetative development in terms of plant height (68.18 to 71.08

cm), collar thickness (16.90 to 18.51 mm), and leaf chlorophyll content (31.53 to 33.01 SPAD) compared to the untreated control. They also found that the application of SA at 30 DAS, 30 DAT, and/or 45 or 60 DAT boosted not only vegetative growth but also bulb production in onion variety ALR.

The combined effect of humic acid and salicylic acid indicated a significant variation ($P<0.05$) in bulb weight (gm) of onion (Table 3). The highest bulb weight (39.50 gm) was found in H_3S_2 (45 ppm humic acid with 20 ppm salicylic acid) treatment which showed a statistically significant difference with all other treatment combinations, whereas the lowest bulb weight (22.56 gm) was found with H_0S_0 (control) treatment.

4.1.6. Bulb yield (t ha^{-1})

Different levels of humic acid showed a statistically significant variation ($P<0.05$) in the bulb yield of onion (Table 1). The highest bulb yield (8.92 t ha^{-1}) was obtained by H_3 (45 ppm humic acid) application whereas the lowest bulb yield (7.26 t ha^{-1}) was obtained by H_0 (control) treatment. This could be linked to enhanced plant growth and a commensurate increase in root biomass, resulting in higher water and nutrient absorption. Transpiration may have slowed as a consequence of the greater water absorption and nutrient supply, resulting in increased carbon dioxide availability via the stomatal opening and decreasing the net gain in photosynthetic rate. The combined impact of all of these variables may have resulted in a total yield increase. Khan, (2017) found similar effects of humic acid on onion yield and reported that the application of plant-derived HSs, such as SFDHSs (sunflower derived humic acid) and MDHSs (maize derived humic acid), yielded the highest bulb yields of 25.1 and 24.5 t ha^{-1}, respectively, while CDHA (coal-derived humic acid) applied at a rate of 20 kg ha^{-1} yielded the highest bulb yield of 24.7 t ha^{-1}.

Bulb yield (t ha^{-1}) varied significantly ($P<0.05$) depending on the amount of salicylic acid application (Table 2). S_3 (30 ppm salicylic acid) treatment produced the maximum bulb production (8.91 t ha^{-1}), while S_0 (control) treatment produced the lowest bulb yield (7.26 t ha^{-1}). This might be attributed to increased chlorophyll content in leaves and improved photosynthetic performance after SA treatment. The use of SA also promotes the usage of photosynthates and the allocation of photosynthates to the economically important parts of the onion, the bulb. Nangare, *et al.* (2018) and Chattoo, *et al.* (2020) supported the findings of this experiment and reported that foliar application of salicylic acid at 30 and 120 days after transplanting recorded maximum plant height (81.55 cm), number of leaves $plant^{-1}$ (12.95), average Bulb weight (98.70 gm), maximum polar diameter (6.38 cm), equatorial diameter (7.16 cm), total bulb yield (322.81 q ha^{-1}), neck thickness (0.46 cm).

The combined effect of humic acid and salicylic acid indicated a significant variation ($P<0.05$) in bulb yield (t ha^{-1}) of onion (Table 3). The highest bulb yield (10.92 t ha^{-1}) was found in H_3S_3 (45 ppm humic acid with 30 ppm salicylic acid) treatment which showed a statistically significant difference with all other treatment combinations, whereas the lowest bulb yield (6.04 t ha^{-1}) was obtained with H_0S_0 (control) treatment.

Table 1. Effect of humic acid on growth and yield parameters of onion

Treatments	Plant height (cm)	Number of leaves	Bulb diameter (cm)	Bulb length (cm)	Bulb weight (g)	Yield (t ha^{-1})
H_0	48.17±1.75^{c}	8.12±0.46^{c}	3.33±0.066^{c}	2.45±0.053^{c}	26.42±1.62^{d}	7.26±0.48^{c}
H_1	50.78±1.29^{b}	8.95±0.44^{b}	3.43±0.039^{bc}	2.53±0.040^{bc}	29.20±1.54^{c}	7.82±0.22^{b}
H_2	52.06±0.95^{ab}	9.15±0.42^{b}	3.47±0.045^{ab}	2.57±0.045^{ab}	31.63±2.34^{b}	8.04±0.26^{b}
H_3	53.99±1.54^{a}	10.16±0.57^{a}	3.58±0.114^{a}	2.66±0.084^{a}	34.09±2.52^{a}	8.92±0.78^{a}
LSD $_{(0.05)}$	2.49	0.49	0.13	0.09	1.58	0.41
P-value	0.00	0.00	0.00	0.00	0.00	0.00
C.V. (%)	5.83	6.4	4.46	4.30	6.23	6.20

Means with the same letter did not significantly differ from each other at $p < 0.05$. Abbreviations are as follows H_0 = 0, H_1 = 15 ppm, H_2 = 30 ppm and H_3 = 45 ppm of humic acid. Values are mean ± SE.

Table 2. Effect of salicylic acid on growth and yield parameters of onion

Treatments	Plant height (cm)	Number of leaves	Bulb diameter (cm)	Bulb length (cm)	Bulb weight (g)	Yield (t ha^{-1})
S_0	48.41 ± 1.83^{c}	8.14 ± 0.48^{c}	3.33 ± 0.063^{c}	2.44 ± 0.050^{c}	26.27 ± 1.59^{d}	7.26 ± 0.48^{c}
S_1	50.79 ± 1.28^{bc}	9.01 ± 0.45^{b}	3.43 ± 0.031^{bc}	2.53 ± 0.033^{b}	29.20 ± 1.45^{c}	7.85 ± 0.22^{b}
S_2	54.02 ± 1.54^{a}	9.12 ± 0.42^{b}	3.59 ± 0.110^{a}	2.67 ± 0.081^{a}	34.26 ± 2.52^{a}	8.91 ± 0.79^{a}
S_3	51.78 ± 1.16^{ab}	10.11 ± 0.602^{a}	3.47 ± 0.034^{ab}	2.57 ± 0.040^{b}	31.62 ± 2.18^{b}	8.03 ± 0.26^{b}
LSD $_{(0.05)}$	2.49	0.49	0.13	0.09	1.58	0.41
P-value	0.00	0.00	0.00	0.00	0.00	0.00
C.V. (%)	5.83	6.40	4.46	4.30	6.23	6.20

Means with the same letter did not significantly differ from each other at $p < 0.05$. Abbreviations are as follows $S_0 = 0$, $S_1 = 10$ ppm, $S_2 = 20$ ppm and $S_3 = 30$ ppm of salicylic acid. Values are mean ± SE.

Table 3. Combined effect of humic acid and salicylic acid on growth and yield parameters of onion

Treatments	Plant height (cm)	Number of leaves	Bulb diameter (cm)	Bulb length (cm)	Bulb weight (g)	Yield (t ha^{-1})
H_0S_0	44.07 ± 1.00^{d}	7.06 ± 0.03^{f}	3.14 ± 0.01^{c}	2.32 ± 0.01^{e}	22.56 ± 0.22^{g}	6.04 ± 0.05^{e}
H_0S_1	48.19 ± 1.00^{cd}	8.13 ± 0.06^{e}	3.36 ± 0.01^{bc}	2.47 ± 0.01^{cde}	26.39 ± 1.96^{ef}	7.56 ± 0.05^{d}
H_0S_2	51.27 ± 1.98^{bc}	8.31 ± 0.09^{de}	3.42 ± 0.14^{b}	2.53 ± 0.01^{bcd}	29.28 ± 0.61^{e}	7.87 ± 0.22^{bcd}
H_0S_3	49.17 ± 1.24^{bc}	8.96 ± 0.05^{de}	3.40 ± 0.01^{b}	2.49 ± 0.02^{bcde}	27.46 ± 0.63^{ef}	7.57 ± 0.07^{cd}
H_1S_0	48.21 ± 1.71^{cd}	8.13 ± 0.10^{e}	3.35 ± 0.01^{bc}	2.45 ± 0.24^{de}	26.10 ± 0.73^{f}	7.54 ± 0.03^{d}
H_1S_1	50.12 ± 3.80^{bc}	8.78 ± 0.32^{de}	3.41 ± 0.02^{b}	2.53 ± 0.02^{bcd}	28.73 ± 1.57^{ef}	7.64 ± 0.03^{bcd}
H_1S_2	53.55 ± 3.51^{ab}	8.94 ± 0.10^{de}	3.51 ± 0.03^{b}	2.62 ± 0.02^{bcd}	32.58 ± 0.67^{bc}	7.71 ± 0.12^{bcd}
H_1S_3	51.24 ± 3.02^{bc}	9.96 ± 0.04^{bc}	3.45 ± 0.15^{b}	2.55 ± 0.02^{bcd}	29.40 ± 1.32^{de}	7.55 ± 0.13^{d}
H_2S_0	50.07 ± 1.74^{bc}	8.29 ± 0.04^{de}	3.39 ± 0.03^{bc}	2.48 ± 0.02^{bcde}	27.22 ± 0.88^{ef}	7.78 ± 0.09^{bcd}

