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ROLE OF SALICYLIC ACID AND POTASSIUM IN ENHANCING STRESS TOLERANCE IN MAIZE (ZEA MAYS L.)

Vikram Singh[1*], Akhil Bharti[2], Aaina Sharma[3], Sultan Singh[4]

[1]Ph.D Research Scholar,Faculty of Agriculture,Maharishi Markandeshwar (Deemed to be University), Mullana, Ambala - 133 207 Haryana, India. Email - sainivikkyy@gmail.com
[2]Assistant Professor, Faculty of Agriculture, Maharishi Markandeshwar (Deemed to be University), Mullana, Ambala - 133 207 Haryana, India. Email id: abharti.bharti@gmail.com
[3]Assistant professor, Faculty of Agriculture, Maharishi Markandeshwar (Deemed to be University), Mullana, Ambala- 133 207 Haryana, India. Email id:sharmaina01@gmail.com
[4]Assistant Professor, Faculty of Agriculture, Maharishi Markandeshwar (Deemed to be University), Mullana, Ambala - 133 207 Haryana, India. Email-sultan.hau@gmail.com

ABSTRACT
Maize (Zea mays L.) is a world-important cereal crop but its productivity is becoming increasingly limited by abiotic stress that includes drought, salinity and heat that alters physiological and biochemical processes and destabilizes yield. There is therefore a need to increase stress tolerance in maize in order to maintain productivity under fluctuating climatic conditions. The review summarizes the available literature on the individual and synergistic effect of salicylic acid and potassium in improving abiotic stress tolerance in maize. Literature was reviewed considering growth parameters, physiological reaction, biochemical stress responses and yield properties.
The literature indicates that abiotic stress has a serious impact on the growth, physiological performance, antioxidant balance, and yield of untreated plants. Salicylic acid and potassium alleviated these negative effects and the combination treatment had the best effects on chlorophyll content, relative water content, antioxidant enzyme activity, membrane stability, and grain yield. The results indicate that the combination of salicylic acid and potassium is a viable and feasible approach to the improvement of the stress tolerance of maize. This has great potential to enhance productivity, input-use efficiency and sustainability of the maize production in the stress-prone agro-ecological areas.

KEYWORDS: Salicylic acid, Potassium nutrition, Abiotic stress, Maize, Stress tolerance, Crop productivity

I. INTRODUCTION

Maize (Zea mays L.) is a very significant cereal crop worldwide, and it is a staple food, animal feed, as well as an industrial raw material. This has seen maize become a great source of global food and economic security due to its adaptability to diverse agro-climatic conditions stability, and specifically in the developing world. Abiotic stresses like drought, salinity, and heat are however becoming an increasing threat to maize productivity as a result of changes in climate [1]. These stresses interfere with physiological and biochemical processes of plants, resulting in decreased growth, photosynthesis, oxidative injury, and high losses in yield. In rain-fed agriculture-based regions, yield volatility as a result of stress can be a severe challenge to sustainable crop production [31]. Therefore, there is a serious research need to enhance stress resistance in maize to maintain consistent yields and hardiness during unfavorable environmental factors.
Plants have an inherent ability to deal with environmental stress; the systems are usually not adequate in the case of stressful conditions which are prolonged and extreme. Plant growth regulators and essential nutrients application have become a viable agronomic approach to increasing plant resistance to stress. The phenolic phytohormone salicylic acid is crucial in the regulation of plant defense, antioxidant and stress signaling pathways [13]. On the same note, potassium is a vital macronutrient that takes part in enzyme activation, osmotic equilibrium, stomatal operation, and cellular homeostasis. Although a few studies have reported the positive influence of salicylic acid or potassium, separately on stress tolerance of crops, few studies have been conducted to understand the combined or interactive effects of the two in maize in the presence of abiotic stress. Moreover, the published review usually targets the single stressors or fails to combine physiological and biochemical measures [32]. This indicates an apparent review gap in comprehending the application of salicylic acid and potassium in synergy to improve stress tolerance in maize, especially in terms of sustainable crop management.
This review aims at assessing the effects of salicylic acid and potassium on abiotic stress tolerance in maize (Zea mays L.). The particular objectives of the review are: - To review the action of salicylic acid usage on maize physiological and biochemical responses to abiotic conditions. To determine the effects of potassium nutrition on stress tolerance and growth in maize and to determine the overall effects of salicylic acid and potassium on stress alleviation and overall crop productivity of maize plants.
The review aims on addressing the following review questions based on the objectives stated below:- How does salicylic acid use affect the physiological and biochemical stress responses of maize? How does maize potassium nutrition aid in increasing abiotic stress tolerance in maize plants? Are stress tolerance and productivity benefits of potassium and salicylic acid treatment more effective than those of individual treatments?

