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RESEARCH ARTICLE

Foliar application of zinc sulphate alone and in combination with GibberellicAcid (GA_3) and Naphthalene Acetic acid (NAA) on the growth, yield and quality of onion

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Abstract

Onion is an important vegetable crop having economic significance. Onion genotypes vary in size, colour and taste. In the current study, three onion genotypes i.e. Shah Alam, Phulkara and Nasr puri were grown in a pot culture to study growth, yield and quality parameters treated with zinc (Zn) and plant growth regulators (PGRs) i.e. gibberellic acid and naphthalene acetic acid. The experiment was carried out for two consecutive years. The results showed that leaf length and number of leaves per plant showed significant differences in their means by application of Zn and PGRs treatments during the initial year of the study and non - significantly in the following year. The yield parameters including bulb diameter and bulb weight pot^{-1} were significantly affected by the fortification of Zn and PGRs. The highest bulb diameter of 7.08 cm was recorded in the Nasr puri genotype which was fortified with 0.5 % Zn and NAA. While Shah Alam and Phulkara genotypes exhibited smaller bulb diameters. The bulb weight per pot showed significantly higher values for both the experimental years with the highest weight of 0.20 and 0.57 kg recorded in the Nasr puri fertilized with zinc sulphate. The qualitative parameters have shown significant variation in treatments fortified with Zn and PGRs. Total sugar and total soluble solids have changed significantly amongst treatments, while pyruvic acid was not significantly changed amongst the genotype by Zn and PGRs treatments. It is concluded that both Zn and PGRs have shown significant effects on onion genotypes in terms of quantitative and qualitative aspects.

Keywords: onion; plant growth regulators; quality; yield; zinc

Introduction

Onion is an indispensable vegetable used in every kitchen. The onion genotypes varied in their qualitative parameters. The two quality characteristics of onion are taste and pungency. The sweetness of onion is determined by the amount of sugar present in the bulb, while the pungency is mainly related to the sulfur base non-protein amino acid (1). The moisture content of onion is another quality parameter that helps in assessing the shelf life of onion (2). Different onion genotypes are grown worldwide for their, yield, taste, quality etc. In Pakistan, Phulkara and Nasr Puri are extensively cultivated onion varieties, valued for their high yield and rich flavor. Meanwhile, Shah Alam, a local landrace, is grown in selected regions of southern Khyber Pakhtunkhwa, prised for its exceptional sweet taste and shelf life.

Micronutrients also play a significant role in the growth, yield and quality of onion. Amongst the micronutrients, Zn is important for the growth and development of Onion. Onion has shown sensitivity to Zn deficiency and positive response by application of Zn (3). Also, It has been reported that various onion varieties exhibit varying levels of Zn efficiency, with Swat I emerging as the most efficient during a varietal screening (4). It clearly indicates that Zn plays an important role in enhancing the growth and yield of onion.

Plant growth regulators (PGRs) are organic compounds that are required in small amount to promote the growth and yield of onion. The plant produces the PGRs naturally, but their external application may increase the physiological process. The PGRs regulate the growth and enhance the flowering, fruiting and seed production (5). Amongst the PGRs, there are different groups including auxin, abscisic acid, cytokinine, ethylene and gibberellin. Gibberellin or Gibberellic Acid (GA_3) is the most common PGRs used in different crops including onion for growth and yield enhancement. Utilization of GA_3 as a foliar application to the onion crop may increase the onion yield (6). Also, Naphthalene Acetic Acid (NAA) is also sprayed onto the plant at different stages may result in promoting the growth and yield parameters i.e. plant height, number of leaves, bulb diameter, marketable onion yield, etc. (7). Plant growth regulators influenced the quality of onion bulb. Another worker has reported that the application of GA_3 and NAA improves the quality of onion (8). The sugar content of onion has been enhanced by using GA_3 at 500 µg mL^{-1} (9).

The application of Zn and PGRs may significantly enhance the yield and quality of onion genotypes by improving physiological efficiency, enzyme activation and stress tolerance under controlled environmental conditions. The current research was designed to investigate the performance of three genotypes i.e. Shah Alam, Phulkara and Nasr Puri for their yield and quality when fortified with the Zn and PGRs.

