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International Journal of Basic and Applied Sciences
(ISSN: 2277-1921) (Scientific Journal Impact Factor: 6.188)

UGC Approved-A Peer Reviewed Quarterly Journal

Full Length Research Paper

Effect of Ascorbic Acid and Salicylic Acid on Growth and Yield of Wheat (*Triticum Aestivum* L.)

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ARTICLE DETAILS

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Key words:
ascorbic acid; salicylic acid; wheat; Triticum aestivum; growth; yield; plant growth regulators; antioxidants

ABSTRACT

In terms of global food security, wheat—scientifically known for enhancing wheat growth and productivity is essential to meet the growing global population's increased need for food. Regulation of growth for plants, like in the ascorbic acid (AsA) and salicylic acid (SA) enhance growth, development, and stress tolerance, among other things. Focusing on their functions in seed germination, seedling growth, photosynthesis, nutrient absorption, antioxidant defence, grain production, and quality, this review study summarises the present understanding of the impacts of AsA. Next, we'll go over some of the possible ways that AsA and SA work their magic on wheat, and we'll point you in the direction of some next steps for studying how to get the most out of them in wheat farming. In order to improve wheat productivity and guarantee food security, it is important to understand how these plant growth regulators affect wheat.

1. Introduction

With a growing global population comes a greater need for food, making it all the more urgent to boost wheat cultivation and output (Tester *et al.,* 2010). A new class of plant growth regulators (PGRs) has shown great promise in enhancing plant development, stress tolerance, and growth in a number of other areas (Fahad *et al.,* 2017). Because of their various functions in plant physiology and their ability to increase agricultural output, two of the many PGRs, ascorbic acid (AsA) and salicylic acid (SA), have attracted a lot of interest (Akram *et al.,* 2017 and Khan *et al.,* 2015).

Essential for plant development, growth, and stress responses. A number of physiological activities rely on it, including cell division, photosynthesis, and the creation of cell walls (Gallie *et al.,* 2013). AsA protects plants from oxidative stress and functions as an enzyme cofactor (Foyer *et al.,* 2011). Yet, SA is a phenolic chemical that regulates several plant processes, including photosynthesis, seed germination, blooming, and senescence, and acts as a plant hormone (Rivas-San Vicente *et al*., 2011).

The potential of AsA and SA to improve a range of growth metrics, yield components, and grain quality has been highlighted by many investigations into their impacts on wheat growth and production (Aziz *et al.,* 2017 and Ullah *et al.,*2018). Unfortunately, there isn't yet a thorough analysis that combines all the information we have on how these PGRs affect wheat. This review

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Received: 15-April-2024; Sent for Review on: 24-April-2024; Draft sent to Author for corrections: 05-May-2024; Accepted on: 10-May-2024

Online Available from 14-May-2024

DOI: 10.13140/RG.2.2.31409.80489

study seeks to fill that void by offering a comprehensive examination of the ways in which AsA and SA impact wheat development and harvest, with a particular emphasis on the functions they play in germination of seeds, growth of seedlings, nutrition absorption, antioxidant defence, harvest yield, and quality. Next, we'll go over some of the possible ways that AsA and SA work their magic on wheat, and we'll point you in the direction of some next steps for studying how to get the most out of them in wheat farming.

2. Roles of Ascorbic Acid and Salicylic Acid in Wheat Growth and Development

2.1. Seed Germination and Seedling Growth

For wheat to successfully establish its grain and, consequently, its production, the phases of its life cycle that encompass seed germination and plant establishment are crucial (Finch-Savage *et al*.,2016). It has been shown that adding AsA and SA to wheat seedlings helps them grow better under stress (Farooq *et al*., 2009 and Guo, Q *et al.,*2017).

In both control and salt-stressed wheat plant growth and sprouting experiments, the length of the seedlings was seen when AsA was introduced externally, and the dry weight of the seedlings. Scientists say that AsA's good effects come from its ability to get rid of reactive oxygen species (ROS) and keep cell walls from getting damaged by oxidation.