H_2S_1	51.37±1.12[bc]	9.11±0.07[bcd]	3.43±0.01[b]	2.54±0.02[bcd]	29.22±2.70[ef]	7.90±0.03[bcd]
H_2S_2	53.59±1.76[ab]	9.18±0.05[bcd]	3.57±0.03[b]	2.66±0.02[b]	35.68±0.84[b]	8.39±0.08[bc]
H_2S_3	53.21±1.52[ab]	10.05±0.05[bc]	3.48±0.04[b]	2.60±0.01[bcd]	34.42±0.70[bc]	8.44±0.08[b]
H_3S_0	51.30±1.65[bc]	9.09±0.05[cde]	3.41±0.02[b]	2.52±0.01[bcd]	29.19±0.69[ef]	8.40±0.04[b]
H_3S_1	53.49±0.55[ab]	10.02±0.06[bc]	3.49±0.02[b]	2.61±0.02[bcd]	32.48±0.71[cd]	8.41±0.05[b]
H_3S_2	57.67±1.29[a]	10.07±0.13[b]	3.86±0.03[a]	2.86±0.02[a]	39.50±0.72[a]	10.92±0.10[a]
H_3S_3	53.52±1.20[ab]	11.47±0.01[a]	3.54±0.03[b]	2.65±0.01[bc]	35.19±0.70[bc]	8.45±0.11[b]
LSD $_{(0.05)}$	4.98	0.97	0.26	0.18	3.15	0.83
P-value	0.03	0.03	0.02	0.04	0.02	0.01
C.V. (%)	5.83	6.40	4.46	4.30	6.23	6.20

Means with the same letter did not significantly differ from each other at $p < 0.05$. Abbreviations are as follows $H_0 = 0$, $H_1 = 15$ ppm, $H_2 = 30$ ppm, $H_3 = 45$ ppm of humic acid and $S_0 = 0$, $S_1 = 10$ ppm, $S_2 = 20$ ppm, $S_3 = 30$ ppm of salicylic acid. Values are mean ± SE.

4.2. Quality parameters of onion

4.2.1. Nitrogen content (%)

The nitrogen content (%) of matured and harvested onion bulbs varied statistically significantly ($P<0.05$) when various doses of humic acid were applied (Table 4). The nitrogen content in onion bulbs was found to be greater in various treatments than in the control treatment. The highest nitrogen content (2.22 %) was obtained with H_3 (45 ppm humic acid) treatment whereas the lowest nitrogen content (1.92 %) was obtained with H_0 (control). Forotaghe *et al.* (2021a) found that humic acid influences the nitrogen content of onion.

When different dosages of salicylic acid were applied the nitrogen content (%) of the matured and harvested onion bulbs changed statistically ($P<0.05$) substantially (Table 5). The nitrogen content in onion bulbs was found to be greater in various treatments than in the control treatment. The highest nitrogen content (2.20 %) was obtained with S_2 (20 ppm salicylic acid) treatment whereas the lowest nitrogen content (1.94 %) was obtained with S_0 (control). Shamsul *et al*. (2014), Ibrahim *et al.* (2014), Deus *et al.* (2020) found the similar result.

Different combinations of humic acid and salicylic acid showed a statistically significant variation ($P<0.05$) in nitrogen content (%) of matured and harvested onion bulbs (Table 6). The highest nitrogen content (2.31 %) was obtained with H_3S_2 (45 ppm humic acid with 20 ppm salicylic acid) treatment which showed statistically similar results with H_2S_2, H_3S_1 and H_3S_3 treatment, whereas the lowest nitrogen content (1.71 %) was obtained with H_0S_0 (control).

4.2.2. Phosphorus content (%)

The phosphorus content (%) of matured and harvested onion bulbs varied statistically significantly ($P<0.05$) when various doses of humic acid were applied (Table 4). The phosphorus content in onion bulbs was found to be greater in various treatments than in the control treatment. The highest phosphorus content (0.79 %) was obtained with H_3 (45 ppm humic acid) treatment whereas the lowest phosphorus content (0.70 %) was obtained with H_0 (control). Forotaghe *et al.* (2021a) found that humic acid influences the phosphorus content of onion.

When different dosages of salicylic acid were applied the phosphorus content (%) of the matured and harvested onion bulbs changed statistically substantially ($P<0.05$) (Table 5). The phosphorus content in onion bulbs was found to be greater in various treatments than in the control treatment. The highest phosphorus content (0.80 %) was obtained with S_2 (20 ppm salicylic acid) treatment whereas the lowest phosphorus content (0.69 %) was obtained with S_0 (control). Safar-Noori *et al.* (2018), Abbasi *et al.* (2020) also observed the same findings.

Different combinations of humic acid and salicylic acid showed a statistically significant variation ($P<0.05$) in phosphorus content (%) of matured and harvested onion bulbs (Table 6). The highest phosphorus content (0.85 %) was obtained with H_3S_2 (45 ppm humic acid with 20 ppm salicylic acid) treatment which showed a statistically significant difference with all other treatments, whereas the lowest phosphorus content (0.64 %) was obtained with H_0S_0 (control).

4.2.3. Potassium content (%)

The potassium content (%) of matured and harvested onion bulbs varied statistically significantly ($P<0.05$) when various doses of humic acid were applied (Table 4). The potassium content in onion bulbs was found to be greater in various treatments than in the control treatment. The highest potassium content (1.33 %) was obtained with H_3 (45 ppm humic acid) treatment which showed a statistically similar result with H_2 (30 ppm humic acid), whereas the lowest potassium content (1.25 %) was obtained with H_0 (control). Forotaghe *et al.* (2021a) found that humic acid influences the potassium content of onion.

When different dosages of salicylic acid were applied the potassium content (%) of the matured and harvested onion bulbs changed statistically ($P<0.05$) substantially (Table 5). The potassium content in onion bulbs was found to be greater in various treatments than in the control treatment. The highest potassium content (1.34 %) was obtained with S_2 (20 ppm salicylic acid) treatment which was statistically similar with S_3 (30 ppm salicylic acid) treatment, whereas the lowest potassium content (1.24 %) was obtained with S_0 (control). Abbasi *et al.* (2020) and Deus *et al.* (2020) observed the similar result.

Different combinations of humic acid and salicylic acid showed no statistically significant variation (P>0.05) in potassium content (%) of matured and harvested onion bulbs (Table 6). The highest potassium content (1.44 %) was obtained with H_3S_2 (45 ppm humic acid with 20 ppm salicylic acid) treatment which showed a statistically significant difference with all other treatments, whereas the lowest potassium content (1.19 %) was obtained with H_0S_0 (control).