Materials and Methods

The three onion genotypes used in the study includes two improved onion varieties i.e. Phulkara and Nasr Puri, procured from a private farm in Bhakkar district, whereas Shah Alam was sourced from the village Shah Alam, where this local landrace has been evolved and cultivated. Each of the three genotypes possesses unique characteristics. Phulkara and Nasr Puri are widely cultivated onion varieties valued for their vibrant color, high yield and uniform bulbs. In contrast, the Shah Alam landrace is renowned for its exceptional taste and extended shelf life.

Sandy loam soil collected from the Indus river was accurately weighed 20 kg and filled in earthen pots for the experiments. The soil sample was taken and analysed for physico-chemical characteristics given in Table 1. The experiment was laid out in complete randomized design with three replications. The onion genotypes were transplanted into the pots after arranging the pots. The NPK fertilizer was applied uniformly to all the pots. The PGRs and zinc sulphate were applied after 25 days respectively to the respective pots. The bolting response of the three onion genotypes was observed and strategies (maintain consistent watering, temperature stability etc.) were used to mitigate bolting occurrence.

Table 1. Physico-chemical characteristic of the soil used in the pots

Parameters	Units	Value
Soil pH		7.47
Bulk density	gcm^{-3}	1.38
Soil EC	dSm^{-1}	1.26
SAR	$(m.molc\ L^{-1})^{1/2}$	7.31
Lime content	%	5.32
Organic matter	%	0.48
Total nitrogen	%	0.0065
Extractable phosphorus	$mg\ kg^{-1}$	6.38
Extractable potassium	$mg\ kg^{-1}$	121
Soil texture		Sandy loam

Weather data

The weather data for the cropping season including average temperature, rainfall and humidity was obtained from the weather station Arid zone research centre and is presented in Fig. 1.

Growth and yield parameters

The plant growth parameters including leave length, number of leaves per plant were measured at the harvest of the crop. The yield parameters measured at harvest were bulb diameter using the vernier calliper and the bulb weigh per pot using the electrical balance.

Qualitative parameters

Total sugar content

To determine the total sugar (%) in the onion juice five gram of the onion sample was crushed with distilled water after staining. Concentrated hydrochloric acid was added 2 - 3 drops. The sample was heated for 2 min until the colour slightly changed. The sample was allowed to cool and after cooling the sample was neutralize by a base 1N NaOH. The neutralization can be confirmed by the pH meter or litmus paper. The final volume was made 50 mL by adding the distilled water. The Fehling solution is used after preparing it by adding 1:1 of Fehling A and B (2 mL each) and the final volume was prepared by distilled water. The Fehling solution with sample and 2-3 drop of methylene blue indicator was heat titrated. As the colour changes to brick red colour material precipitated (10).

Pyruvic acid analysis

Pyruvic acid was determined in an onion sample by chopping 10 g of onion after 3 min of homogenizing in 10 mL distilled water. For assaying the pyruvate the homogenate was centrifuged for ten min at 20000 rpm and the supernatant was decanted. The supernatant was taken 1.5 mL and diluted 10 times with distilled water. From the extract 0.5 mL of the aliquot was transferred to 2,4-dinitrophenyl hydrazine (DNPH) 1 mL in a 2 mol/LHCl. After the mixture was vortexed at 37 °C for ten mins. As the mixture was cooled 0.6 mol/L sodium hydroxide was taken 5 mL and poured in the solution. Using the UV- spectrophotometer the absorbance was measured at a wavelength of 420 nm (11).

Total Soluble Solids (TSS)

A refractometer was used for measuring the total soluble solids (TSS) after the harvest of crop (10).

Statistical analysis

The analysis of variance (ANOVA) and least significant difference (LSD) were computed through the statistical software Statistics 8.1, ensuring precise evaluation of treatment effects and statistical significance (12).