In the same way, (Alam *et al*., 2013) looked into how SA changed the growth and germination of wheat plants that were stressed by drought. A test was done with seedlings that were under a lot of water stress. The SA treatment made the plants longer and heavier when they were fresh and when they were dried, compared to the control group that wasn't treated. Researchers say that SA made wheat plants more resistant to drought by controlling the buildup of osmolytes. Our results show that AsA and SA may help wheat plants grow and sprout when they are subject to abiotic stress.

2.2. The Amount of Chlorophyll and Photosynthesis

Photosynthesis is the main way that plants turn light energy into chemical energy (Nazar, R *et al.,* 2011). It affects how crops grow and how well they gather. It was shown that adding AsA and SA to wheat made its photosynthesis efficiency and chlorophyll content better (Fatma, M *et al.,* 2016 and Khan, M.I.R. *et al.,* 2014). (Malik, S *et al*.,2012) studied how AsA changed gas exchange factors and chemicals that help plants make food when they are hot. If you compare the AsA treatment to the control. The authors say that AsA kept the membranes of the photosynthetic machinery steady and protected them from oxidative damage caused by heat.

A study by (Alaey, M *et al.,* 2011). looked at how SA changed photosynthetic measurements and chlorophyll levels in wheat plants that were under salt stress and a higher net photosynthetic rate than the control group that was grown in saltwater.
The people who wrote the study thought that SA made photosynthesis better by making PSII work better and managing the activity of important Calvin cycle enzymes.

These studies show that AsA and SA can help wheat grow and produce more by improving photosynthesis and chlorophyll levels. This is especially true when abiotic stress is present.

2.3.1 How Nutrients Are Absorbed and Used

Plants need to be able to take in and use minerals well in order to grow to their full potential (Kumar *et al.,* 2015). Both AsA and SA have been shown to help wheat absorb and use nutrients better (Ahanger, M.A *et al.,*2017 and Ahanger, M.A *et al.,*2018). (Fatemi, H *et a* 2013). looked into how AsA affects wheat's ability to absorb and use nitrogen (N) and phosphorus (P) when it is stressed by drought. Scientists saw those plants given AsA had more nitrogen and phosphorus in their roots and shoots compared to a control group. They also saw that the enzymes acid phosphatase and nitrate reductase were working better in these plants. Controlled the production of genes involved in N and P metabolism to help plants absorb and use nutrients.

A study by (El-Sakhawy *et al*.,2018). [also looked at how SA changed the way salt-stressed wheat absorbed and used K. Compared to the control group that did not get SA treatment under salty circumstances. It also boosted the plant's H+-ATPase enzyme activity, which is responsible for transporting K+ throughout the plant. Researchers say that SA improved K uptake and assimilation by changing the production of K+ transporter genes and by making roots stronger and better at what they do.
These findings show that AsA and SA can help wheat grow and produce more by making it better at absorbing nutrients and digesting food, especially when it is under abiotic stress.

3. Effects of Ascorbic Acid and Salicylic Acid on Wheat Yield and Quality

3.1. Yield Components and Grain Yield

Grain yield is the ultimate goal of wheat production; a variety of factors influence yield, such as plant density, spike density. Adding AsA and SA to wheat can boost grain output and yield components, according to publications (Aldesuquy, H *et al.,* 2011 and Aldesuquy, H *et al.,* 2012).

They found that in both cases, compared to the control, administering AsA significantly increased the number of spikes per plant. The research found that AsA enhanced photosynthetic efficiency, nutritional absorption, and antioxidant defense. These elements increased production.

Also, when wheat was stressed by salt, (Iqbal, N *et al.,* 2012) looked at how SA affected the various components of wheat production as well as grain yield. In saline circumstances, their data demonstrated that SA treatment enhanced tiller density, spike density, 1000-grain weight, and grain production in comparison to the control group that was not treated. Scientists hypothesised that SA increased output by decreasing oxidative stress, enhancing photosynthetic efficiency. These studies show that AsA and SA can boost wheat productivity by increasing grain yield.

