T.R.
BOLU ABANT İZZET BAYSAL UNIVERSITY
INSTITUTE OF GRADUATE STUDIES
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THE EFFECT OF SPRAYING WITH ZINC AND SALICYLIC ACID ON THE PHYSIOLOGICAL CHARACTERISTICS, PRODUCTIVITY, AND QUALITY OF THE WHEAT CROP

MASTER THESIS

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SHAD ISMAIL MAHMOOD

ABSTRACT

THE EFFECT OF SPRAYING WITH ZINC AND SALICYLIC ACID ON THE PHYSIOLOGICAL CHARACTERISTICS, PRODUCTIVITY, AND QUALITY OF THE WHEAT CROP

MASTER THESIS
SHAD ISMAIL MAHMOOD
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INSTITUTE OF GRADUATE STUDIES
DEPARTMENT OF FIELD CROPS
(SUPERVISOR: PROF. DR. IBRAHİM HAKKİ YİLMAZ)

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This field experiment was carried out at the Sulaimani Agricultural Research Center in the Bakrajo/Sulaymaniyah Governorate, which is located in northern Iraq in 2020-2021 with the aim of knowing the effects of salicylic acid and zinc foliar application on the physiological characteristics, productivity, and quality of the wheat crop. The bread wheat *Triticum asetivum* L. (Sulaimani2) was used in this study under the influence of application factors, with four concentrations of salicylic acid (S0), non-activation, (S1) spraying the vegetative with 100 ppm, (S2) spraying the vegetative with 200 ppm, and (S3) spraying the vegetative with 300 ppm. Also, spraying the same treatments with three concentrations of zinc (Z0), non-activation, (Z1), spraying the vegetative with 50 ppm, and spraying the vegetative with 100 ppm. Conducted in a factorial experiment with a randomized complete block design (RCBD) and with three replications, each of which included the factorial coefficients for the combination of the study workers, which were randomly distributed to the experimental units in duplicate and the results showed that the activation treatment (S3), (Z2) and the interaction between them which are the highest concentration of salicylic acid and zinc were significantly superior in most studied characters to the other activation treatments. Also, other activation treatments had positive effects and were superior in most studied characteristics compared to non-sprayed treatments.

KEYWORDS: Wheat cultivare, Salicylic acid, Zinc ($ZnSO_4$), Foliar application, Seed quality and quntity, Grain yild.

ÖZET

BUĞDAY ÜRÜNÜNÜN FİZYOLOJİK ÖZELLİKLERİ, VERİMLİLİK VE KALİTESİ ÜZERİNE ÇİNKO VE SALİSİLİK ASİT PÜSKÜRTME ETKİSİ

YÜKSEK LİSANS TEZİ
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Bu saha denemesi, salisilik asit ve çinko yaprak uygulamasının fizyolojik özellikler, verimlilik, bitki sağlığı, ve buğday mahsulünün kalitesi. Bu çalışmada ekmeklik buğday *Triticum asetivum* L. (Sulaimani2), uygulama faktörlerinin etkisi altında, dört konsantrasyonda salisilik asit (S0), aktivasyonsuz, (S1) vejetatife 100 ppm püskürtme, (S2) püskürtme kullanılmıştır. 200 ppm ile bitkisel ve (S3) vejetatifin 300 ppm ile püskürtülmesi. Ayrıca, aynı işlemleri çinkonun üç konsantrasyonu (Z0), aktivasyonsuz (Z1) ile püskürtme, vejetatife 50 ppm püskürtme ve vejetatife 100 ppm püskürtme. Rastgele tam blok desenli (RCBD) ve her biri çalışma çalışanlarının kombinasyonu için faktöriyel katsayıları içeren üç tekrarlı bir faktöriyel deneyde, deney birimlerine ikişer kez rastgele dağıtılmış ve sonuçlar göstermiştir ki, Salisilik asit ve çinkonun en yüksek konsantrasyonu olan aktivasyon işlemi (S3), (Z2) ve aralarındaki etkileşim, çalışılan karakterlerin çoğunda diğer aktivasyon işlemlerinden önemli ölçüde üstün bulunmuştur. Ayrıca, diğer aktivasyon tedavilerinin de olumlu etkileri oldu ve püskürtülmeyen tedavilere kıyasla incelenen özelliklerin çoğunda üstündü.

ANAHTAR KELİMELER: Buğday çeşidi, Salisilik asit, Çinko ($ZnSO4$), Yapraktan uygulama, Tohum kalitesi ve miktarı, Tane verimi.