Results and Discussion

Leaf length

The leaf length of onion genotypes has shown a significant effect of Zn fertilizer and plant growth regulators (Table 2). During the first year of the experiment the longest leaf of 40.27 cm was recorded in the control of Phulkara variety which was statistically similar to the rest of the treatments of Shah Alam and Nasr puri genotypes except for the T_5 (Zinc sulphate at 0.5 % + GA_3 at 100 mg L^{-1}) of Shah Alam, T_6 (Zinc sulphate at 0.5 % + NAA at 100 mg L^{-1}) of Phulkara. The least was recorded 28.65 cm in the Nasr puri varieties where T_6 (zinc sulphate at 0.5 % + NAA at 100 mg L^{-1}) was applied. During the following year the leaf length was non-significantly changed at 5 % level of significance. An increase in the leaf length of onion by the application of Zn at 10 kg ha^{-1} has been reported in previous research studies (13). Also, GA_3 and NAA applied at 100 mg L^{-1} have enhanced the leaf length of onion (14). GA_3 has been extensively used in agriculture for regulating plant growth, flowering and overall economic yield (15).

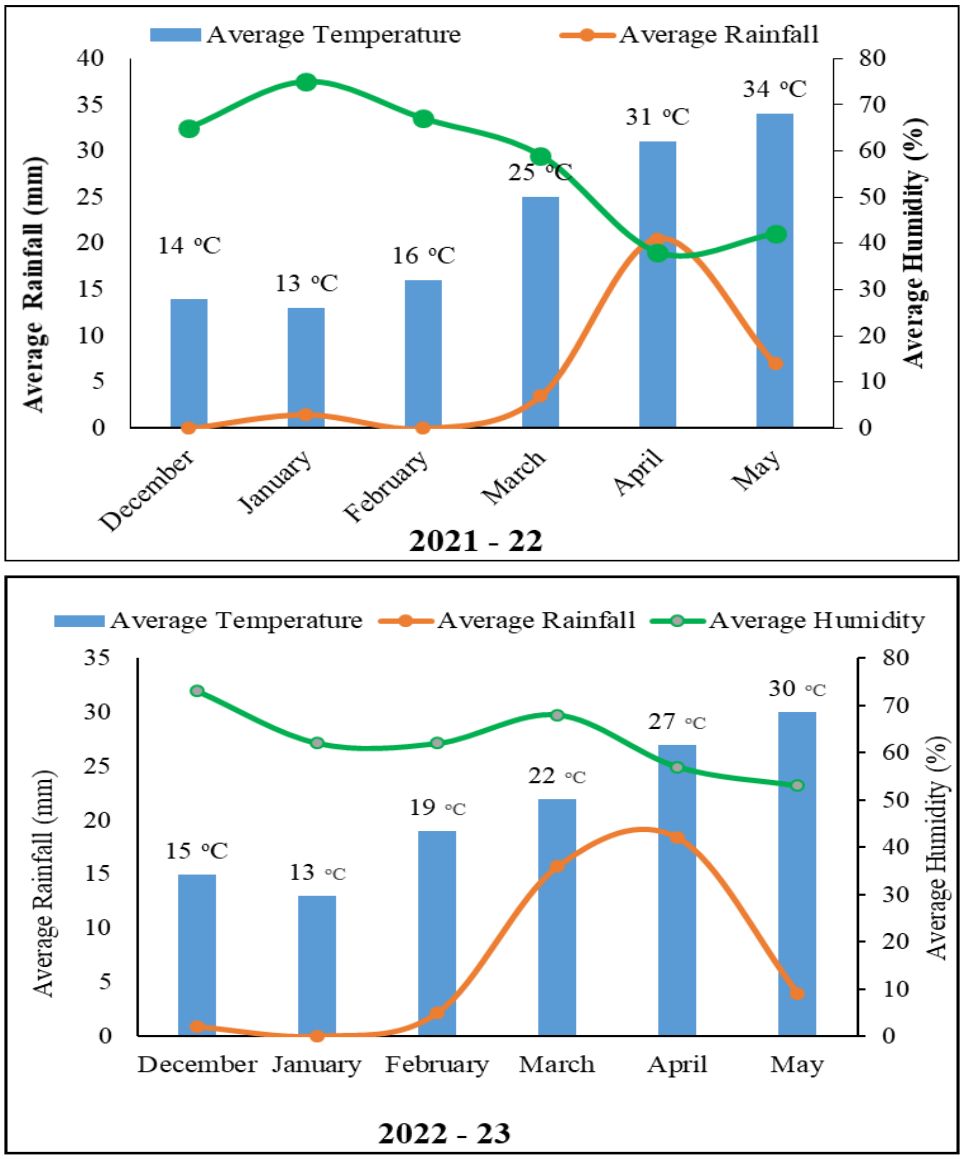

Fig. 1. Weather data for two years (2021-22 and 2022-23).