II. LITERATURE REVIEW

Tas (2022) examined the physiological and biochemical of hybrid maize varieties to natural heat stress conditions and reported major decreases in grain yield, chlorophyll content, and leaf water potential, and greater cell membrane damage [19]. Heat stress is a significant abiotic limiting factor in maize growth especially in areas where temperatures are increasing because of global warming. The review proved that heat stress interferes with cell stability and photosynthetic efficiency resulting in penalties during yield [33]. Notably, the differences between maize hybrids demonstrated a high genetic effect on heat stress tolerance, with some hybrids showing a better physiological ability. These results point at the cell membrane damage as a significant measure of stress sensitivity and the necessity of agronomic and physiological provisions to increase maize tolerance in high-temperature environments.

Teng et al. (2022) conducted a review of the yield penalties of heat stress at various developmental stages of maize [20]. The heat stress response of maize in later growth stages is also different and hence stress management is complicated. They found that flowering and grain-filling are most sensitive, with heat stress in these phases strong degrading reproductive development and partitioning of assimilates. Other major physiological upheavals identified during the review include impaired photosynthesis and slowed kernel growth, which add up to loss of yield [34]. The review highlights the relevance of specific management approaches in curbing the effects of heat stresses at various stages of maize development by suggesting a framework on how timing of stresses may be correlated with yield components [99].

Bheemanahalli et al. (2022) studied the impact of single and combined post-flower heat and drought stresses on maize physiology and yield [4]. The review also established that a combination of stress resulted in more severe cuts in stomatal conductance, rise in leaf temperature, and yield losses than single stress treatments. The genotypic variations in stress response could be identified and some maize genotypes were more tolerant of the combined stress conditions. Besides heat stress per se, it is the combination of heat and drought that poses an exponential danger to maize production [98]. These results point out the intricacy of stress interactions and the importance of combined nutrient and hormonal interventions to boost maize resilience to various abiotic stresses.

Rasheed et al. (2022) emphasized the key role played by SA in increasing the salinity tolerance of plants through the regulation of ion homeostasis, antioxidant defenses, and stress transmission [15]. Salicylic acid (SA) is a major phytohormone that regulates plant reactions to abiotic stress by regulating physiological, biochemical, and molecular processes. The analysis has highlighted that the SA enhances the stability of membranes and photosynthetic efficiency through alleviation of oxidative stress due to reactive oxygen species (ROS) that is excessively precipitated by salt.

Barwal et al. (2024) have shown that exogenous treatment of maize seedlings with SA was able to significantly reduce salt-inhibited growth by recovery of morpho-physiological characteristics and antioxidant enzyme activity [3]. Mechanistic mechanism of SA-mediated stress tolerance has also been explained in maize under salt stress. It was discovered that SA usage lowers the oxidative stress indicators (hydrogen peroxide and malondialdehyde) and energizes the major elements of the ascorbateglutathione cycle (superoxide dismutase, catalase, and peroxidases). Furthermore, the positive ionic balance was also enhanced by the means of sodium extrusion and cellular homeostasis which was promoted by SA [35]. These findings show a clear indication that SA is a effective stress signaling molecule, it activates antioxidant defense mechanisms and enhances cellular protective responses to salinity stress in maize [100].

Wang et al. (2024) examined the influence of exogenous SA on high-temperature stress on waxy maize on the grain-filling phase and found significant positive changes in kernel weight, starch content, and starch physicochemical properties [22]. In addition to growth and stress reduction, SA is also important in ensuring quality yield in the case of heat stress. The SA treatment minimized starch thermal damage caused by heat and enhanced the starch thermal stability and digestibility properties [36]. The results indicate that SA is an effective physiological stress tolerance enhancer as well as protectant of thermal stress under metabolic and quality characteristics. In general, the evidence indicates that signaling pathways involving SA do play a role in the stress resilience and preservation of yield quality of maize in unfavorable environmental conditions.