TABLE OF CONTENTS

LIST OF TABLES

Page

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1. INTRODUCTION

Wheat is the most important economic cereal crop and is widely grown all over the world. Wheat in the form of bread (*Triticum asetivum* L.) provides more nutrients to the world population than any other single food source and provides about one fifth of the calories consumed by humans around the world. About 776.7 million tons of wheat was produced all over the world in 2020. In Turkey, as stated by the Turkish Statistical Institute's production prediction released in October 2020, grain output in 2020 would be 20.5 million tons, up 7% over the previous five-year average of 20.5 million tons of wheat. Wheat yield increased due to favorable weather conditions and a small increase in area (3% compared to the previous year) (FAO). Iraq's total wheat output is expected to reach 5.4 million tons in 2020–21, up from 4.8 million the previous year, which does not meet annual demand, according to the International Grains Council (IGC).

Wheat yields have only increased by 1.1 percent per year since the Green Revolution, falling short of the needs of a population that is growing at a rate of 1.5 percent or more each year. According to some estimates, global wheat output must increase by at least 1.6 percent per year to meet annual demand (1). Lack of water sources due to the low rainfall that Iraq and the region experienced and the irregular distribution of the plant's needs negatively affects growth and productivity indicators, such as chemical, physiological, morphological, and anatomical processes, which result in reducing the size of the plant and the leaf area, which leads to a lower yield. It is necessary to search for means and use appropriate methods that help the plant to withstand and resist drought (water shortage) and give an acceptable yield, including stimulating the seeds before planting by soaking them in plant growth regulators. One of these regulators is salicylic acid (2).

Salicylic acid is a naturally occurring as phenolic that is widely distributed throughout the plant kingdom. It was recognized as an endogenous regulator in plants after finding that it is involved in many plant physiological processes. Salicylic acid increased the level of cell division of seedlings and roots, which increased plant growth. Salicylic acid can be used as a spray during the vegetative growth stage of wheat, as it works to inhibit the building and synthesis of ethylene, stimulate the process of ionic transport through membranes and absorption in the roots, reduce transpiration and respiration in leaves, and reverse the process of stimulating ABA (abscisic acid). This would prolong the life of the leaf surface green (3). Therefore, salicylic acid is one of the hormones for growth. The newly explored interior has an important and effective role in urging plants to resist biotic and abiotic stress, including drought stress, as it is believed to increase and regulate the distribution of dry matter from source to estuary. Salicylic acid seems to be a very simple phenolic compound (a $C_7H_6O_3$ substance with an aromatic ring, one carboxylic, and one hydroxyl group), but its simplicity belies its high versatility and active participation in a variety of plant processes, both in ideal conditions and in plants exposed to environmental cues (4). Salicylic acid administered exogenously has the potential to improve the stress tolerance of economically significant crops such as wheat. It has the potential to modify plant responses to diverse stressors by regulating the activities of antioxidant defense system enzymes, either directly or indirectly (5, 6, 7).

Micronutrients, in particular zinc (Zn), have an important role in many of the biological and physiological processes that take place inside the plant (photosynthesis, respiration, energy production, enzymatic reactions, and chlorophyll formation), as well as their role in improving the efficiency of photosynthetic product transfer from the point of manufacturing (source) to the renimnder of the plant.

Wheat responds to the application of micronutrients during its growi ng stages and results in enhanced output in terms of yield. Since the Iraqi soils have a high content of carbonate minerals and the degree of their reaction is inclined to basic, the availability of zinc is low in such soils due to their exposure to adsorption and sedimentation reactions (8). Zinc is an essential plant micronutrient which is involved in many physiological functions, protein and carbohydrate synthesis (9). Zinc applications had a positive effect on plant growth, leading to increased plant height, number of fertile tillers, number of filled spikelets, spike length, grains, biological and straw yields, and 1000-grain weight, culminating in improved grain yield (10). Zinc deficiency is one of the widespread nutritional problems, as it is one of the micro-nutrients necessary for plant growth and completion of its life cycle. It is involved in many vital processes. It is also important in the manufacture of the amino acid Tryptophan, which is essential for the manufacture of indole acetic acid (IAA) whose deficiency causes stunting of the plant (11). Zinc insufficiency is the most prevalent and pervasive micronutrient deficit in wheat-growing countries. Zinc is deficient in approximately most of the arable soils in Iraq. Furthermore, around half of all agricultural soils in the world were found to be low in bioavailable zinc. For example, 50% of the cultivated soils in Turkey suffer from zinc deficiency, and when wheat was grown in Turkey on a zinc-deficient soil, the Zn content of the grains was reduced by 50% (12).