Number of leaves per plant

The data pertaining to the number of leaves per plant of onion revealed that the onion genotypes fortified with Zn and PGRs application have shown significant differences between the means ($P < 0.05$) during the first year of the experiment (Table 2). The highest number of leaves was 10.63 recorded in the Shah Alam genotypes where zinc sulphate at 0.5 % + GA_3 at 100 mg L^{-1} was applied. The least number of leaves was found 4.53 in the treatment where only GA_3 at 100 mg L^{-1} was applied. In the subsequent year the onion genotypes and Zn and PGR treatments showed non-significant effect on the number of leaves per plant. A higher number of onion leaves per plant was observed when the application of Zn was done at 0.70 kg ha^{-1} over the control in earlier research studies (16). The use of PGRs also has a significant role in enhancing the number of leaves per plant of onion. GA_3 has been reported to increase the number of leaves by application at 100 μgml^{-1}. The increase in the number of leaves may be due to the rapid increase in cell division by exogenous application GA_3 (14, 17).

Table 2. Growth parameters of onion genotypes as affected by Zinc and PGRS

Treatment	Leaf length						Number of leaves plant^{-1}					
	2022			2023			2022			2023		
	Shah Alam	Phulkara	Nasr puri	Shah Alam	Phulkara	Nasr puri	Shah Alam	Phulkara	Nasr puri	Shah Alam	Phulkara	Nasr puri
T_1: Control	33.12 abc	40.27 a	35.01 abc	41.63	49.26	46.01	6.67 bcd	6.50 cd	6.09 cd	10.17	9.23	9.90
T_2: Zinc sulphate @ 0.5 %	35.92 abc	36.32 ab	38.24 ab	42.49	45.38	47.66	5.84 cd	7.34 abcd	6.84 cd	9.34	8.85	11.28
T_3: GA3 @ 100 mg L^{-1}	33.61 abc	32.42 abc	32.21 bc	42.88	41.66	41.99	7.42 abcd	4.58 d	5.67 cd	9.46	8.35	8.84
T_4: NAA @ 100 mg L^{-1}	33.04 abc	33.23 abc	34.15 bc	39.66	42.66	44.06	7.42 abcd	10.00 ab	7.08 abcd	9.30	9.99	10.03
T_5: $ZnSO_4$ @ 0.5 % + GA3 @ 100 mg L^{-1}	32.40 bc	35.12 abc	35.49 abc	42.40	42.19	38.78	10.33 a	7.34 abcd	7.22 abcd	10.09	9.32	11.30
T_6: $ZnSO_4$ @ 0.5 % + NAA @ 100 mg L^{-1}	34.69 abc	30.48 bc	28.65 c	39.78	40.44	39.49	5.58 cd	9.15 abc	7.33 abcd	11.14	10.07	10.17
LSD		6.9003		Non - significant				3.3319		Non - Significant		

Bulb diameter

Bulb diameter is an important yield contributing parameters. In the current research the interaction of onion genotypes to the Zn and plant growth regulators treatments has shown non-significant effect during the first year of the experiment (Table 3). While in the second year the bulb diameter was significantly changed. The highest bulb diameter of 7.08 cm was recorded in the pots of Nasr puri variety where zinc sulphate was applied in integration with the NAA as PGR. It was statistically similar to the other treatments of Shah Alam and Nasr puri varieties, the least was recorded 4.96 cm in the Phulkara variety where sole GA_3 was applied through foliar application.

Wider bulb dimeter of onion by use of Zn at 5 % has been reported over the control where no Zn was applied (18). Similar, results have been reported in earlier research (19), where 7.5 kg ha^{-1} Zn fertilizer showed the wider bulb, whereas the control with no Zn showed narrower bulb diameter. In another study higher value of onion bulb by the application Zn at 0.5 % (20). Bulb diameter of onion was recorded significantly higher at 1 % level of significance by the application of PGRs (21).