Javed et al. (2024) revealed that optimized nutrition of nitrogen made a significant impact in enhancing potassium efficiency and ionic homeostasis in salty maize [9]. K is one of the basic elements of ionic balance and osmotic adjustment of plants under salinity stress. They found that higher nitrogen levels lowered the Na^+/K^+ ratio and promoted potassium uptake, potassium use efficiency, and proline regulation, ultimately leading to better plant growth, yield, and quality [97]. Osmoregulation through K was important in maintaining turgor and metabolic activity of cells during salinity stress [37]. It was noted that good nutrition management practices lead to indirect potassium functionality, thus the significance of potassium in stress tolerance due to better osmotic balance and reduced ionic toxicity in maize.

Wang et al. (2025) tested maize genotypes under saline and alkali stress and found that tolerant genotypes had a much greater potassium and calcium content, and a lesser Na^+ accumulation and lower Na^+/K^+ ratios [21]. Genotypic variation of potassium accumulation and use is also a decisive factor of stress resilience. An improved potassium status was linked to high antioxidant enzyme activity, high membrane stability, and low lipid peroxidation. Such physiological benefits allowed tolerant genotypes to continue their metabolic efficiency and cell integrity in stress conditions [38]. The review highlighted the importance of potassium in the process of enzyme activation and signaling of stresses that promote the process of water-use efficiency and resistance to oxidative damages, and hence, growth and survival in saline-alkali conditions [7].

Xia et al. (2023) have studied the relationship between root zone temperature and potassium status and have stated that root zone high temperatures with potassium deficiency severely affected root development, potassium uptake, and photosynthetic efficiency [23]. Environmental conditions also impact on potassium absorption and its stress-reducing ability in maize. The sufficient availability of potassium at high-temperature conditions improved root activity, light energy use, and dry matter gain, suggesting an increase of water-use efficiency and enzymatic activity [39]. Although the available literature has unquestionably defined the importance of potassium in osmoregulation, enzyme activation, and stress tolerance, a crucial review gap is the interaction of potassium with plant-signaling molecules in the presence of combined abiotic stresses [94].

III. BACKGROUND AND CONTEXT OF THE REVIEW

The reviewed studies were carried out under different agro-climatic conditions, both in the controlled setting and in the field [93]. A lot of the experiments were conducted in subtropical climates that are either moderate to high temperature with any degree of humidity. These environmental conditions give significant background to the interpretation of stress responses in maize [17].

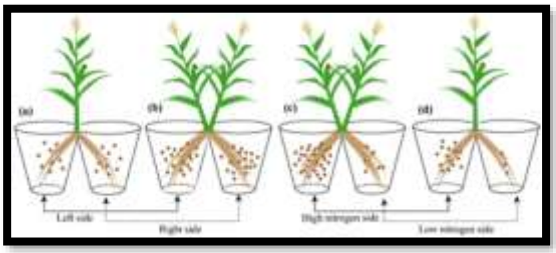

Fig 1: Schematic representation of nutrient distribution patterns and crop cropping patterns [11]

A. Maize Crop and Agronomic Considerations

The plant material used in the review was certified seeds of maize (Zea mays L.). Factorial completely randomized designs have been used with many experimental studies assessing salicylic acid and potassium in maize [40]. In most of the experimental researches, replication of treatments was done to achieve the level of statistical validity [96].

B. Abiotic Stress Conditions Reported in Literature

Abiotic stress has often been applied in the vegetative stages of growth to measure the effect of stress in earlier works. The stress was induced by the manipulated use of stress factors by controlled conditions to ensure that there was equal exposure to treatments [41]. Stress duration and intensity in most published studies was carefully controlled in order to have reliable comparison of stressed and untreated plants. This method allowed determining the physiological and biochemical responses, which can be attributed solely to stress and treatment effects [95].

C. Salicylic Acid and Potassium Application Approaches

Past experimental research has generally used salicylic acid as a foliar spray at various concentrations, and potassium has been applied to the soil by fertilizing or using nutrient solutions. They have also been studied in combination to determine possible synergistic effects in the abiotic stress conditions [8]. Foliar sprays were evenly sprayed at the early morning time to maintain the highest absorption efficiency and Potassium treatments were done at the critical stages of growth to facilitate the metabolic processes and ionic balance [91].