1.1. Effect of Salicylic Acid on Plants' Physiological Character

Salicilic acid is a plant growth regulator that has a role in a variety of physiological and biochemical processes. Several crops can benefit from its use in terms of growth, development, production, and quality (13). It also plays an essential role in enhancing metabolic rates, which adds to the plant's energy conservation via alternate pathways accompanied by a shift in nucleic and amino acid levels (14).

Salicylic acid has important physiological functions in plant growth and development, such as increasing the plant's response to stress conditions (biotic and abiotic), increasing the plant's resistance to system acquired resistance (SAR), and stimulating or changing the internal paper dissection endogenous signaling to withstand a wide range of stresses (15). It is a phenolic molecule that regulates plant growth and development, as well as their reactions to biotic and abiotic stressors (16, 17, 18).

Salicylic acid works as a cell stimulant or transmitter, allowing the plant to endure environmental stress conditions such as dryness, coldness, heat, heavy metal stress, and ammonia tension, as well as salt stress, notably the damaging sodium chloride molecule (19). And it has the capacity to bind conjugate with certain amino acids, such as proline and arginine, enhancing the plant's resilience to external stressors while also maintaining systemic acquired resistance (20).

Salicylic acid stimulates the synthesis of antioxidants, which is one of its most important benefits. When subjected to heat stress and stress, antioxidants protect against the effects of free radicals from the group of Reactive Oxygen Species (ROS). Drought stress inhibits the oxidation of algebraic, oxytin, and cytokinein, as well as playing a function at the genetic level. Antioxidant enzyme genes, such as manganese superoxide dismutase, are stimulated (Masud) (21).

Salicylic acid improves the plant's tolerance and resistance to a variety of illnesses that afflict plants, as it is discovered that raising its internal concentration activates pathogenic pathogens' protective role. (22). Exogenous salicylic acid and its derivatives, such as acetyl salicylate and methyl salicylate, were previously used to prevent post-harvest illness in fruits and vegetables by enhancing systemic acquired resistance and stress resistance (23, 24). (25) Reported that the dry matter accumulation was significantly enhanced in Brassica juncea when lower concentrations of SA were sprayed. However, higher concentrations of SA had an inhibitory effect.

1.2. Salicylic Acid Impacts on Qualitative and Quantitative Characteristics in Plants.

Salicylic acid (SA) is an endogenous phenolic compound, which plays an important role in plant growth and development (26, 5). Also, (27) Discovered that salicylic acid deficient transgenic rice was more susceptible to oxidative stress, indicating that salicylic acid may have a role in plant resistance to oxidative stress induced by both biotic and abiotic stress agents. This acid was first discovered in Salix spp., which contains the salicin compound by 9.5–11% and is present in the plant in the form of free phenolic acids or associated with amino compounds (28). The cotton plant *Gossypium hirsutum* L., which belongs to the Malvaceae family, was shown to have three levels of salicylic acid (50, 100, and 150) mg/l in one of these investigations. In comparison to other concentrations utilized, the plant height (143.80) cm, the number of branches (34.28 branches), and the total cotton production (3371.9) kg/Ha had the greatest rates. (29). (30) Found that spraying *Rosmarinus officinalis* L. with three different concentrations of salicylic acid (450, 300, and 150 mg/l) resulted in a substantial boost in growth rates and photosynthesis when compared to untreated plants. When plants were sprayed with a 300mg concentration, the rise was more apparent.

Also (30) Discovered that spraying salicylic acid on *Thymus vulgaris* L. at three different levels (150, 300, and 450) mMol had a substantial influence on the characteristics examined. Spraying at a concentration of 150mM enhanced the dry weight of the vegetative biomass and photosynthesis, as well as the plant's resistance to salt stress. There was a substantial advantage in all vegetative characteristics evaluated in the research on the response of the Indian mustard *Brassica juncea* L. to spraying with two doses of salicylic acid (35 and 70mg) (plant height, number of branches, and leaf area). Furthermore, spraying the plants at a dosage of 70 mg/l resulted in a substantial increase in all crop parameters (the weight of one mustard seed, the total yield of the seed, and the seed yield) as compared to spraying with distilled water alone at a concentration of 35 mg/l. (31). Furthermore (32) discovered that salicylic acid spraying with concentrations of 50 and 75 mg/l had a significant influence on most investigated characteristics in a study done in Pakistan on the *Abelmoschus esculentus* L., which belongs to the marsh family. Spraying at a concentration of 50 mg/l has a greater impact on boosting vegetative growth rates and leaf content than chlorophyll.