4.2.4. Sulfur content (%)

The sulfur content (%) of matured and harvested onion bulbs varied statistically significantly (P<0.05) when various doses of humic acid were applied (Table 4). The sulfur content in onion bulbs was found to be greater in various treatments than in the control treatment. The highest sulfur content (0.45 %) was obtained with H_3 (45 ppm humic acid) treatment whereas the lowest sulfur content (0.35 %) was obtained with H_0 (control). Forotaghe *et al.* (2021a) observed similar results in onion plants.

When different dosages of salicylic acid were applied the sulfur content (%) of the matured and harvested onion bulbs changed statistically substantially (P<0.05) (Table 5). The sulfur content in onion bulbs was found to be greater in various treatments than in the control treatment. The highest sulfur content (0.44 %) was obtained with S_2 (20 ppm salicylic acid) treatment whereas the lowest sulfur content (0.34 %) was obtained with S_0 (control). Amin *et al.* (2007) found that salicylic acid influences the sulfur content of onion.

Different combinations of humic acid and salicylic acid showed no statistically significant variation (P>0.05) in sulfur content (%) of matured and harvested onion bulbs (Table 6). The highest sulfur content (0.49 %) was obtained with H_3S_2 (45 ppm humic acid with 20 ppm salicylic acid) treatment which showed a statistically significant difference with all other treatments, whereas the lowest sulfur content (0.28 %) was obtained with H_0S_0 (control).

Table 4. Effect of humic acid on Nitrogen, Phosphorus, Potassium content and Sulfur content of onion

Treatments	Nitrogen content (%)	Phosphorus content (%)	Potassium content (%)	Sulfur content (%)
H_0	1.92±0.107^{d}	0.70±0.021^{c}	1.25±0.020^{c}	0.35±0.028^{c}
H_1	2.05±0.071^{c}	0.74±0.022^{b}	1.28±0.017^{bc}	0.39±0.021^{b}
H_2	2.12±0.050^{b}	0.76±0.024^{b}	1.29±0.024^{ab}	0.40±0.022^{b}
H_3	2.22±0.075^{a}	0.79±0.024^{a}	1.33±0.023^{a}	0.45±0.021^{a}
LSD $_{(0.05)}$	0.05	0.02	0.04	0.01
P-value	0.00	0.00	0.00	0.00
C.V. (%)	3.97	3.68	3.86	4.31

Means with the same letter did not significantly differ from each other at $p < 0.05$. Abbreviations are as follows H_0 = 0, H_1 = 15 ppm, H_2 = 30 ppm and H_3 = 45 ppm of humic acid. Values are mean ± SE.

Table 5. Effect of salicylic acid on Nitrogen, Phosphorus, Potassium content and Sulfur content of onion

Treatments	Nitrogen content (%)	Phosphorus content (%)	Potassium content (%)	Sulfur content (%)
S_0	1.94±0.092^{c}	0.69±0.026^{c}	1.24±0.026^{c}	0.34±0.029^{c}
S_1	2.08±0.065^{b}	0.74±0.027^{b}	1.27±0.023^{bc}	0.39±0.022^{b}
S_2	2.20±0.062^{a}	0.80±0.029^{a}	1.34±0.026^{a}	0.44±0.022^{a}
S_3	2.09±0.036^{b}	0.76±0.029^{b}	1.30±0.032^{ab}	0.41±0.021^{b}
LSD $_{(0.05)}$	0.05	0.02	0.04	0.01
P-value	0.00	0.00	0.00	0.00
C.V. (%)	3.97	3.68	3.86	4.31

Means with the same letter did not significantly differ from each other at $p < 0.05$. Abbreviations are as follows S_0 = 0, S_1 = 10 ppm, S_2 = 20 ppm and S_3 = 30 ppm of salicylic acid. Values are mean ± SE.

Table 6. Combined effect of humic acid and salicylic acid on Nitrogen content (%), Phosphorus content (%), Potassium content (%) and Sulfur content (%) of onion

Treatments	Nitrogen content	Phosphorus content	Potassium content	Sulfur content
H_0S_0	1.71±0.019^{h}	0.64±0.036^{j}	1.19±0.012^{f}	0.28±0.032^{f}
H_0S_1	1.94±0.022^{g}	0.69±0.042^{i}	1.25±0.015^{def}	0.35±0.025^{e}
H_0S_2	2.10±0.052^{cde}	0.75±0.050^{efg}	1.30±0.036^{bcde}	0.40±0.034^{d}
H_0S_3	1.93±0.028^{g}	0.70±0.032^{hi}	1.26±0.580^{cdef}	0.36±0.025^{e}
H_1S_0	1.93±0.028^{g}	0.68±0.015^{i}	1.24±0.026^{ef}	0.34±0.022^{e}
H_1S_1	2.02±0.032^{efg}	0.74±0.026^{fg}	1.25±0.035^{def}	0.39±0.059^{d}
H_1S_2	2.20±0.074^{bc}	0.79±0.046^{bcd}	1.33±0.042^{bcd}	0.43±0.039^{bc}
H_1S_3	2.06±0.042^{def}	0.76±0.015^{defg}	1.28±0.035^{bcde}	0.40±0.031^{d}
H_2S_0	1.97±0.028^{fg}	0.69±0.042^{i}	1.25±0.006^{def}	0.35±0.037^{e}
H_2S_1	2.15±0.081^{bcd}	0.76±0.012^{defg}	1.26±0.025^{cdef}	0.39±0.016^{d}
H_2S_2	2.21±0.049^{ab}	0.81±0.025^{b}	1.34±0.015^{bc}	0.44±0.027^{b}
H_2S_3	2.18±0.019^{bc}	0.77±0.036^{cdef}	1.32±0.021^{bcde}	0.41±0.037^{cd}
H_3S_0	2.16±0.023^{bcd}	0.73±0.035^{gh}	1.27±0.031^{bcdef}	0.40±0.034^{d}
H_3S_1	2.21±0.057^{ab}	0.78±0.040^{bcde}	1.31±0.026^{bcde}	0.44±0.016^{b}
H_3S_2	2.31±0.026^{a}	0.85±0.035^{a}	1.44±0.026^{a}	0.49±0.012^{a}
H_3S_3	2.22±0.018^{ab}	0.80±0.021^{bc}	1.35±0.008^{b}	0.45±0.004^{b}
LSD $_{(0.05)}$	0.10	0.03	0.08	0.03
P-value	0.02	0.04	0.11	0.16
C.V. (%)	3.97	3.68	3.86	4.31

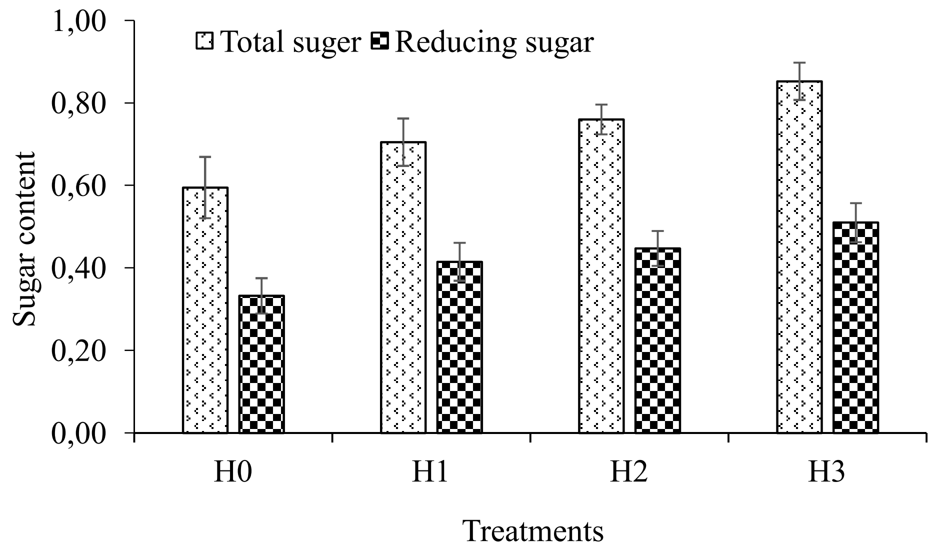
Means with the same letter did not significantly differ from each other at $p < 0.05$. Abbreviations are as follows H_0 = 0, H_1 = 15 ppm, H_2 = 30 ppm, H_3 = 45 ppm of humic acid and S_0 = 0, S_1 = 10 ppm, S_2 = 20 ppm, S_3 = 30 ppm of salicylic acid. Values are mean ± SE.