3.2. The Carbohydrate and Grain Profile

The market value and end-use features of wheat are heavily influenced by its grain quality and nutritional content (Blandino, N *et al.,*2015). Grain quality and nutritional composition in wheat can be improved with the addition of AsA and SA, according to reports (Ali, M *et al.,* 2019 and Hayat, S *et al.,* 2018).

When wheat grains were subjected to heat stress, Noreen, S *et al.,*2012), looked into the effects of AsA on the protein content and gluten quality. Results showed that following AsA treatment, grain protein content, gluten content, and gluten index prevented heat-induced denaturation and degradation of proteins, making grain quality better.

Alam, M.M *et al* 2014), investigated what happened because of SA on the mineral composition and antioxidant content of wheat when it was stressed by drought. Results showed that SA treatment increased grain concentrations of minerals, total phenolic content. Researchers hypothesized that SA controlled gene expression for mineral absorption and antioxidant synthesis, which in turn increased nutrient transfer from plant to grain, therefore improving grain nutritional quality. These results demonstrate that AsA and SA have the ability to increase wheat's nutritional value and marketability by increasing grain quality and nutritional composition.

4. Mechanisms of Action of Ascorbic Acid and Salicylic Acid in Wheat

4.1. Antioxidant Defense and ROS Scavenging

The subsequent stunting of plant growth and development is the result of this (Hasanuzzaman, M *et al.,*2012). Wheat plants are protected from the oxidative stress by AsA and SA, which strengthen that there antioxidant safeguards and capacity to rid of ROS (Goud,P.B *et al.,*2012 and Kosta, S *et al.,*2018).

Khan, A.L *et al.,* 2013), tracked reactive oxygen substances (ROS) levels while participating antioxidant enzyme activities as part of their study on the harmful effects of chemical stress on wheat. After AsA was administered, there was a significant decrease in malondialdehyde (MDA), considered an indicator of the peroxidation of a enzyme called super (SOD (sing), catalase in (CAT), and of ascorbate (APX) various phases, among others, were also said to have gone up. Researchers discovered that AsA enhanced antioxidant safeguarding itself activities by directly removing reactive oxygen species, which are (ROS) as well as through regulating the level of activity by a gene that carry genes throughout antioxidant-producing enzymes.

SA treatment boosted SOD, CAT, APX, and GR activities while lowering H2O2 and O2•- levels, in comparison to the untreated control group. Scientists hypothesised that SA enhanced ROS scavenging via modulating cellular redox status and promoting antioxidant gene expression.

The results show that AsA and SA make wheat's antioxidant defence and ROS scavenging better, especially when abiotic stress is present. In turn, this can help protect wheat from oxidative damage, which can help it grow and produce more.

4.2. Gene Expression and Signalling Pathways

Reports say that AsA and SA control the production of many wheat genes that play a role in growth, development, and how the plant reacts to stress (Li, T *et al.,* 2014 and Miura, K *et al.,* 2014). In order to control how plants react to messages from their surroundings, these PGRs also work with other communicating molecules and pathways (Dempsey, D.A. *et al.,* 2011 and Mateo, A *et al.,*2006).

The effect of AsA on the expression of heat shock protein (HSP) coding genes in heated wheat was investigated in a research by (Malik, S *et al.,*2012). Compared to the control group, those who received AsA had significantly greater levels of gene expression for HSP70 and HSP90. Because it increased the synthesis of genes for heat-shock proteins (HSPs), scientists believed that AsA improved wheat's heat tolerance. High temperatures can cause proteins to denature and clump together, but these genes prevent this.

In the same way, (Li, D *et al.,* 2013) looked at how SA affects gene expression that responds to drought and how it works with ABA signals in wheat plants that are stressed by drought. The researchers say that SA made wheat more resistant to drought by changing the production of genes that react to stress and by working with ABA signals to change how stomata close and how much water is lost.

These findings show that AsA and SA can change gene expression by working with other signalling pathways. This can help wheat develop, grow, and handle stress better.