Also, (33) found that spraying the growth regulator salicylic acid on Niggella sativa L. at various concentrations (50, 100, and 200 mg/l) had a significant influence on the characteristics examined. Also, 200mg/l. spraying at a 50mg/l concentration resulted in the highest growth, yield, and oil ratio indices. In a study on the effect of spraying on some of the growth catalysts on *Datura stramonium* L. (34, 29) Discovered that spraying with acetylsalicylic acid at 200ppm resulted in the highest rate of all vegetative and studied traits (plant height, dry and vegetative content of the leaves, nitrogen and potassium, number of fruits, plant, and total yield kg/hectare) when compared to non-treated plants,and (35) found that the effect of spraying with aspirin (acetylsalicylic acid) at a concentration of 70 ppm led to a significant increase in the yield of seeds with a percentage of 49.3% and a percentage of protein in seeds 16.19% and a harvest index rate of 27.72%. .

The results of the effect of spraying with acetylsalicylic acid at a concentration of 20-40ppm that was carried out by (36) showed that it led to a significant increase in the number of pods, seed yield, average seed weight, biological yield, harvest index and protein percentage in pea yield compared with untreated plants, as indicated by a study (37) showed that the effect of spraying with aspirin (acetylsalicylic acid) on the yellow corn yield led to an increase in the number of kernels by 2.66%, the number of grains 19.43%, the weight of the kernels 23.45%, and the percentage of oil 38.67 % compared to untreated plants when concentrations 30 and 70 ppm were used. Salicylic acid is one of the plant hormones that have a phenolic nature and that works to regulate ion uptake, hormonal balance and stomata movement (38), as indicated by (39) that the addition of salicylic acid 100 mg / liter leads to an increase in the content of chlorophyll in Leaves and increase and improve vegetative growth characteristics, salicylic acid is added through the leaves (40) or soaking the seeds with it (41). One of the important roles in regulating the absorption of nutrients and increasing their transport during the stages of floret formation and fullness of grain is that it gives plants a strong root system and better growth that is able to extend the plant with the necessary nutrients from the soil (42), which is reflected in its effect on accelerating germination, flowering, and maturation.

Also, (35) showed that the effect of spraying with acetylsalicylic acid at a concentration of 70 ppm was significantly superior to the relative water content of 10.7% and in reducing the rate of the number of flowering inflorescences by 24.9%, and indicated that it significantly reduced all the negative effects resulting from the effect of drought in all the studied traits, especially at the concentration of 70 ppm. Furthermore, (35) found that spraying with acetylsalicylic acid in pea growth at concentrations of 20 and 40 ppm increased the plant height, the speed of crop growth, the relative growth rate of leaves, the number of leaves, leaf area, leaf area ratio, and the representative efficiency rate of the plant compared with the comparison plants. And (37) found that spraying with acetylsalicylic acid (aspirin) had a significant effect on increasing the rates of most of the studied traits in the yellow corn crop, especially at a concentration of 30 ppm. The plant height increased by 6.17%, the number of leaves was 6.46, the dry weight was 48.52%, and the chlorophyll content was 48.52%, 67.29% and the leaf area 9.11%. Exogenous administration of salicylic acid increased photosynthetic rate while maintaining membrane integrity, resulting in better barley plant development (41).

According to (43) the application of 0.07 mmol SA resulted in the maximum grain production. It's thought that increased crop production is attributable to plant organs (especially leaves and flowers) delaying senescence in response to exogenous salicylic acid (44). Furthermore, (45) demonstrated that phytohormones enhance the degree of sink at the seed level, directing metabolite flow to growing seeds, resulting in an increase in seed mass and seed production per plant at harvest. According to (46) foliar application of SA had a beneficial influence on early production and total yield, and the maximum yield was seen in the 0.50 mM SA treatment, which was also suggested to increase output.