4.2.5. Sugar content (%)

The influence of different concentrations of humic acid on sugar content (%) in bulbs at harvest has been presented in Figure 1. From the result, it is evident that statistically significant variation was observed due to the effect of different levels of humic acid application. The highest total sugar content (0.85 %) and reducing sugar content (0.51 %) were obtained by H_3 (45 ppm humic acid) treatment, whereas the lowest total sugar content (0.60 %) and reducing sugar content (0.33 %) showed by H_0 (control). Similar findings was found by Forotaghe *et al.* (2021a) showed that sugar content was increased by humic acid.

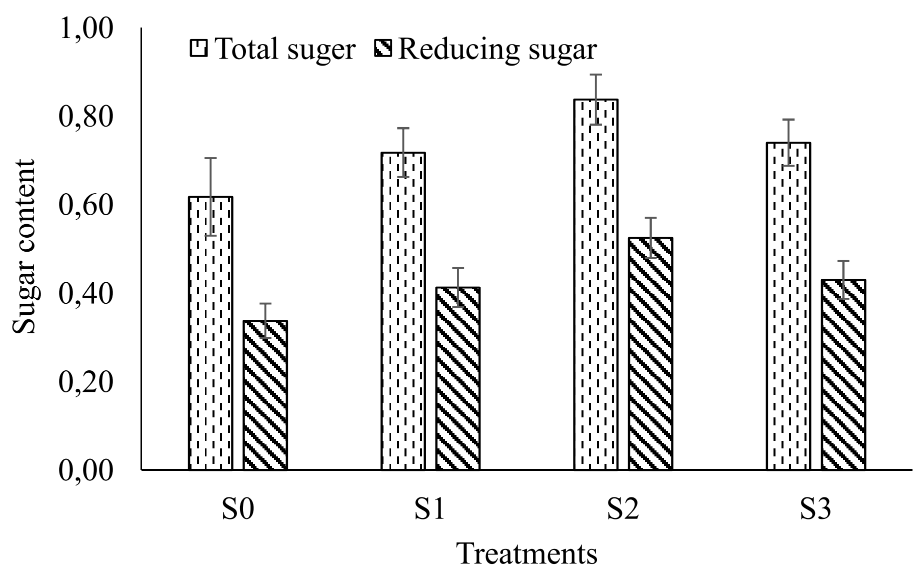
The influence of different concentrations of salicylic acid on sugar content (%) in bulbs at harvest has been presented in Figure 2. From the result, it is evident that statistically significant variation was observed due to the effect of different levels of salicylic acid application. The highest total sugar content (0.84 %) and reducing sugar content (0.53 %) were obtained by S_2 (20 ppm salicylic acid) treatment, whereas the lowest total sugar content (0.62 %) and reducing sugar content (0.34 %) were obtained with S_0 (control). Suger content increased by salicylic acid was also observed by Amin *et al.* (2007).

The influence of different combinations of humic acid and salicylic acid on sugar content (%) in bulbs at harvest has been presented in Figure 3. From the result, it is evident that statistically significant variation was observed due to the effect of different combinations of humic acid and salicylic acid application. The highest total sugar content (0.95 %) and reducing sugar content (0.61 %) were obtained by H_3S_2 (45 ppm humic acid with 20 ppm salicylic acid) treatment, whereas the lowest total sugar content (0.42 %) and reducing sugar content (0.25 %) showed by H_0S_0 (control).



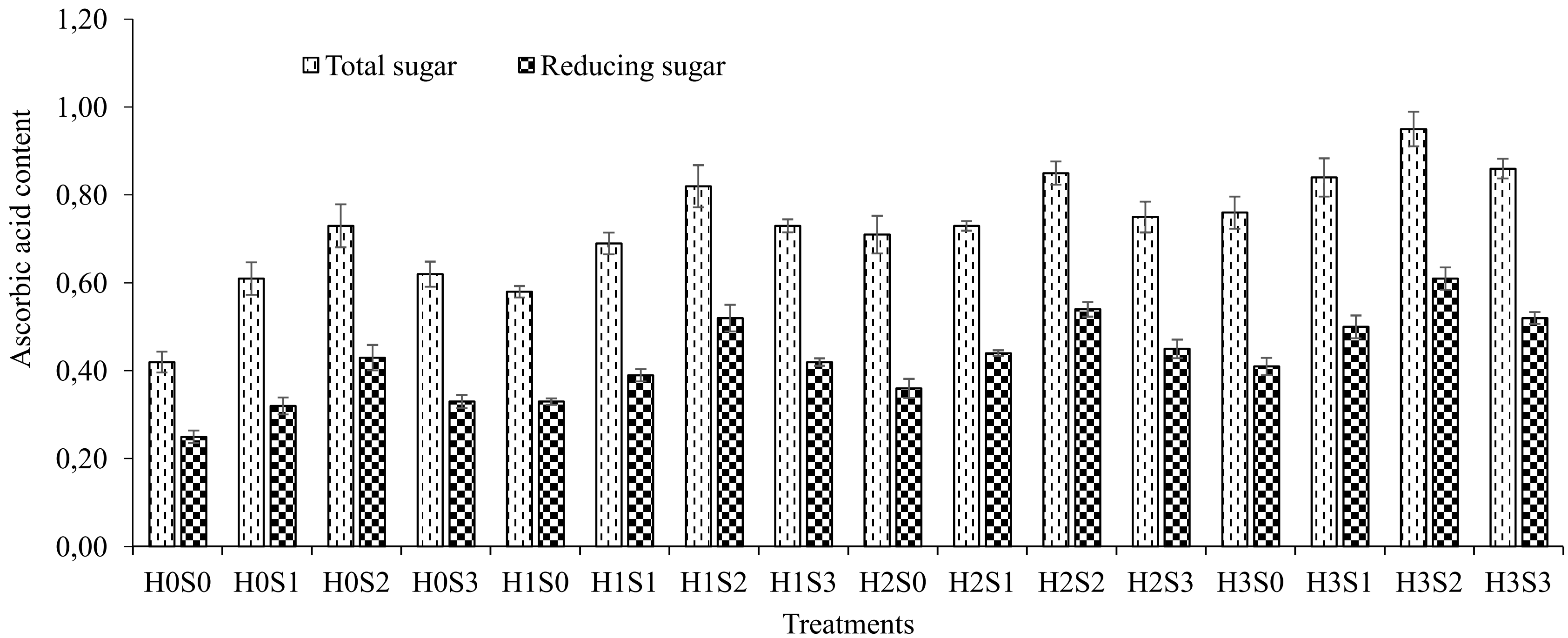
Where, H_0 = 0, H_1 = 15 ppm, H_2 = 30 ppm and H_3 = 45 ppm of humic acid. Vertical bar represents the standard error.

Figure 1. Effect of humic acid on sugar content (%) of onion



Where, S_0 = 0, S_1 = 10 ppm, S_2 = 20 ppm and S_3 = 30 ppm of salicylic acid. Vertical bar represents the standard error.