5. Future Perspectives and Research Directions

We have learned a lot about how AsA and SA affect the growth and production of wheat, but there are still some things we don't know and areas where more research could be done. For future studies on PGRs for wheat farming systems, the following should be the main areas of study:

5.1: Methods and Doses for Application Optimisation

It is important to find the best amounts of AsA and SA for wheat based on its growth stage and the conditions in which it grows. Two common ways to get these poisons to plants are through foliage sprays and seed priming. Future research should find the best time, regularity, and quantity to use AsA and SA, which help wheat grow and produce more, so that they work as well as possible.

5.2. How it Deals with Other Agrochemicals and PGRs

Pesticides, auxins, gibberellins, cytokinins, and cytokinins are just some of the agrochemicals and PGRs that are used to grow wheat that might interact with AsA and SA. More study is needed to find out if these effects are positive or negative. By understanding these connections better, we can come up with better and more long-lasting ways to take care of crops.

5.3. Differences in Genotype and How Breeding Works

Because different wheat genotypes have different genetic makeups and are better or worse at adapting to different environments, they may react differently to AsA and SA. In future research, it will be important to compare how these treatments affect different types of wheat in order to learn more about which kinds of wheat are sensitive to AsA and SA. Using this knowledge, we can breed and change the genes of wheat to make new types that are more resistant to certain PGRs.

It is best to use AsA and SA along with other crop management tools, like watering, fertilisation, and pest control, to get the most out of their effects on wheat growth and yield. Future study should look into the links between these PGRs and other management techniques in order to make combined crop management methods that get the most out of using AsA and SA while minimising the harm they may cause to people and the environment.

Table 1. Impact of ascorbic acid (AsA) on the vegetative development of wheat seeds and the growth of seedlings in both physiological before stressful environments.

Treatment	Condition	Germination percentage (%)	Germination rate (seeds/day)	Seedling length (cm)	Seedling dry weight (mg)	Reference
Control	Normal	85.2 ± 2.3	17.5 ± 0.8	12.6 ± 0.5	98.3 ± 3.6	[17]
AsA	Normal	92.8 ± 1.9*	21.3 ± 1.2*	15.2 ± 0.7*	115.7 ± 4.2*	[17]
Control	Salinity	68.4 ± 3.1	12.8 ± 0.6	8.9 ± 0.4	72.5 ± 2.8	[17]
AsA	Salinity	79.6 ± 2.6*	16.4 ± 0.9*	11.5 ± 0.6*	89.2 ± 3.3*	[17]

Values are means ± standard deviation. AsA treatments within each condition ($P < 0.05$).

Table 2. Effects of salicylic acid (SA) on wheat photosynthetic parameters and chlorophyll content under salinity stress.

Treatment	Net photosynthetic rate (µmol CO2 m-2 s-1)	Stomatal conductance (mol H2O m-2 s-1)	Chlorophyll a (mg g-1 FW)	Chlorophyll b (mg g-1 FW)	Total chlorophyll (mg g-1 FW)	Reference
Control	12.3 ± 0.8	0.18 ± 0.02	1.42 ± 0.05	0.51 ± 0.03	1.93 ± 0.07	[23]
SA	15.7 ± 1.1*	0.24 ± 0.03*	1.68 ± 0.06*	0.62 ± 0.04*	2.30 ± 0.09*	[23]

Values are means ± standard deviation.

Table 3. Effects of ascorbic acid (AsA) on wheat yield components and grain yield under normal and drought stress conditions.

Treatment	Condition	Number of spikes per plant	Number of grains per spike	1000-grain weight (g)	Grain yield (t ha-1)	Reference
Control	Normal	5.6 ± 0.4	42.8 ± 2.5	38.2 ± 1.3	5.2 ± 0.3	[32]
AsA	Normal	6.8 ± 0.5*	48.5 ± 3.1*	41.9 ± 1.7*	6.1 ± 0.4*	[32]
Control	Drought	4.2 ± 0.3	35.6 ± 2.2	32.5 ± 1.1	3.8 ± 0.2	[32]
AsA	Drought	5.3 ± 0.4*	41.3 ± 2.8*	37.1 ± 1.4*	4.6 ± 0.3*	[32]

The data are expressed as means ± deviations from means. Within the every treatment group, asterisks (*) denote any significant variations (P < 0.05) compared with the AsA while managing treatments..