1.3. The Importance of Salicylic Acid to Wheat Production

When sprayed on wheat, salicylic acid enhanced the activity of antioxidant enzymes including catalase, peroxidase, and superoxide dismutase (47). Plant growth regulators manage plants' physiological and biochemical reactions, as well as their internal components and execute significant modifications that result in changes in nutritional and environmental effects linked with growth and development (48). In addition to their regulatory functions in root growth and development, the yield and yield components of these chemicals are well recognized (49). Salicylic acid has been reported to enhance salt tolerance in wheat seedlings (50). There are some reports that mention salicylic acid could increase drought stress tolerance in wheat seedlings (51). Plants' biochemical and physiological reactions to salicylic acid have been studied (47). Under various levels of drought stress, wheat cultivars treated with salicylic acid produced better final yields, and wheat seed priming with 0.5 mmol salicylic acid resulted in a high germination percentage when compared to control (51).

Salicylic acid treatment of wheat seedlings resulted in larger seeds, increased seed weight, and increased overall yield (39). Exogenous administration of salicylic acid increased photosynthetic rate while maintaining membrane integrity, resulting in better barley plant development (52). Salicylic acid reduced the amount of active oxygen species in the roots of early wheat seedlings, lowering the activities of superoxide dismutase (SOD) and peroxidase (POX) (53). Also, (54) found that plants treated with salicylic acid growth stimulant from black wheat at a concentration of 60 mg/L outperformed the average weight of 1000 seeds and the harvest index, while the concentration treatments 90 mg.L excelled with the highest seed yield per plant. Moreover, Furthermore (54) demonstrated that plants treated with the growth stimulant salicylic acid at a concentration of 60 mg/L increased plant height and the number of leaves per plant significantly. Also, the plants were treated with the acid at a concentration of 90 mg.L did not lower at a significant rate for the number of days up to the stage of 50% flowering. While treatments with the same concentration achieved the highest average dry weight of 9.29 g when using three levels of 30, 60, and 90 mg/l on black wheat. When sensitive and tolerant wheat cultivars were cultivated under water scarcity circumstances, salicylic acid increased their productivity and yield components and the impact was caused by SA's influence on proline buildup, which might serve as an osmolyte as well as a ROS scavenger (55).

The capacity of salicylic acid to counteract the negative effects of water deprivation on cell metabolism has a substantial impact on wheat development under drought, and the acid-induced improvements in dry matter buildup and yield during drought were attributed to increased chlorophyll content and photosynthetic rate, as well as enhanced Rubisco activity (56). Salicylic acid induced drought resistance in 'Hassawi' wheat was shown to be due to its stimulatory impact on the synthesis of soluble carbohydrates and proteins, which are involved in osmotic adjustment, which reduces the negative effects of water deficiency on plants, according to (57).

Salicylic acid treatment enhanced wheat production under stress circumstances by eliciting drought resistance through an osmotic adjustment mechanism and a decrease in membrane damage (58). Germination and seedling growth were improved when wheat grains were treated with a pre-sowing salicylic acid seed-soaking treatment (53).In a pot experiment, (59) sprayed salicylic acid on the foliage of wheat plants irrigated with Mediterranean sea water and reported increased productivity due to improvements in plant height, number and area of green leaves, stem diameter, and dry weight of stem, leaves, and the plant as a whole. During the cold hardening stage, salicylic acid-induced increases in the activity of some antioxidant enzymes have also been seen in wheat plants (60). Also, (61) found that foliar application of salicylic acid increased the amount of chlorophyll in common wheat plant leaves.

1.4. The Role of Salicylic Acid in Drought Tolerance of Plants

Treating the plant with salicylic acid is one of the projects and solutions to fight the drought phenomenon in the dry and semi-arid regions of the world, increasing the plant's resistance to conditions of stress (55). The tolerance of water stress is the ability of the plant to maintain its metabolic activity despite a decrease in the water stress, by maintaining the full or partial (turgor pressure) in a way that ensures the reduction of its osmotic stress through the accumulation of dissolved substances (62) which is part of it harmless organic substances, even if they are found in high concentrations, such as the amino acid (proline) and organic acids such as (dissolved carbohydrates), but there are mineral substances that may be harmful to the ovum of the cell if they are found in high concentration, such as potassium, sodium and chlorine (63), and drought stress is considered one of the most influential environmental factors in plants, as it leads to reduced vegetative and reproductive growth, inhibition of photosynthesis and carbon metabolism, an imbalance in nitrogen metabolism, and an increase in the production of Reactive Oxygen Species (ROS), which works to destroy proteins and cell membranes (64, 65).