Figure 2. Effect of salicylic acid on sugar content (%) of onion



Where, H_0 = 0, H_1 = 15 ppm, H_2 = 30 ppm and H_3 = 45 ppm of humic acid; S_0 = 0, S_1 = 10 ppm, S_2 = 20 ppm and S_3 = 30 ppm of salicylic acid. Vertical bar represents the standard error

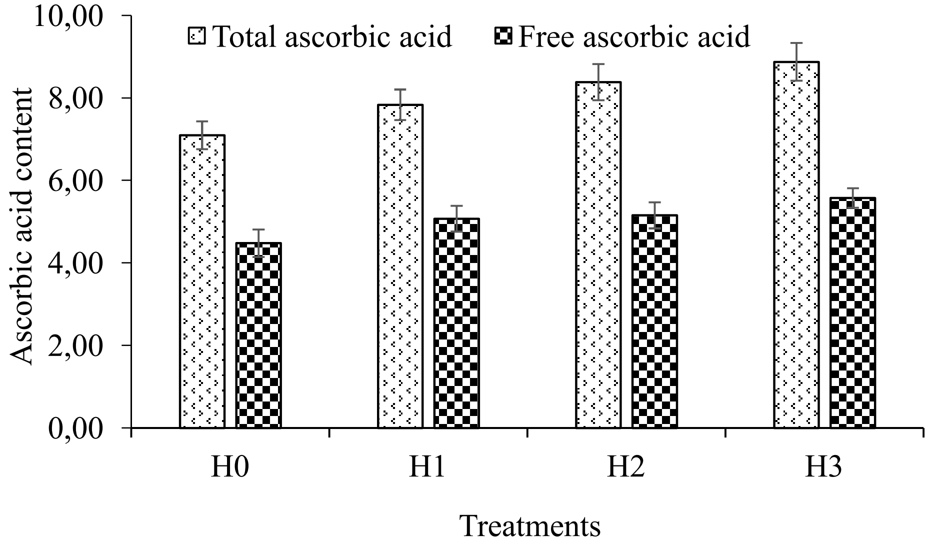
Figure 3. Combined effect of humic acid and salicylic acid on sugar content (%) of onion

4.2.6. Ascorbic acid content (mg/100g)

The effect of different doses of humic acid on ascorbic acid content (mg/100g) in bulbs at harvest was presented in Figure 4. From the result, it is evident that statistically significant variation was observed due to the effect of different levels of humic acid application. The highest total ascorbic acid content (8.88 mg/100g) and free ascorbic acid content (5.58 mg/100g) were obtained by H_3 (45 ppm humic acid) treatment, whereas the lowest total ascorbic acid content (7.10 mg/100g) and free ascorbic acid content (4.48 mg/100g) showed by H_0 (control). Forotaghe *et al.* (2021a) found the similar results.

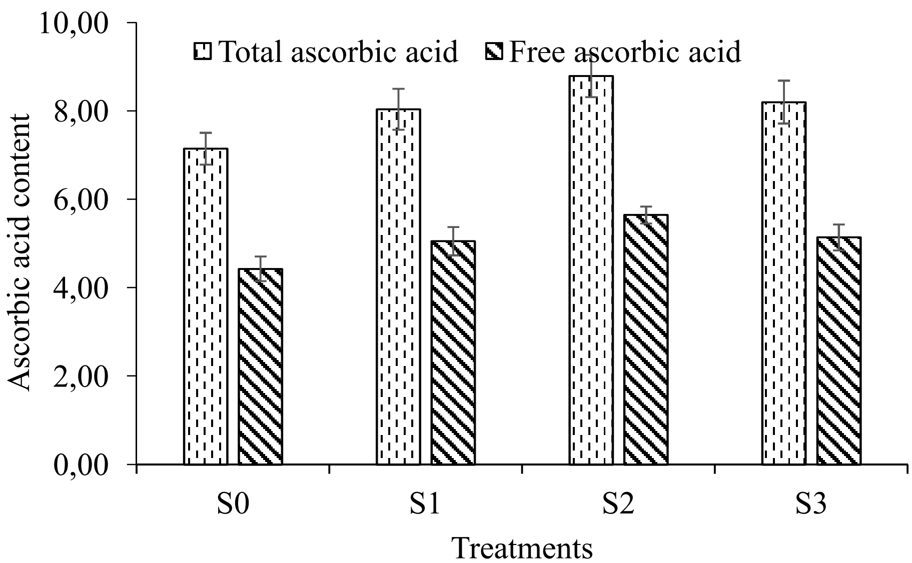
The influence of different concentrations of salicylic acid on ascorbic acid content (%) in bulbs at harvest has been presented in Figure 6. From the result, it is evident that statistically significant variation was observed due to the effect of different levels of salicylic acid application. The highest total ascorbic acid content (8.80 mg/100g) and free ascorbic acid content (5.65 mg/100g) were obtained by S_2 (20 ppm salicylic acid) treatment, whereas the lowest total ascorbic acid content (7.15 mg/100g) and free ascorbic acid content (4.43 mg/100g) were obtained with S_0 (control). Ascorbic acid content increased by salicylic acid was also observed by Amin *et al.* (2007).

The influence of different combinations of humic acid and salicylic acid on ascorbic acid content (%) in bulbs at harvest has been presented in Figure 7. From the result, it is evident that statistically significant variation was observed due to the effect of different combinations of humic acid and salicylic acid application. The highest total ascorbic acid content (9.70 mg/100g) and free ascorbic acid content (6.10 mg/100g) were obtained by H_3S_2 (45 ppm humic acid with 20 ppm salicylic acid) treatment, whereas the lowest total ascorbic acid content (6.30 mg/100g) and free ascorbic acid content (3.95 mg/100g) showed by H_0S_0 (control).



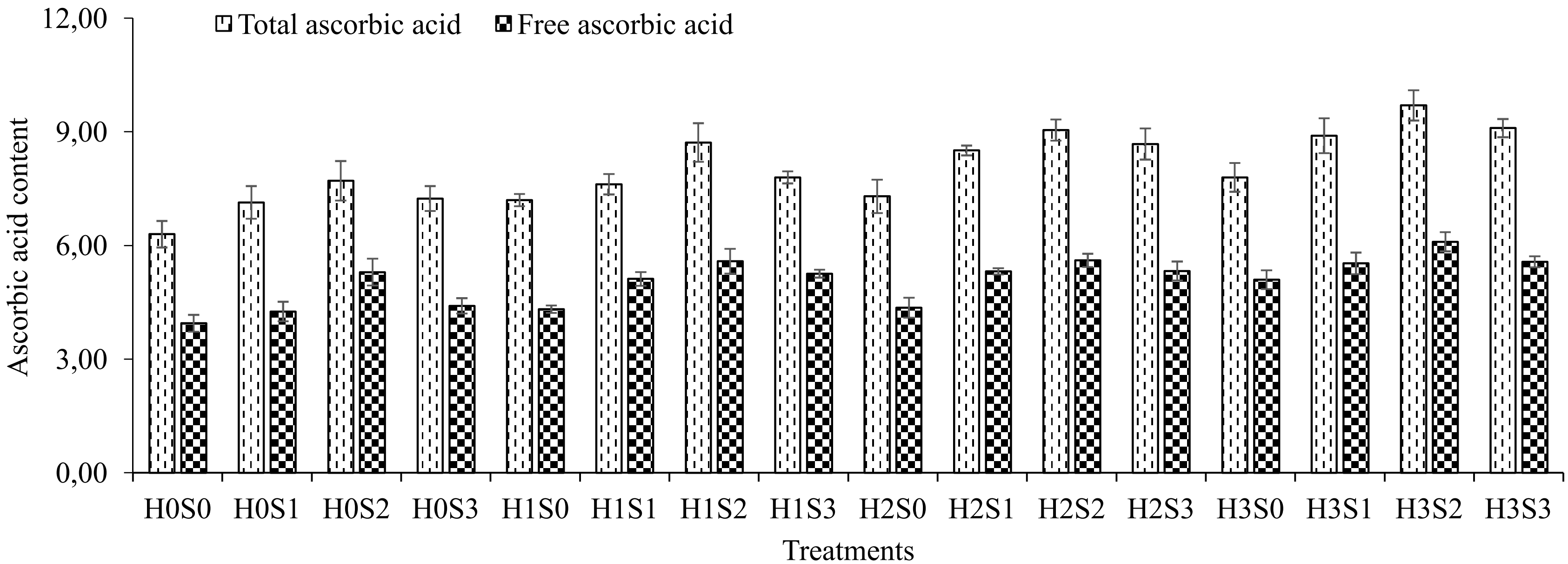
Where, H_0 = 0, H_1 = 15 ppm, H_2 = 30 ppm and H_3 = 45 ppm of humic acid. Vertical bar represents the standard error