Bulb weight per pot

Bulb weight of onion grown for two consecutive years has yielded significant effect of the Zn fertilizer and plant growth regulators. During the first year the bulb weight was found higher 0.20 kg in the Nasr puri variety where zinc sulphate was applied sole at 0.50 %, it was statistically at par with Phulkara variety which also yielded 0.20 kg bulb weight (Table 3). The least bulb weight was recorded 0.11 kg in the control of Nasr puri. In the following year similarly higher bulb weight of 0.57 kg was recorded in the Nasrpuri variety where zinc sulphate was applied alone at 0.5 % and 0.37 kg was the least recorded in the Shah Alam genotype where NAA was sole applied.

Increased weight of fresh onion bulb by the increasing level of Zn fertilizer have been reported in another study (19). The increase may be attributed to the photosynthates and their translocation to the bulb which as cause greater weight of individual bulbs. Zn contributes to bulb enlargement and firmness, enhancing market quality.

NAA and GA_3 has found to increase in the bulb weight of onion (22). They further stated in their study that the PGRs help in cell elongation and cell division which ultimately increases the bulb weigh of onion. In another study it was found that greater weight of onion bulb has been found when GA_3 and NAA were applied (21).

Total sugar (%)

The total sugar content of the onion determines the quality of onion. The total sugar content measured during the two years of study showed that the sugar content of onion genotypes significantly varied by the application of foliar Zn and Plant growth regulators application (Fig. 2). Comparing the means during the initial year of study showed significant higher sugar content of 4.39 % in the Shah Alam genotype where Zn was sprayed as foliar application. It was statistically at par with Nasr puri variety where Zn was applied also to the GA_3 treatments alone and integrated with Zn of Shah Alam variety. The least sugar content of was found 3.32 % in the control of Phulkara. During the second year the highest sugar content was found in Shah Alam, where Zn was applied along with the GA_3. It was evident from the result that genetically the sugar content was held more in the Shah Alam and Nasr puri genotype, while the Phulkara variety yielded the least sugar content. Amongst the treatment the application of Zn and the GA_3 plant growth regulator has a role in enhancing the sugar content of onion. The least total sugar during the second year was recorded in the control of Phulkara variety.

The total sugar content varies in genotypes having different potential to accumulate total sugar. A significant variation was observed in the sugar content when 20 onion genotypes were compared and highest yielding was 14.45 % and the lowest onion variety shows 3.90 % yield in earlier research studies (23). Total sugar content of onion varied in genotype and the light red variety gave maximum (24). The sugar content has been reported to influence the marketable yield of onion. In another study it has been reported that the lesser the sugar content of onion the higher will be the yield of onion (25). Impact of PGRs on onion and garlic have been studied and found that use of GA_3 has significantly enhanced the bulb sucrose content by 43 % (26) Also, they further revealed that the ratio between the glucose to fructose was remained constant.

Pyruvic acid

Pyruvic acid is an important qualitative parameter of onion crop. The pyruvic acid determines the pungency of the onion bulb. The data pertaining to this qualitative parameter showed non-significant effect between the three genotypes and also the application of Zn and PGRs did not significantly alter the results of pyruvic acid (Fig. 3). However, from the data it has been

Table 3. Yield parameters of onion genotypes as affected by Zn and PGRS

Treatment	Bulb diameter (cm)						Bulb weight pot^{-1} (kg)					
	2022			2023			2022			2023		
	Shah Alam	Phulkara	Nasr puri	Shah Alam	Phulkara	Nasr puri	Shah Alam	Phulkara	Nasr puri	Shah Alam	Phulkara	Nasr puri
T_1: Control	4.43	4.72	3.05	5.81 cdef	6.08 abcde	5.71 cdef	0.13 abc	0.14 abcd	0.11 d	0.43 cdef	0.51 abc	0.41 def
T_2: Zinc sulphate @ 0.5 %	4.14	4.76	4.46	6.61 abc	5.52 def	6.08 abcde	0.19 abc	0.20 a	0.20 a	0.43 cdef	0.47 bcde	0.57 a
T_3: GA3 @ 100 mg L^{-1}	4.21	4.18	4.28	5.59 cdef	4.96 f	5.99 bcdef	0.18 abcd	0.13 abcd	0.12 cd	0.4 def	0.38 ef	0.46 bcdef
T_4: NAA @ 100 mg L^{-1}	3.91	4.20	3.93	5.69 cdef	6.09 abcde	5.28 def	0.14 abcd	0.13 abcd	0.19 abc	0.37 f	0.48 abcd	0.43cdef
T_5: $ZnSO_4$ @ 0.5 % + GA3 @ 100 mg L^{-1}	4.36	3.78	4.80	5.98 bcde	5.11 ef	6.86 ab	0.12 cd	0.13 abcd	0.16 abcd	0.42 cdef	0.44 bcdef	0.54 ab
T_6: $ZnSO_4$ @ 0.5 % + NAA @ 100 mg L^{-1}	3.77	4.40	4.54	5.69 cdef	6.30 abcd	7.08 a	0.13 abcd	0.14 abcd	0.14 abcd	0.47 bcde	0.44 bcdef	0.47 bcde
LSD	**On – significant**			**1.0299**			**0.0770**			**0.0843**		