Table 4. Effects of salicylic acid (SA) on wheat grain mineral composition and antioxidant content under drought stress.

Treatment	Fe (mg kg-1)	Zn (mg kg-1)	Mn (mg kg-1)	Total phenolic content (mg GAE g-1)	Flavonoids (mg CE g-1)	Reference
Control	28.5 ± 1.6	21.3 ± 1.2	15.8 ± 0.9	1.82 ± 0.11	0.95 ± 0.06	[38]
SA	34.2 ± 2.1*	26.7 ± 1.5*	19.4 ± 1.3*	2.35 ± 0.14*	1.24 ± 0.08*	[38]

You can see that the numbers are averages with +/- standard deviations. Asterisks (*) show significant changes between the control and SA (P < 0.05). These letters stand for gallic acid equivalent (GAE) and catechin (CE). The main findings from the study that was looked at are summed up in these tables. In different settings, they show that AsA and SA make wheat grow better, produce more, and be of better quality. The tables that let readers compare different treatments and stress levels make it easier for them to understand the possible benefits of these plant growth factors in wheat production systems.

6. Molecular Mechanisms Underlying the Effects of AsA and SA on Wheat

6.1. Regulation of Gene Expression

AsA and SA control the production of many wheat genes that are important for development, growth, and how the plant reacts to stress. Because they work with transcription factors and other control proteins and change the epigenetic landscape of the cell, these PGRs can change how genes are expressed (Chen, Z *et al.,* 2015 and Song, J *et al.,* 2011).

When wheat was stressed by heat, (Farooq, M *et al.,*2014) studied how AsA changed the activity of genes that manage carbon and make food through photosynthesis.Compared to the control group, those who received AsA showed significantly increased expression of genes encoding. Scientists thought that AsA controlled the production of important genes to help wheat absorb more carbon and do better at photosynthesis.

(Zhang, Y *et al.,*2015) also looked into how SA affects nitrogen metabolism in wheat that has been stressed by drought. In conditions of water stress, they found that treating plants with SA increased the activities of glutamate synthase (GOGAT), nitrate reductase (NR), and glutamine synthetase (GS). Scientists thought that SA helped wheat take in more nitrogen by controlling the amounts of important enzymes in the nitrogen biosynthesis pathway.

These findings show that AsA and SA control gene expression to change many biological and physiological processes in wheat. This makes the plant grow faster, produce more, and handle stress better.

6.2. Epigenetic changes

DNA methylation and histone modifications are two important epigenetic changes that affect gene expression and how plants respond to messages from their surroundings (Mirouze, M *et al.,*2011). New study (Huang, Y *et al.,*2019 and Hu, L *et al.,*2012) suggests that the changes that AsA and SA make to wheat's epigenetics may help explain how they affect the plant's development, growth, and ability to handle stress.

(Wang, D *et al.,*2011) looked at how AsA affected DNA methylation patterns in wheat that was stressed by salt. They found that using AsA greatly reduced the amount of methylation in the DNA and changed the methylation state of several genes that respond to stress compared to the control. The researchers thought that changes in DNA methylation caused by AsA might help wheat handle salt better.

(Liu, L *et al.,*2016) also looked into how SA affected changes in wheat histones caused by heat. Compared to the control group, the SA treatment increased the amounts of histone H3 acetylation (H3K9ac and H3K14ac) and reduced the amounts of histone H3 methylation (H3K9me2 and H3K27me3) at the starting points of genes that respond to heat stress. The study's authors thought that SA-induced changes in histone modifications might help the production of genes which would make wheat better able to handle heat.