Figure 4. Effect of humic acid on ascorbic acid content (mg/100g) of onion



Where, S_0 = 0, S_1 = 10 ppm, S_2 = 20 ppm and S_3 = 30 ppm of salicylic acid. Vertical bar represents the standard error

Figure 5. Effect of salicylic acid on ascorbic acid content (mg/100g) of onion



Where, H_0 = 0, H_1 = 15 ppm, H_2 = 30 ppm and H_3 = 45 ppm of humic acid; S_0 = 0, S_1 = 10 ppm, S_2 = 20 ppm and S_3 = 30 ppm of salicylic acid. Vertical bar represents the standard error

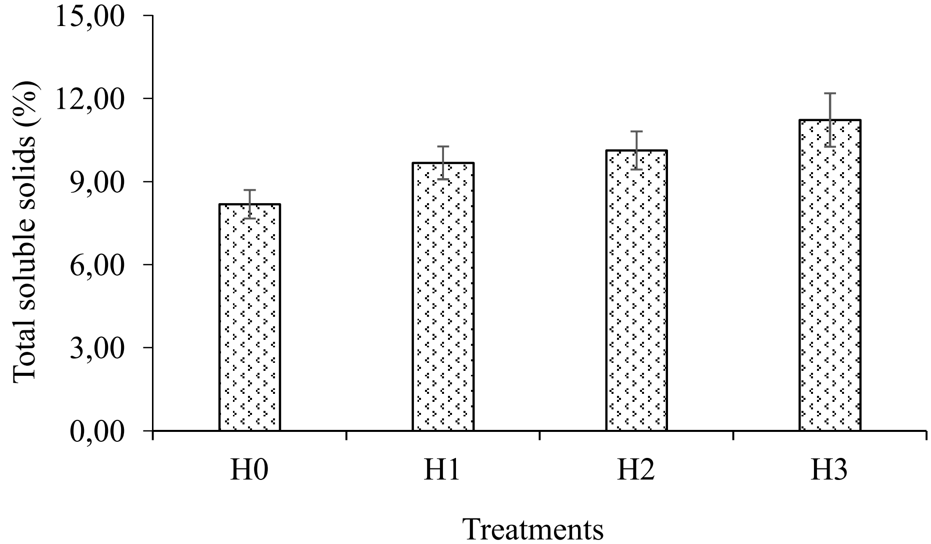
Figure 6. Combined effect of humic acid and salicylic acid on ascorbic acid content (mg/100g) of onion

4.2.7. Total soluble solids (%)

The influence of different concentrations of humic acid on total soluble solids (%) in bulbs at harvest has been presented in Figure 8. From the result, it is evident that statistically significant variation was observed due to the effect of different levels of humic acid application. The highest total soluble solids (11.23 %) were obtained by H_3 (45 ppm humic acid) treatment, whereas the lowest total soluble solids (8.19 %) showed by H_0 (control). Forotaghe *et al.* (2021a) also found that humic acid influences the total soluble solids percentage.

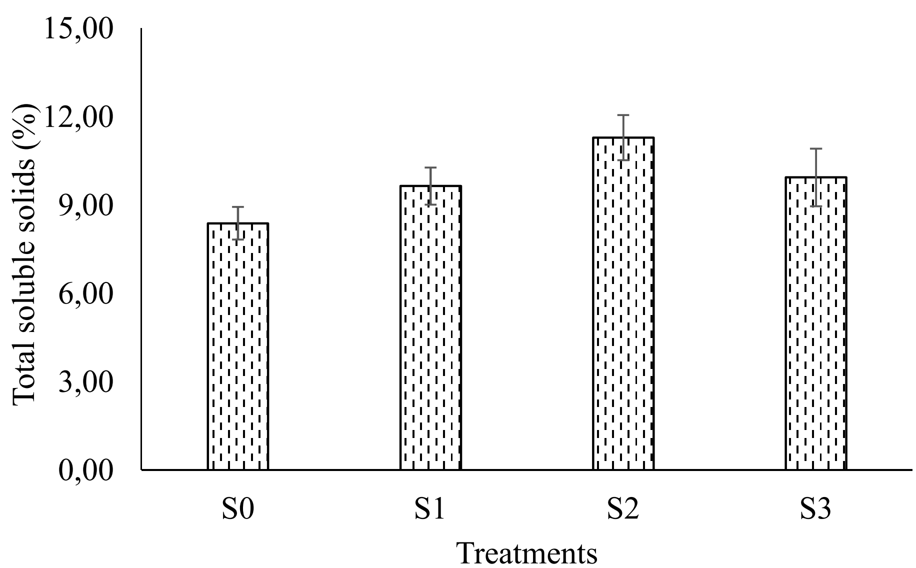
The influence of different concentrations of salicylic acid on total soluble solids (%) in bulbs at harvest has been presented in Figure 9. From the result, it is evident that statistically significant variation was observed due to the effect of different levels of salicylic acid application. The highest total soluble solids (11.28 %) were obtained by S_2 (20 ppm salicylic acid) treatment, whereas the lowest total soluble solids (8.38 %) were obtained with S_0 (control). Total soluble solids increased by salicylic acid was also observed by Amin *et al.* (2007).

The influence of different combinations of humic acid and salicylic acid on total soluble solids (%) in bulbs at harvest has been presented in Figure 10. From the result, it is evident that statistically significant variation was observed due to the effect of different combinations of humic acid and salicylic acid application. The highest total soluble solids (11.40 %) were obtained by H_3S_2 (45 ppm humic acid with 20 ppm salicylic acid) treatment, whereas the lowest total soluble solids (7.10 %) showed by H_0S_0 (control).