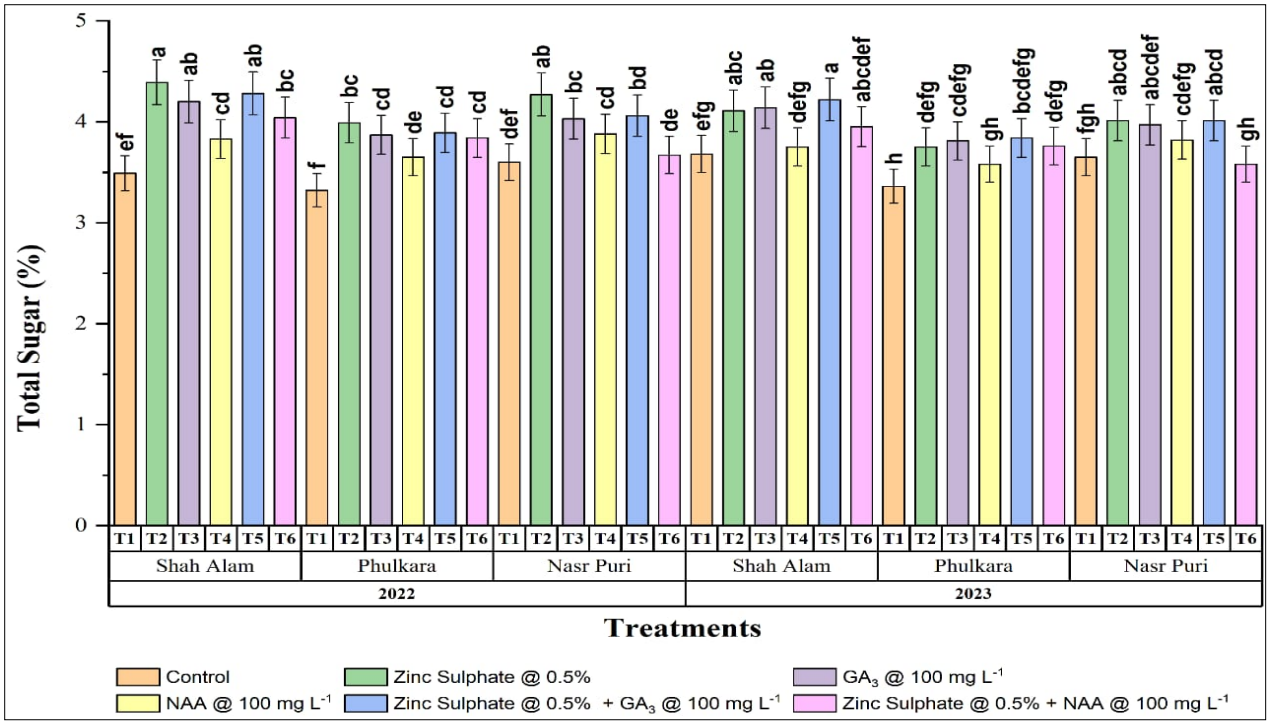

Fig. 2. Total sugar (%) of onion genotypes affected by the zinc sulphate and plant growth regulators.