This study adds to the proof that AsA and SA can change the epigenetic makeup of wheat. More research is needed to find out how these PGRs change the epigenetic landscape and how that affects wheat's growth, yield, and ability to handle stress.

7. AsA and SA in Wheat Stress Tolerance

7.1. Drought Stress

Drought is one of the main nonliving things that lowers the world's wheat output (Fahad, S *et al.,*2016). To make wheat more resistant to drought, AsA and SA change a number of physiological, biological, and molecular processes (Wang, Y *et al.,*2014 and Malik, S *et al.,*2015).

Looked into how AsA affects the growth and output of wheat that has been stressed by drought. Working with water stress, they found that adding AsA greatly increased RWC, photosynthetic rate, and chlorophyll content while lowering electrolyte leaks and membrane lipid breakdown compared to the control.

In the same way, (Kang, G *et al,.*2012) looked into how SA changed how wheat responded to drought. Results showed that SA treatment improved root water content (RWC). The researchers discovered that drought-responsive genes, such as TaDREB2 and TaERF3, had their expression levels elevated after SA treatment. It did more than that; it boosted ABA levels and enzyme activity that synthesizes ABA. Wheat improved its drought tolerance and yield as a result of these alterations.

These findings show that AsA and SA can make wheat more resistant to drought by changing how water moves through the plant, how it makes food, how it protects itself from free radicals, how much osmolyte it builds up, and how stress-responsive genes are expressed.

7.2. Heat Stress

Heat stress is a big abiotic factor that affects growth and output in places where temperatures are high during the reproductive stage of wheat's life cycle (Farooq, M *et al.,*2011). AsA and SA may help wheat plants deal with heat stress by changing several molecular and biochemical processes (Kumar, R.R *et al.,*2012 and Liu, X *et al.,*2000).

(Asthir, B *et al*., 2012) study looked at how AsA affected the growth's reaction to climate stress and found that whole-grain wheat was very grain-filling. They found that when AsA was given in heat-stressed settings, antioxidant enzyme functioning (SOD, CAT, the other compounds, and grazing) were significantly increased. Concurrently, lipid peroxidation and reactive oxygen species (ROS) levels were lower than the control. Researchers discovered that aspartame improved the photosynthetic rate, chlorophyll content, and stomatal permeability of wheat. Its productivity and heat tolerance were both enhanced. Additionally, (Khan, M.I.R *et al.,*2013) investigated SA's effects on heat-stressed wheat's development and yield. Researchers discovered that SA treatment elevated osmolyte levels (such as proline and soluble carbohydrates) and antioxidant enzyme activity in heat-stressed plants. Heat shock protein (HSP) genes, including TaHSP70 and TaHSP90, were discovered to be upregulated in response to SA treatment of cells. This helped protect proteins from denaturation and clumping caused by heat.

These changes helped the wheat crop's ability to handle heat, grow, and produce more. AsA and SA seem to be able to help wheat grow faster, produce more, and handle more heat by making its antioxidant defences stronger, building up osmolytes, and turning on genes that react to heat.

Stress from Salt 7.3

Soil salt makes it hard to grow wheat in many places of the world (Shrivastava, P *et al.,*2015). AsA and SA make wheat better able to handle salt by controlling many molecular, physiological, and biological processes (Isayenkov, S.V *et al.,*2019 and Szepesi, A *et al.,*2009).

Rehman, H *et al.,*2015) looked at how AsA affects wheat growth and output when it was exposed to salt stress. In salty conditions, plants treated with AsA had much higher than the control group. Conversely, root and shoot Na+ and Cl-ion concentrations were lower. Treatment with raised concentrations of osmolytes such as proline and glycine betaine, according to the authors. Wheat yielded more, grew better, and was less susceptible to salt damage after these adjustments.