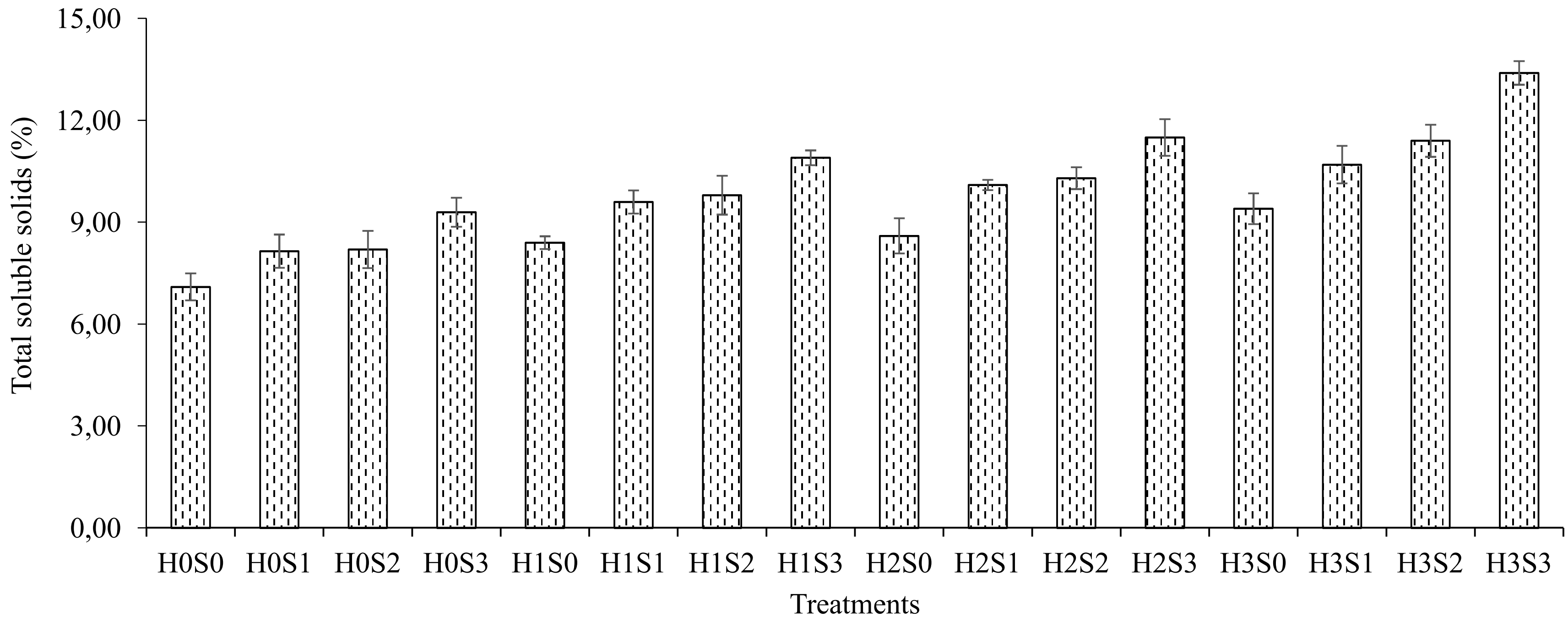
Where, H_0 = 0, H_1 = 15 ppm, H_2 = 30 ppm and H_3 = 45 ppm of humic acid. Vertical bar represents the standard error

Figure 7. Effect of humic acid on total soluble solids (%) of onion



Where, S_0 = 0, S_1 = 10 ppm, S_2 = 20 ppm and S_3 = 30 ppm of salicylic acid. Vertical bar represents the standard error

Figure 8. Effect of salicylic acid on total soluble solids (%) of onion



Where, H_0 = 0, H_1 = 15 ppm, H_2 = 30 ppm and H_3 = 45 ppm of humic acid; S_0 = 0, S_1 = 10 ppm, S_2 = 20 ppm and S_3 = 30 ppm of salicylic acid. Vertical bar represents the standard error

Figure 9. Effect of humic acid and salicylic acid combinations on Total soluble solids (%) of onion

Figure 10. Experimental activities and field view. A. Prepared seedbed; B. Seed germination in the seedbed; C. Seedling growing in the seedbed; D. Experimental onion field; E. Spraying humic acid and salicylic acid in onion plants

CHAPTER V

SUMMARY AND CONCLUSION

Onion is the most common and used spice in Bangladesh. Onion is considerably important in the daily Bangladeshi diet which the bulbs and the lower stem sections are the most popular as seasonings or as vegetables in stews. Onion production is still low in Bangladesh due to poor soil health conditions, unfavorable weather, a lack of summer tolerant varieties and adequate cultural methods. The average onion yield is roughly 10.55 t ha^{-1}. However, this output does not meet the country's needs. Furthermore, neither the output nor the area under onion production in Bangladesh has risen. So, it's important to adopt new management to increase onion production.

The field experiment was conducted at Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, from October 2019 to February 2020 to find out the effect of humic acid and salicylic acid on the growth, yield and quality in onion. BARI Piaz-1 was used as test crop material. Four different doses of humic acid, *viz*., H_0= 0 ppm, H_1= 15 ppm, H_2= 30 ppm and H_3= 45 ppm; four doses of salicylic acid *viz.* S_0= 0 ppm, S_1= 10 ppm, S_2= 20 ppm and S_3= 30 ppm were used to conduct this experiment. The experiment was set up in a two-factor Randomized Complete Block Design (RCBD) and three replications. Data on growth and yield parameters were gathered, and quality parameters and the obtained data were statistically examined to assess treatment effects.

The analysis of variance showed that plant height, the number of leaves $plant^{-1}$, bulb diameter (cm), bulb length (cm), single bulb weight (g), yield (t ha^{-1}), total nitrogen content (%), total phosphorus content (%), total potassium content (%), total sulfur content (%), sugar content (%), ascorbic acid content (mg/100g) and total soluble solids (%) were significantly influenced by humic acid, salicylic acid and their combined application.

From this study, in the case of humic acid at harvest, the tallest plant height (53.99 cm) was obtained with H_3 treatment and the lowest plant height (48.17 cm) was recorded from H_0. Likewise, highest number of leaves $plant^{-1}$, bulb diameter, bulb length, single bulb weight, bulb yield, nitrogen content, phosphorus content, potassium content, sulfur content, total sugar content, reducing sugar content, total ascorbic acid content, free ascorbic acid content, and total soluble solids were recorded from the H_3 treatment and the lowest results obtained with H0 treatment.

In the case of salicylic acid, the tallest plant height (54.02 cm); highest number of leaves plant^{-1} (10.11), bulb diameter (3.59 cm), bulb length (2.67 cm), single bulb weight (34.26 gm), bulb yield (8.91 t ha^{-1}) obtained with S_2 treatment when the smallest plant height (48.41 cm); the lowest number of leaves plant^{-1} (8.14), bulb diameter (3.33 cm), bulb length (2.44 cm), single bulb weight (26.27 gm), bulb yield (7.26 t ha^{-1}) recorded from S_0 treatment. The highest nitrogen, phosphorus, potassium, sulfur, total sugar, reducing sugar, total ascorbic acid, free ascorbic acid content and total soluble solids were recorded from the S_2 treatment when the lowest was recorded from S_0 treatment.

In this study, the combined effect of humic acid and salicylic acid showed statistically significant in plant height, the number of leaves plant^{-1}, bulb diameter (cm), bulb length (cm), weight bulb^{-1} (g), yield (t ha^{-1}), total nitrogen content (%), total phosphorus content (%), total potassium content (%), total sulfur content (%), sugar content (%), ascorbic acid content (mg/100g) and total soluble solids (%). The tallest plant height (57.67 cm) was recorded from the H_3S_2 treatment and the smallest plant height (44.07 cm) was obtained with the H_0S_0 treatment. Significantly the highest number of leaves plant^{-1}, bulb diameter, bulb length, single bulb weight, bulb yield, nitrogen content, phosphorus content, potassium content, sulfur content, total sugar content, reducing sugar content, total ascorbic acid content, free ascorbic acid content was obtained by H_3S_2 treatment, whereas the lowest result recorded from H_0S_0 (control).

Conclusion

Based on the overall results of the treatments, it can be stated that humic acid and salicylic acid, either alone or in combination, may improve onion production and quality. However, as the experiment was done for only one season and a single location, it has to be repeated over seasons and locations to make a conclusive recommendation.