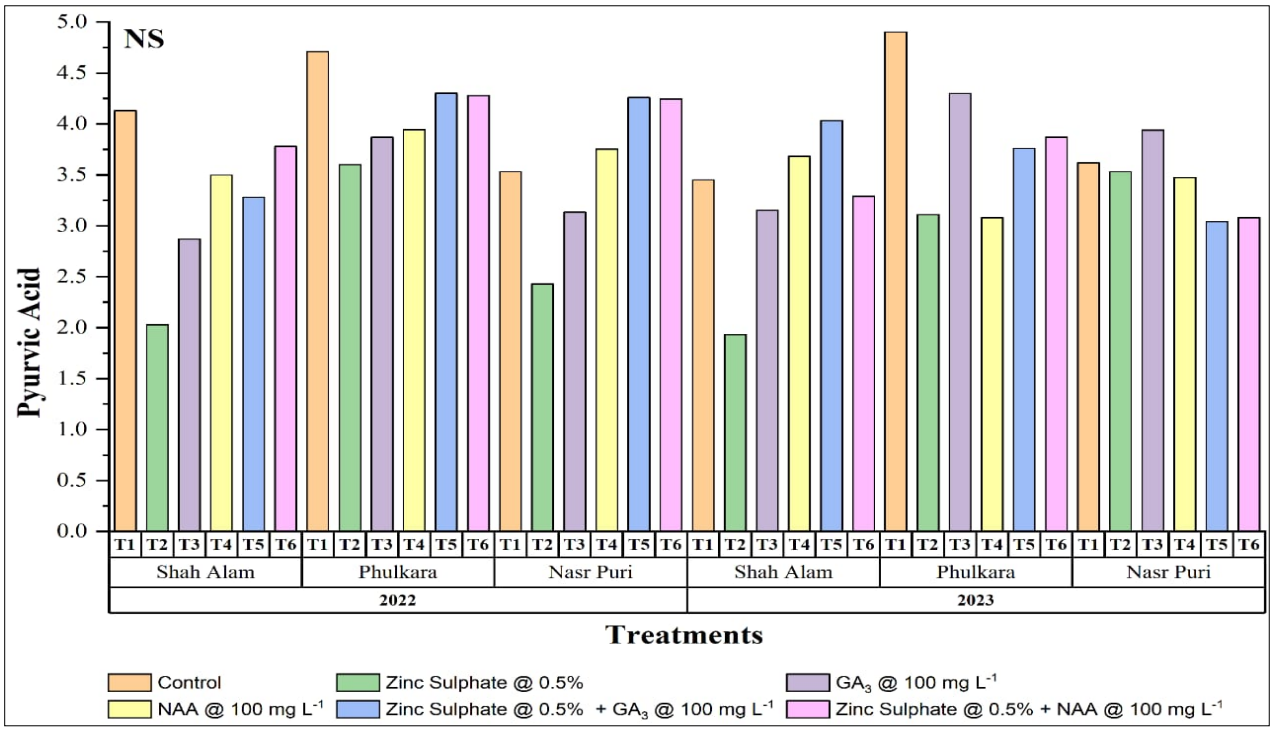

Fig. 3. Pyruvic acid of onion genotypes affected by the zinc sulphate and PGRs.

extracted that the use of zinc sulphate reduced the pyruvic acid content in the onion bulb in all the three genotypes. Amongst, the genotype Phulkara variety was comparatively more pungent than the other two. It has been reported that the pyruvic acid is not positively correlated with sulphur content of soil and was also inversely correlated with bulb size (27).

Total soluble solids

Total soluble solids determined during the two years of experiment showed significant variation between the interaction of genotypes and treatments means (Fig. 4). During the year 2022, the highest total soluble solids of 16.20 % were found in Shah Alam genotype where GA_3 was applied at 100 mg L^{-1}. It was statistically at par Shah Alam and Phulkara variety where zinc sulphate at 0.5 % was applied. The least total soluble solid was recorded in the control of Nasr puri variety which yielded 13.03 %.

The experimental result of total soluble solids during 2023 showed the highest value of 15.94 % in Phulkara variety. The application of treatments of Zn and PGRs significantly enhanced the total soluble solid. The control of the three genotype showed the least value of 13.52, 14.12 and 14.00 % in Shah Alam, Phulkara and Nasr puri variety respectively.