(Jiani and Joseph 2017) also looked into how SA affected how wheat responded to salt stress. When they put the treated and untreated groups in saltwater, they found that SA treatment increased. The researchers also found that SA treatment boosted the production of genes that respond to salt, such as TaSOS1 and TaNHX1. These genes help the body handle salt and keep the balance of ions. The changes made to wheat made it grow and give more while also being able to handle salt better.
These findings show that AsA and SA can make wheat more resistant to salt by changing how ions are balanced, how antioxidants work, how osmolytes build up, and how genes that react to salt are controlled.

Table 5. Effects of ascorbic acid (AsA) on wheat growth and yield under drought stress.

Treatment	Relative water content (%)	Photosynthetic rate (µmol CO2 m-2 s-1)	Chlorophyll content (mg g-1 FW)	Grain yield (t ha-1)	Reference
Control	65.3 ± 2.8	14.2 ± 1.1	1.85 ± 0.09	3.24 ± 0.18	[62]
AsA	78.6 ± 3.2*	18.9 ± 1.4*	2.32 ± 0.12*	4.15 ± 0.22*	[62]

The average variation ± mean is used to express values. Large variations between the combinations of AsA and manage treatments are indicated by the letters asterisk (*) (P < 0.05).

Table 6. Effects of salicylic acid (SA) on wheat antioxidant enzyme activities and osmolyte levels under heat stress.

Treatment	SOD (U mg-1 protein)	CAT (U mg-1 protein)	APX (U mg-1 protein)	Proline (µmol g-1 FW)	Soluble sugars (mg g-1 DW)	Reference
Control	18.5 ± 1.2	10.3 ± 0.8	5.6 ± 0.4	3.2 ± 0.2	28.4 ± 1.9	[68]
SA	24.8 ± 1.6*	14.7 ± 1.1*	8.3 ± 0.6*	4.5 ± 0.3*	36.2 ± 2.3*	[68]

The data are expressed to be a way ± deviations of significance. Significant discrepancies between the group being studied and SA means (P less than 0.05), are indicated by symbol (*). Ascorbate an antioxidant (APX), catalase in order (CAT), superoxide anion (either SOD), its raw state (FW), and allow to dry weighs (DW).

8. Conclusion and Future Perspectives

This study piece has everything we know so far about how ascorbic acid (AsA) and salicylic acid (SA) affect wheat growth, production, quality, and its ability to handle stress. This article talks about the complicated roles that these plant growth factors play in wheat. They change biological, chemical, and molecular processes. The result is that wheat fields can do better and stay strong in both good and bad conditions. When wheat is stressed by abiotic factors like heat, salt, and drought, adding AsA and SA helps in many ways. It improves seed germination, seedling growth, photosynthesis, nutrient intake, antioxidant defence, and osmolyte buildup. To make wheat even more resistant to stress and adaptable, these PGRs also change epigenetics and manage the production of genes that react to stress.

It has also been said that AsA and SA may make it easier for wheat grains to absorb important micronutrients like Fe, Zn, and Se. They may also increase wheat yield components, grain yield, and grain quality. These findings show that these PGRs can raise the yield, nutritional value, and market value of wheat.

There has been a lot of work done to explain how AsA and SA affect wheat, but there are still a lot of questions and areas that need more research. One of them is to find the best AsA and SA concentration, time, and application method for different types of wheat and weather conditions. Finding specific target genes and regulatory networks, as well as shed light on the complicated molecular processes that AsA and SA use to affect wheat development, growth, and how it reacts to stress. Looking into whether AsA, SA, and other PGRs or agrochemicals that are commonly used in wheat production methods work together or against each other.

Looking at how useful, long-lasting, and cost-effective it is to use AsA and SA on wheat fields over a long period of time to improve growth, yield, and soil health. Looking into and making new ways to give AsA and SA to wheat plants to make them work better, stay stable, and be soluble. Using SA and AsA together with other crop management methods like precision agriculture, biotechnology, and organic farming to make wheat production systems that are stronger and last longer.
SA have a lot of potential to improve wheat growth, output, quality, and resistance to stress. Making wheat production methods that are more sustainable, productive, and healthy might help improve world food security and people's health. This can be done by doing more study and coming up with new ideas in this area.

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