CHAPTER VI

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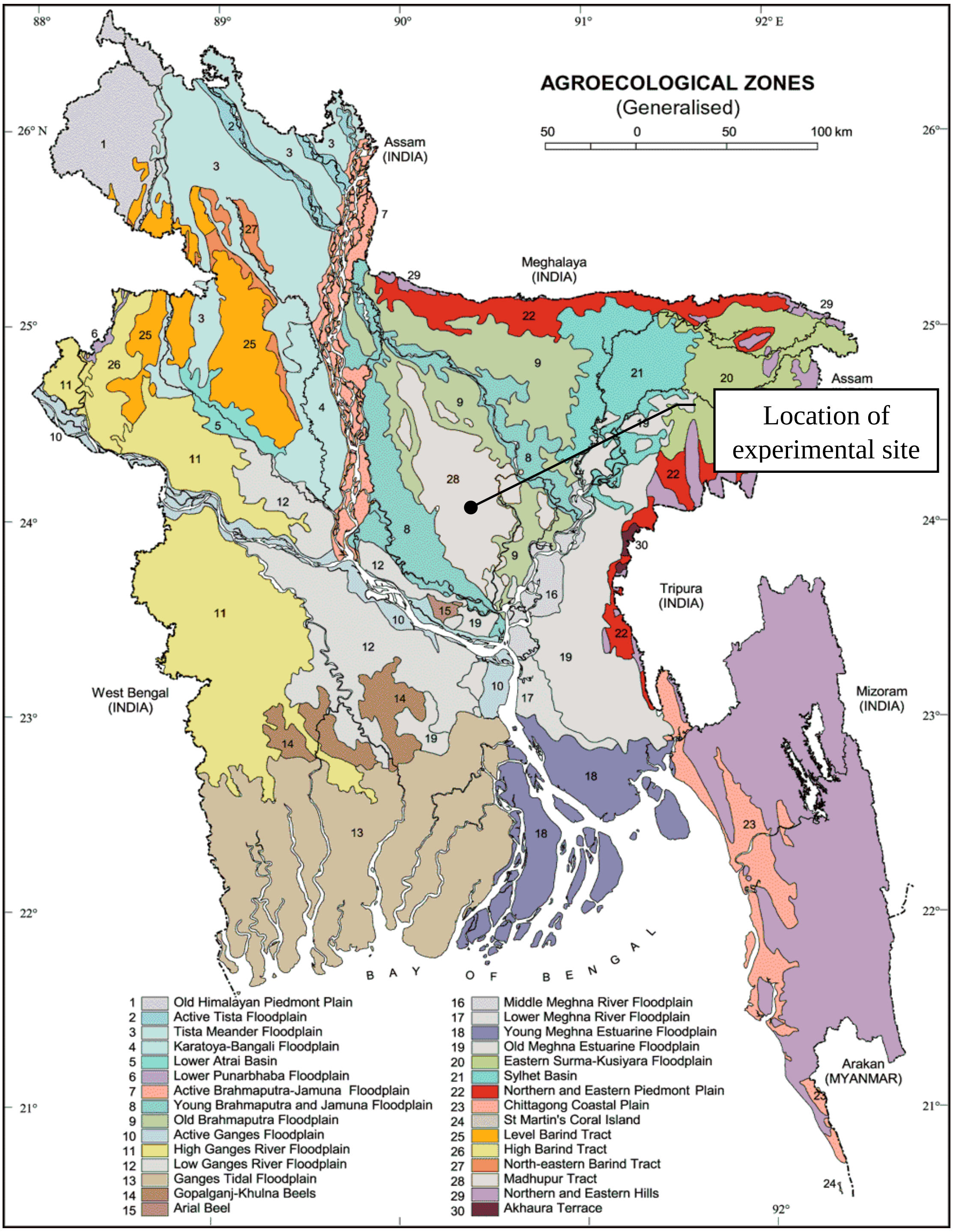
APPENDICES

Appendix I: Map showing the location of the site of the experiment.



Appendix II: Morphological characteristics of the experimental field.

Morphology	Characteristics
Location	SAU Farm. Dhaka
Agro-ecological zone	Madhupur Tract (AEZ 28)
General Soil Type	Deep Red Brown Terrace Soil
Parent material	Madhupur clay
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

Source: (FAO and UNDP, 1988)

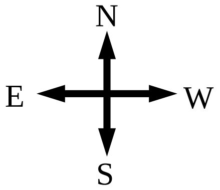
Appendix III: Physical and chemical properties of the soil

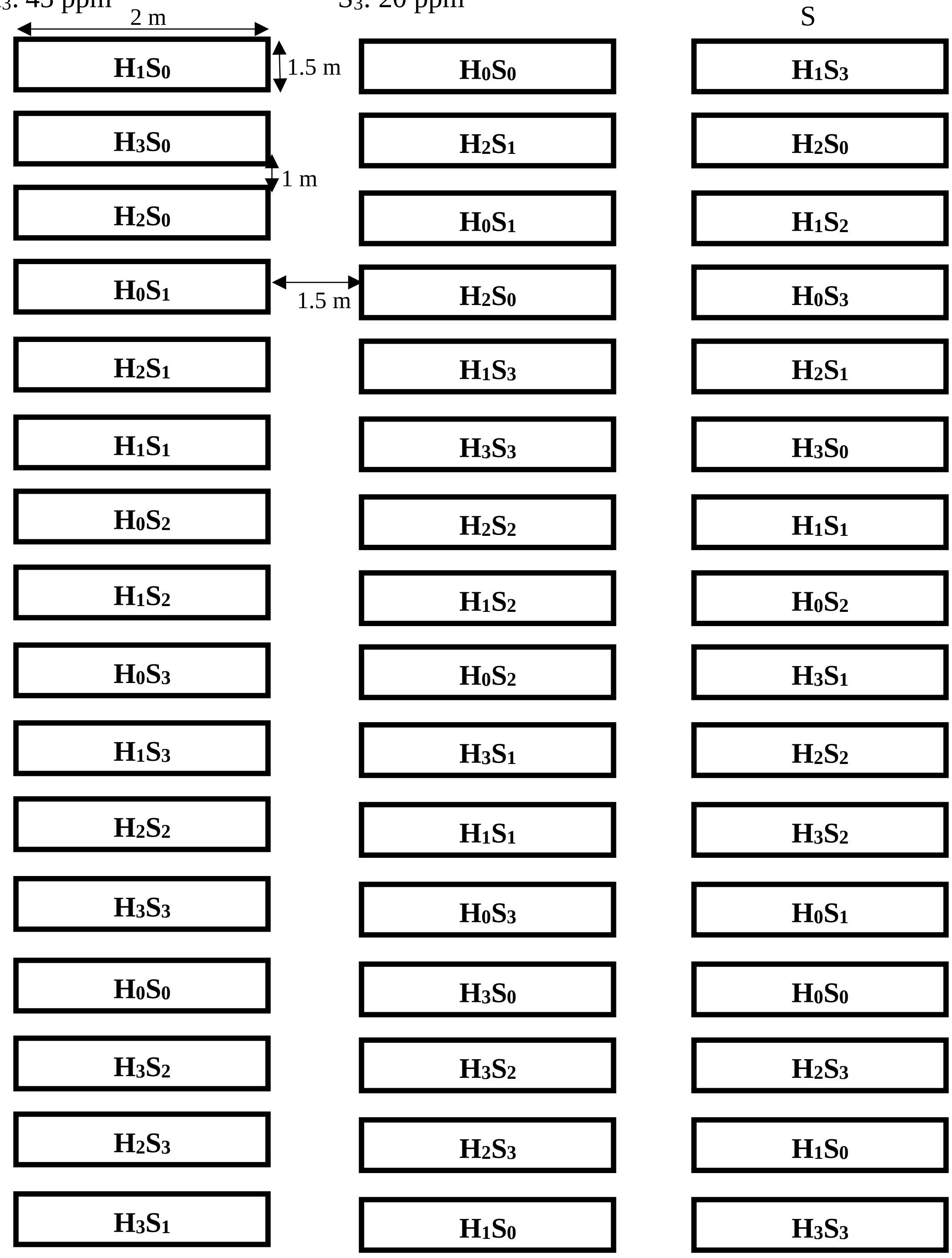
Characteristics	Value
Particle size analysis	
% Sand	30
% Silt	40
% Clay	30
Textural class	Clay loam
Consistency	Granular and friable when dry
pH	5.6
Bulk Density (g/cc)	1.45
Particle Density (g/cc)	2.53
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.06
Available P (ppm)	20.0
Exchangeable K (meq/100g soil)	0.12

Source: SRDI, 2015

Factor1: Humic acid
H_0: Control
H_1: 5 ppm
H_2: 30 ppm
H_3: 45 ppm

Factor 2: Salicylic acid
S_0: Control
S_1: 10 ppm
S_2: 20 ppm
S_3: 20 ppm





Appendix IV. Showing the layout of the experiment