D. Commonly Reported Physiological and Biochemical Indicators

The measured parameters were physiological parameters (plant height, leaf relative water content, chlorophyll content, and membrane stability index) using standard procedures [90]. Biochemical assessments comprised the determination of proline level, antioxidant enzyme activity, and determination of oxidative stress to evaluate stress tolerance processes [42].

IV. SYSTEMATIC REVIEW OF EXISTING REVIEW

A. Growth parameters

The literature is consistent in its demonstration that abiotic stresses (drought, salinity, heat, etc.) have undesired effects on maize growth as they slow cellular growth, reduce biomass accumulation, and have adverse effects on overall plant health [44]. The stress conditions have been reported to decrease the height of plants, growth of leaves and dry matter production due to impaired photosynthesis and low nutrient uptake. In this respect, it has been widely reported that the use of salicylic acid (SA) and potassium (K) as individual agents or as a combination of both positively impacts stress-induced growth inhibition.

It was also reported that Salicylic acid acted as a stress-signaling molecule, regulating the behavior of plant growth to unfavorable environmental conditions. Empirical data reveal that the application of SA enhances the separation and swelling of the cells, consequently facilitating the vegetative growth, despite the stresses [84]. Similarly, the nutritional benefits of potassium have been significantly associated with good plant growth because of the preservation of the osmotic state, enzyme catalysis, and cell turgor [30]. In stressful conditions, it has been reported through diverse studies that the availability of potassium leads to long term growth due to increased water uptake and nutrient translocation [85].

Interestingly, recent studies show that a blend of salicylic acid and potassium is better positioned to deliver optimal growth performance compared to the use of each independently [48]. It is observed that the rationalization of this synergistic interaction is the complementary action of SA in stress signaling and potassium in physiological regulation, which collaborate to maintain the stability of maize plants in a fluctuating environment.

B. Physiological indicators

The most sensitive parameters to abiotic stresses in maize are photosynthetic efficiency, water relations, and membrane integrity. Stressful environments in the literature have been shown to interfere with the production of chlorophyll, reduce relative water content, and make the membranes permeable, leading to abnormal plant functioning [89].

The stability of the photosynthetic apparatus in the protective effect of salicylic acid has been extensively reported to protect chlorophyll pigmentation and facilitate photosystem activity under stress. It has been demonstrated in other studies how the application of SA can maintain the elevated chlorophyll levels by reducing the oxidative stress that affects the chloroplast membranes [43]. Such a protective characteristic of SA is a critical component of sustaining photosynthesis in harsh environmental conditions.

Potassium helps in the control of plant water balance and stomata. Relative water content and water-use efficiency are found to be enhanced by using proper nutrition containing potassium especially during drought and salinity stress [45]. K^+ stomatal control mediation allows plants to lose water using less carbon [86].

A blend of salicylic acid and potassium has as well displayed an extraordinary impact on maize physiological stability. Hormonal signals and nutrient regulation have been linked to increased membrane stability, water status, and long-term photosynthetic sustainability [46]. These physiological benefits are synergistic and enable the maize plants to react more in response to the altered stress regimes.

C. Biochemical markers

The biochemical reactions to stress determine the stress tolerance of plants, particularly, the accumulation of osmolytes and antioxidant defense. Abiotic stress has also been said to lead to the overproduction of reactive oxygen species (ROS), which causes oxidative stress on lipids, proteins, and nucleic acids in maize plants.

Among the most renowned triggers of antioxidant defense mechanisms is salicylic acid. It has been documented in literature that the use of SA enhances the action of key antioxidant enzymes such as superoxide dismutase, catalase, and peroxidases and consequently the elimination of ROS [47]. Moreover, SA has been found to regulate osmoprotectant deposition that helps in cell protection in times of stress.

Potassium is also another biochemical modulator that contributes to ionic homeostasis and decreased oxidative stress. Sufficient levels of potassium have been associated with decreased lipid peroxylation and membrane stability. Potassium-mediated enzyme activation also promotes the efficiency of the metabolism during exposure to stress [50].

Interestingly, a study also shows that a synergistic effect of salicylic acid and potassium increases biochemical defenses. Such a synergistic effect enhances antioxidant capability, osmotic adjustment, and reduces cell damage. Such metabolic changes are instrumental in maintaining metabolic stability and survival of plants in prolonged stress conditions.