Higher total soluble solid have been observed in the treatment where NAA was applied at 150 mg L^{-1} (28). The genetic advances and effective selection of those characteristics that result in the additive gene can confirm

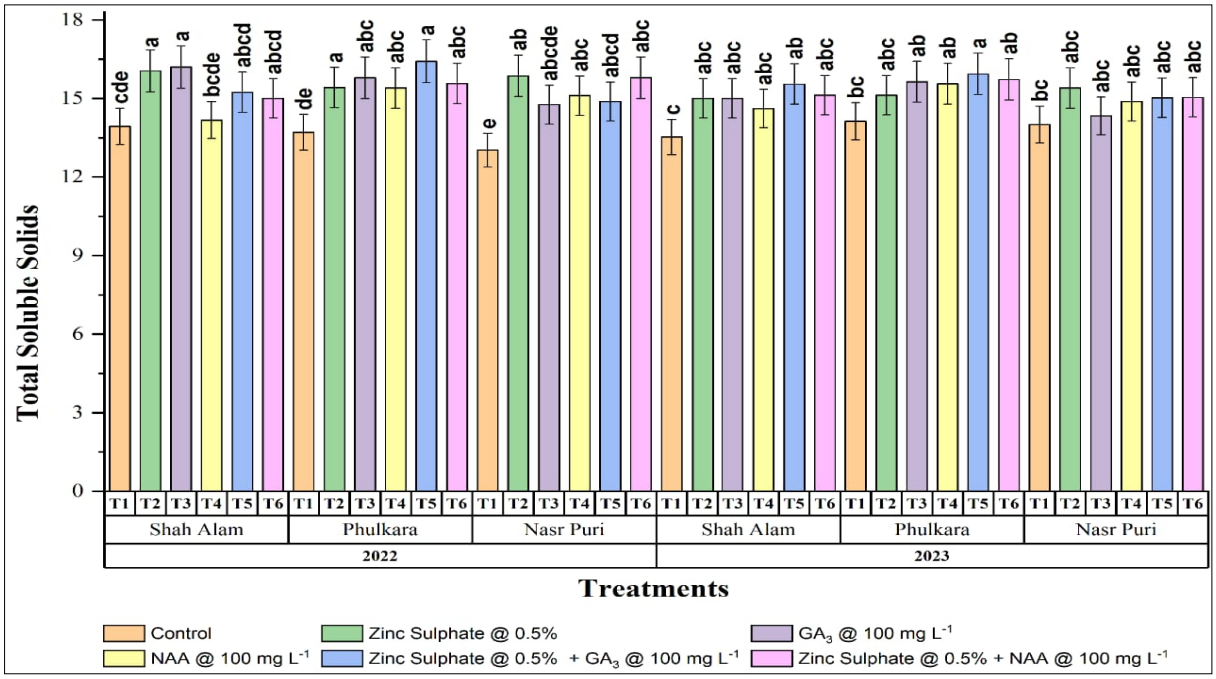

Fig. 4. Total soluble solids of onion genotypes affected by the zinc sulphate and PGRs.

total soluble solid in onion (29). Also, application of GA_3 and NAA can improve TSS, sugar-acid balance and post-harvest durability of onion (30).

Conclusion

Effects of Zn and PGRs including GA3 and NAA on three onion genotypes viz. Shah Alam, Phulkara and Nasr Puri was studied for two years. The results showed that largest bulb diameter of 7.08 cm were found in Nasr puri with 0.5 % Zn and NAA and maximum bulb weight of 0.57 kg was also found in Nasr puri when supplemented with Zn. Zn and PGRs have significantly enhanced the quality parameters including total sugar and total soluble solids. However, pyruvic acid content remained unchanged by the interaction of genotypes and Zn and PGRs treatments. It may be concluded from the finding of current research that Zn and PGRs may enhance onion growth, yield and quality of onion. However, further field testing is necessary to validate these results and assess their practical benefits for farmers.

Authors' contributions

IUK did conceptualization of the concept, IUK and MSJ contributed in designing the methodology, IUK collected the data, statistical analysed and wrote the manuscript. MK, MSJ and QUK did the literature review, defined the problem and derived the objectives and overall supervision of the work.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare

Ethical issues: None

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