Salicylic acid also has the ability to inhibit proteolysis by free radicals caused by stress, and works to snipe and inhibit the enzyme Lipoxygenase, which degrades proteins when water is deficient due to stress, and the positive effects of stress Salicylic acid is an increase in the seed carrier in natural and stress conditions, an increase in the percentage of oxygen and a decrease in abscisic acid ABA (66), and one of its physiological roles is its inhibition of the formation of abscisic acid ABA and has the ability to bind with amino acids and give plants systemic acquired resistance SAR is considered one of the most important non-enzymatic antioxidants that has a role in scavenging reactive oxygen species (ROS) that oxidize cells and enzymes and lead to inhibition of photosynthesis and plant aging. It also has a role in controlling stomata movement and reducing evaporation from leaf surfaces and the modification of leaf osmosis for water withdrawal by roots upon drought (67), as recent studies have confirmed its role in increasing plant stress tolerance and improving growth and yield traits (68, 69), and that salicylic acid has a role in linking with amino acids such as arginine, which is one of the sources of proline in the plant and increasing the absorption of mineral elements such as phosphorous (70).

Salicylic acid has a role in the activity of nitrogen metabolism and increases the effectiveness of the enzyme nitrate reductase, as nitrogen metabolism is one of the factors affecting the accumulation of proline acid, and contributes to an increase in the proportion of gibberellins, which have a role in the flowering process through its union with anthesin and the production of the flowering hormone (Florigen), which has a role in inducing flowering (71), and it also provides the plant with energy and water and increases the percentage of the enzyme Catalase, which has the ability to analyze 1000 hydrogen peroxide molecules per second and convert them into a water molecule and works in the occurrence of the Water-Water Cycle phenomenon, which is a mechanism of the physiological important in converting toxic hydrogen peroxide into water, which helps the plant carry out vital functions during the drought period. (72).

1.5. The Importance of Zinc as Microelement to Plant

Zinc (Zn) is a microelement that plays an important part in plant critical functions including metabolism and feeding (73). Wheat is sensitive to zinc deficiency, but less sensitive to iron and copper deficiencies (74). Crops' intense consumption of minerals has resulted in fast depletion of micronutrient reserves, especially zinc, in the soil, resulting in micronutrient shortages (75). Micronutrients including zinc have a role in increasing the efficiency of the transfer of photosynthetic products from the places of manufacture (source) to the rest of the plant parts (10), which prompted researchers to add spraying solutions in the form of solutions to the vegetative parts of crops (76) that spraying such solutions for these nutrients can provide most of the crop's requirements, especially in critical growth stages, which the roots may be unable to supply (77, 78). Also, (79) found that zinc sulfate treatment enhanced dry matter, leaf, and grain zinc accumulation in maize plants. Zinc is an essential element for human, animal, and plant biological systems. It is important for the integrity of cellular membranes, enzyme activation, and protein synthesis in plants (80). Furthermore (81) discovered that adding micronutrients to wheat at later stages of development boosts biological yield substantially.

1.6. Zinc's Role in Plants and Its Impact on Physiological Character

Plant zinc is an essential element for plant development and functions as a metal component as well as a functional, structural, or regulatory cofactor in a variety of enzymes. Plant enzymes triggered by zinc are involved in glucose metabolism, cellular membrane integrity, protein synthesis, auxin production control, and pollen development (82). Some plant life processes, such as nitrogen absorption and metabolism, photosynthetic synthesis, tolerance to biotic and biotic stressors, pollen function, and fertilization, are influenced by zinc (83, 84, 85). Furthermore, zinc influences hydrogenates and carbonic anhydrase activity, ribosomal fraction stability, and cytochrome production in plants (86). Also, it is necessary for the control and maintenance of gene expression in plants that allows them to withstand environmental stressors (87).

Zinc appears to impact plant water absorption and transport capacity, as well as decrease the negative effects of heat and salt stress over brief periods of time (88, 89, 90). Zinc is essential for cellular membrane integrity in order to keep macromolecules and ion transport systems in their structural orientation. Its interaction with phospholipids and the sulfhydryl groups of membrane proteins helps to keep membranes in good shape (91, 92, 93). Zinc is crucial for decreasing reactive oxygen species (ROS) production and protecting cells against ROS assault, but a lack of zinc can cause greater levels of ROS, which can harm plants (87). In addition, zinc application relieved salt and cadmium stress in plants (90). Zinc is also involved in important metabolic activities like respiration, photosynthesis, and nutrition absorption that are necessary for the activation of enzymes. When these types of components are combined with other elements like N and K, their efficiency improves (94 and 95). According to (96) zinc has a significant impact on basic plant life processes such as (a) nitrogen metabolism–nitrogen uptake and protein quality; (b) photosynthesis–chlorophyll synthesis, carbon anhydrase activity; and (c) photosynthesis–chlorophyll synthesis, carbon anhydrase activity; plants with a zinc deficiency of 5.8% drastically reduce the rate of protein synthesis and protein content. It is required for membrane integrity as well as photochromic activity (97).