Authors	Description	Key Outcomes
Ali et al. (2023)	Examined synergistic effects of salicylic acid on maize under salt stress	SA improved antioxidant activity and enhanced salt stress tolerance
Barwal et al. (2024)	Investigated SA-mediated mechanisms in maize seedlings under salinity	Enhanced ROS scavenging, membrane protection, and ionic balance
Feng et al. (2022)	Studied physiological defense responses of maize following SA application	SA activated systemic defense signaling and stress protection pathways
Rasheed et al. (2022)	Reviewed role of salicylic acid in plant salinity tolerance	SA regulated antioxidant systems and improved cellular stability
Song et al. (2023)	Comprehensive review of SA roles under biotic and abiotic stresses	SA acted as a key signaling molecule enhancing stress resilience

Table 1: Selected studies highlighting the role of Salicylic Acid in maize stress tolerance

D. Yield attributes

Maize yields are highly dependent on the biochemical activities and physiology that the plant is able to maintain at crucial periods of growth. The capacity of abiotic stresses to induce high rates of assimilate reduction and partitioning to result in low grain formations and variation in yields [52].

Literature analysis suggests that the use of salicylic acid can help stabilise yield through stabilisation of photosynthetic activity and delay stress-related senescence [28]. The stress resistance available in SA encourages a continuous supply of assimilates to the developing reproductive organs. On the other hand, Potassium is directly related with increased assimilate translocation and grain filling, which is crucial in stabilizing yield against stress.

Nutritional potassium enhances the growth of grains and the quality of grains, according to diverse studies, due to the interactions between carbohydrate metabolism and source sink [29]. It is the interaction between salicylic acid and potassium that contributes to higher yield resilience because the two substances are complementary regarding their physiological activity and nutrient efficiency [51].

Overall, much evidence currently leads to the perception that the joint action of salicylic acid and potassium to help in the rejection of the yield losses induced by stress in maize is a promising approach [83]. This symbiotic activity contributes to productivity, and stability of stress sensitive agricultural systems.

Authors	Description	Key Outcomes
Javed et al. (2024)	Studied potassium efficiency and ionic homeostasis in maize under salinity	Improved K uptake, osmotic balance, and yield stability

Karvar et al. (2023)	Evaluated potassium application under drought conditions in maize	Enhanced water-use efficiency and drought tolerance
Samadi et al. (2024)	Assessed potassium nutrition and physiological traits under drought stress	Improved nutrient uptake and physiological performance
Xia et al. (2023)	Analyzed potassium absorption under varying root zone temperatures	Adequate K improved photosynthesis and stress adaptation
Munsif et al. (2022)	Examined synergistic effects of potassium and salicylic acid under drought	Combined SA–K enhanced antioxidant capacity and stress resilience

Table 2: Selected studies emphasizing the role of Potassium and combined SA–K application in maize stress tolerance

E. Summary of Key Evidence from Existing Literature

The essence of maize stress response: A synthesis of data sets revealing physiological, biochemical and nutrient-mediated stress response in maize has been provided in tables 3 and 4.

Authors	Description	Key Outcomes
Tas (2022)	Evaluated physiological and biochemical responses of maize under heat stress	Heat stress reduced chlorophyll content and increased membrane damage
Teng et al. (2022)	Reviewed yield penalties of maize under heat stress at different growth stages	Flowering and grain-filling stages were most sensitive to heat stress
Bheemanahalli et al. (2022)	Studied combined heat and drought stress effects in maize	Combined stresses caused severe physiological disruption and yield loss
Wang et al. (2025)	Compared stress-tolerant and sensitive maize genotypes under saline–alkali stress	Tolerant genotypes showed higher antioxidant activity and ionic balance
Ali et al. (2024)	Investigated antioxidant production and gene expression in maize under abiotic stress	Enhanced antioxidant defense improved stress tolerance mechanisms

Table 3: Selected studies describing physiological and biochemical stress responses in maize

Authors	Description	Key Outcomes
Altaf et al. (2023)	Studied foliar application of salicylic acid under water stress	Improved physiological traits and maize yield under drought
Shoukat et al. (2023)	Examined exogenous salicylic acid application under salinity stress	Improved ionic balance, photosynthetic pigments, and antioxidants
Xia et al. (2023)	Analyzed root-zone temperature effects on potassium absorption	Adequate potassium enhanced photosynthesis and stress adaptation
Thenveettil et al. (2024)	Modeled potassium nutrition effects on maize physiology	Potassium improved growth efficiency and physiological stability
Singhal et al. (2023)	Reviewed role of beneficial nutrients in abiotic stress tolerance	Nutrient-use efficiency improved stress resilience and yield stability

Table 4: Selected studies focusing on nutrient regulation, growth regulators, and yield stability under stress

V. DISCUSSION

Abiotic stresses, like drought, salinity, and heat, are among the main constraints to maize productivity all over the world [53]. The systematic review has conclusively synthesized evidence showing that these stresses impair essential growth, physiological, and biochemical processes, as well as yield-related aspects, of maize. Across various studies it has been reported that there are reductions in vegetative growth, chlorophyll stability, relative water content, and assimilate partitioning. These perturbations affect cellular metabolism, water relations and oxidative balance [5]. These stress-induced impairments match known maize physiological traits under the environmental stressors where yield penalty was due to restriction of photosynthesis and nutrient transport [54].

The literature review strongly supports that salicylic acid (SA) is an effective stress-signalling molecule that can enhance maize tolerance to abiotic stresses. As outlined in Section IV, SA is involved in the stabilization of the photosynthetic apparatus, retention of chlorophyll pigments, and maintenance of membrane stability [56]. The physiological impacts mentioned above are largely due to SA-regulating antioxidant systems and stress-responsive signaling pathways. SA allows maize to maintain metabolic activity when subjected to protracted stress by reducing oxidative damage and delaying the initiation of stress-induced senescence [55].

Additionally, potassium affects the maize's capacity to tolerate stress [82]. As discussed in the reviewed articles, potassium plays a key role in osmotic regulation, stomatal activity, activation of enzymes and ionic homeostasis. Numerous studies have linked adequate potassium availability to a higher relative water content, better water-use efficiency, and continuous biomass production when exposed to drought and salinity stress [24]. Potassium aids in maintaining cellular turgor and metabolic efficiency thus supporting the physiological processes which may otherwise hamper severely under abiotic stress condition [57].

An important contribution of the literature is the tendency of scientists to agree that two mechanisms of salicylic acid and potassium can help to better reduce stress than just one with these substances [58]. The information in Section IV suggests that SA and potassium operate by different mechanisms, with SA mainly regulating stress signaling and antioxidant defense, and potassium mainly regulating ionic balance, enzyme activation, and stomatal regulation [16]. By incorporating these stress signals in advancement of one another, sunflower's joint stress-mitigating efficacy is enhanced [59]. The combination of these effects contextualizes the consistently improved growth stability and biochemical protection of the plant, as well as yield resilience, reported by various studies with integrated SA-K applications [60].

The review highlighted that biochemical adaptations also play an important role in stress tolerance. Osmolytes build up (proline) and activation of antioxidant enzymes (superoxide dismutase, catalase and peroxidases) facilitate reversal of oxidative stress [81]. The evidence reviewed indicates that SA increases the activity of antioxidant enzymes and regulates osmoprotectants, while potassium reduces lipid peroxidation and stabilizes membranes [61]. The action of chemical compounds reduces the toxicity of reactive oxygen species and protect cellular structures that have harmful effects. Thus, maintain metabolic homeostasis during the episode of stress [65].

The systematic review discussion of yield-related responses the need to integrate stress management strategies further [77]. The impact of abiotic stress on source-sink relations comes from limitation of assimilate production and translocation that reduces grain filling and yield stability. Review shows that SA being involved in yield maintenance, chlorophyll content, net photosynthetic rate, delaying senescence of leaves [62]. Potassium enhances the movement of assimilates and filling of grain [18]. As a result, using both products boosts harvest efficiency and stabilizes yield in-stress-prone environments.

The results of the present review fit well with literature that focuses on the two distinct roles of salicylic acid in stress signalling and of potassium in osmotic metabolic regulation [64]. Although understanding hasn't changed when focusing on single factors, this review adds to current knowledge by concentrating on their interaction. According to a latest study, proposal of an integrated SA–K framework could provide a more comprehensive picture of stress tolerance mechanisms to enhance maize [26].