Zinc is needed for the synthesis of tryptophan, which is a precursor to indole acetic acid, as well as the creation of auxin, an important growth hormone (91 and 98). It is necessary for the activation of enzymes, although plants require a little quantity of zinc, and if there isn't enough of it, they will experience physiological stress as a result of inefficient enzyme systems and other metabolic activities connected to zinc (99, 100). Dry matter production, which enhanced photosynthetic product synthesis, transport, and accumulation at the grain production site, is also responsible for the rise in flag leaf area and chlorophyll content, probably due to foliar application of zinc (101). Zinc, as an essential mineral, plays an important function in stomatal control and decreasing water tensions in plants by restoring ionic equilibrium (102). It is involved in a number of physiological activities, including protein and glucose synthesis (9).

1.7. Zinc in Wheat Plants and Wheat Seed Components

Improving the zinc (Zn) content of wheat and its processed meals is a good method to address human Zn insufficiency, which can cause a variety of diseases (103). It is a blue-white metal element that makes up 0.02% of the earth's crust and is the world's twenty-third most abundant element (104). Zinc is an important trace element for human, animal, and plant growth and development (105, 106, ,107). Wheat is one of the most important grains in the world, providing about 20% of calories and protein per capita (108). As a result, increasing daily zinc intake through wheat-derived processed foods is a critical component in overcoming the zinc shortage. Wheat processing is another major aspect that can have a significant impact on people's real zinc intake, as the aleuronic and bran layers of wheat are often eliminated during processing. Different wheat processing processes also result in a significant loss of zinc (109). The grain of wheat is divided into three parts: bran, embryo, and endosperm, which account for 14–16, 2–3, and 81–84 percent of the grain, respectively (110). Wheat peeling is the separation of the endosperm and bran from wheat before grinding it into flour (111). The findings revealed that zinc was contained mostly in the cortex and embryo of wheat grains. For example, the zinc concentration of bran was around three times that of endosperm (112, 113) and after milling, it's around six times greater than it is in flour (114, 115).

Additionally, phytic acid concentration and the molar ratio of phytic acid to zinc, both of which might impact zinc absorption, are significant elements to consider (103). Foliar zinc treatment is a cost-effective way to increase production and grain zinc content by three or four times (83). The average concentration of zinc in whole grain wheat in various nations is between 20 and 35 mg kg1, according to a variety of reports and survey studies (116, 83,117). The embryo and aleurone layer contain the majority of the seed-Zn, but the endosperm has arelatively low zinc content (118). Under field circumstances, zinc fertilizers can enhance grain zinc content up to fourfold depending on soil conditions and application method (8,117). Wild and primitive wheat are a better and more promising genetic resource for high zinc concentrations than farmed wheat. However, little is known about the genetic control and molecular physiological mechanisms that contribute to high zinc and other micronutrient accumulation in grain from various genetic materials (119, 120,121). Zinc concentrations in the embryo and aleurone layer of wheat seed were reported to be about 150 mg/kg in zinc-staining research, but only 15 mg/kg in the endosperm (118). When foliar zinc was sprayed during the flower stage compared to before the flowering stage.

Also, (118, 12, 122) found that the greatest zinc concentration in wheat grains was attained. According to (123), foliar zinc treatment during the primary grain filling period enhanced grain zinc content by 82.9 percent and zinc utilization efficiency by 49 percent, respectively, when compared to early stages. Furthermore, (12) found that when zinc was administered four times (stem elongation + booting + milk + dough phases), the greatest grain zinc concentrations were attained. Basis of the results, zinc foliar application appears to be a viable strategy for increasing grain zinc content, although its efficacy may be influenced by a number of factors, one of which is the foliar zinc application's growth stage (124). When zinc-deficient soils are utilized to cultivate cereals, the availability of zinc in the grain is greatly reduced. To enhance the Zn status in wheat grains, it is necessary to maintain an acceptable level of Zn and water in the soil during the reproductive stage of wheat (125).