Taken together, available literature indicates that salicylic acid and potassium use in maize may prove to be useful. It notes that this practice should be performed in a cost-effective manner. All such inclusive practices can lessen yield variability, make nutrient-use efficiency better, and boost resilience in climate-vulnerable agro-ecosystems [67]. This is important for areas that are facing rising climatic uncertainty, stressing on the need for implementing adaptive stress control measures for maize production and food security [27].

VI. MANAGEMENT AND PRACTICAL IMPLICATIONS

The results of the review present valuable suggestions on sustainable Maize cultivation systems, especially in agro-ecological zones that are prone to stresses. The presented efficiency of salicylic acid and potassium in attenuating abiotic stress and its role as effective means of improving the resilience of crops to evolving climatic conditions is revealed [2]. Combining hormonal and nutrition intervention strategies promotes sustainable agriculture because it helps decrease yields variability caused by stress without high chemical input [80]. These strategies are in line with sustainable intensification objectives of ensuring that resources are used efficiently and productivity is not compromised. These practices in the long run can lead to climate-resilient cropping systems that can reconcile production and environmental stewardship and resource conservation [66].

On a farm-scale management level, salicylic acid combined with potassium would be a good stress management approach to maize production [79]. Potassium fertilization increases the efficiency of water-use, osmotic balance, and enzyme activation, and salicylic acid increases stress signaling and antioxidant defense mechanisms [63]. This combined approach can be adopted by farmers to mitigate crop losses during drought, salinity or heat stress periods [10]. Promptness during critical growth periods can enhance physiological operation and bring results that will lead to increased stability in production in unfavorable environmental conditions [68]. The strategy has been especially useful to small and medium farmers who are interested in cheap, flexible ways to deal with production risks that are caused by climatic conditions [69].

Synergistic application of salicylic acid and potassium can be effective in boosting returns to investment by increasing yield and mitigating stress-related inefficiencies in agribusiness and input-use efficiency [78]. Greater nutrient-use efficiency and a superior assimilate partitioning leads to increased grain production in relation to the amount of input applied [6]. To the farm managers and agribusiness stakeholders, this strategy aids informed decision-making in terms of fertilizer management and stress mitigation planning, as well as risk reduction. In general, the results will help to create resilient systems of maize production that are both economically feasible and sustainable [76]. This is important to enhance the reliability of supply chains and food security in an ever-changing climatic environment.

VII. LIMITATIONS AND FUTURE SCOPE

Although the lessons were meaningful, this review is limited in some ways as well. A number of studies have been done in controlled conditions of subtropical settings with few treatment and replications which might not take in the full variation encountered in field conditions [74]. Also, the review mainly concerned short-term physiological, biochemical, and yield outcomes, and did not examine long-term soil health, and seasonal variability. Nevertheless, there is a lack of extrapolation of the results to large-scale agricultural systems.

To confirm the effectiveness of salicylic acid and potassium application in various agro-climatic regions, Multi location and long term field experiments should be carried out in the future [75]. The application of various maize genotypes and levels of stress would also enhance the generalizability of results. In addition to that, molecular-level examinations of gene expression, signaling pathways and ion transport systems related to salicylic acid and potassium interaction are required to enhance mechanistic insight [71]. Such studies would underpin optimized, location specific stress management measures to sustainable production of maize.

VIII. CONCLUSION

Salicylic acid and potassium have been extensively studied as a means of mitigating abiotic stress in maize using growth, physiological, biochemical and yield parameters. These adverse effects of abiotic stress on plant growth, photosynthetic efficiency, antioxidants balance, and grain yield of untreated plants have been reported to be significant [70]. Nonetheless, salicylic acid and potassium application, specifically together, were useful in alleviating such undesirable effects [72]. The positive effects of these treatments were ascertained by the improvements in chlorophyll content, relative water content, antioxidant enzyme activity, and yield characters.

According to published literature, there is always synergistic effect of salicylic acid and potassium in enhancing stress traits of maize [73]. Practically, the findings justify the use of a combined salicylic acid and potassium application as a viable solution towards enhancing the productivity of maize in stress-stricken soils [25]. This combination strategy can contribute to crop sustainability and yield stability and farm level profitability under ever-changing climatic conditions.

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