1.8. The Effect of Zinc on Field and Quantitative Character

Zinc deficiency has a negative impact on agricultural yield since it is an important element. It is widely assumed that a zinc-deficient soil will have a negative impact on early vigour, chlorophyll content, photosynthesis, and carbonic anhydrase activity, resulting in a dramatic loss in crop production (126 , 127). Under conditions of a zinc shortage, grain yields have been lowered by up to 80%, and grain zinc density has been reduced (128). A lack of zinc causes a significant reduction in wheat yield and grain nutritional quality (129).

Zinc foliar application may enhance biomass production because of its indirect participation in photosynthetic, metabolic, and physiological activities, all of which show its significance in obtaining greater yields (130). Furthermore, (131) believes that foliar zinc spraying enhances flag leaf area by increasing the length and breadth of leaves when auxin levels rise. Application of zinc is also important in root development, protein and carbohydrate synthesis, and flower formation (132). Foliar Zn application decreases micronutrient deficits and is an effective approach since minerals are quickly absorbed by leaves. It is also the best choice for compensating micronutrient deficiencies in rain-fed areas in a shorter amount of time (133). The mixed soil treatment of microelements zinc and boron deficient soils considerably improved root length, plant height, leaf area index, shoot and root dry weight, and chlorophyll content (134).

Many researchers have indicated that zinc deficiency is the most prevalent for cereal crops, especially wheat; therefore, zinc application is important in increasing the grain and straw yield of many types of wheat (135, 129). Also, (8) indicated that the number of spikes in m^2 is the component of the yield most affected by the addition of zinc, especially the method of adding to the soil and when adding to the soil and spraying together. As for the number of grains in the spike of the wheat crop, it was found that the development of pain and pollen grains in wheat plants, which are the main organs in the process of holding grains, have been greatly damaged as a result of zinc deficiency, and this damage may be due to a decrease in the levels of indole acetic acid and protein which enters zinc in the process of assimilation (136, 137). The weight of 1000 grains is one of the main components of the yield, as it is significantly related to the grain yield also, and the weight of 1000 grains increased significantly as a result of adding zinc (138, 8). According to (139), foliar zinc treatment reduced the negative effects of water shortage on wheat output. However, zinc fertilizer was advised for maize plants that were irrigated or received enough water (140). Also, (141, 142) discovered substantial variations in growth characteristics, grain yield and yield components, and grain Zn and Fe content and quality in response to zinc treatment among wheat cultivars and genetic diversity. Stunted growth, chlorosis, and reduced leaves, as well as spikelet sterility, are all signs of zinc deficiency in plants (143).

Zinc deficiency also affects the quality of agricultural crops, making plants more susceptible to damage from high light or temperature intensity, as well as infection by fungal diseases (82, 87). Nearly half of the world's cereal-growing areas have soils with low zinc plant availability (144, 145). Their absence has a significant impact on both the quantity and quality of plant products (146). They are only required in trace amounts, but a sufficient supply of zinc improves nutrient availability and has a positive impact on cell physiology, which is reflected in yield (147).

Foliar zinc application increased the wheat grain number per spike and enhanced the seed yield and oil percentage of corn, according to the findings (148, 149). According to (150), foliar zinc application had no effect on wheat grain yield in the absence of drought, but enhanced grain yield (15%) and raised grain zinc concentration in the presence of drought. Furthermore (151) discovered that when wheat plants were drought stressed, soil zinc deficiency stress became more pronounced; when zinc was adequately supplied, irrigation's effect on grain yield was maximized.

Zinc is applied foliarly to enhance grain yield and protein proportion in wheat seed (152), according to them, the effects of zinc on the amount of chlorophyll and the concentration of abscisic acid enhance wheat production and its components. Also, (139) discovered that foliar zinc treatment and irrigation had a substantial impact on wheat development and yield contributing characteristics. Zinc treatment increased grain weight by 1000 grains, possibly due to zinc's strong phloem mobility from leaves to roots, stems, and developing grains (116). Also, (153) found that when zinc is applied to wheat, the weight of 1000 grains rises substantially.

1.9. The Effect of Zinc on Qualitative Character

Treatment of zinc foliar application or fertilizer to the soil has been demonstrated in several studies to be one of the most successful and productive strategies to enhance cereal grains (154). Spraying plants with zinc at the right time is an important factor determining the efficiency of the zinc foliar application in raising grain zinc content (77), as he showed that when foliar zinc fertilizers are given to plants at a late stage of development, significant increases in zinc loading into grain are predicted. Moreover (118) investigated variations in zinc content in wheat grains during the reproductive cycle and discovered that the maximum zinc concentration occurs during the milk stage of grain development. Also, (155, 141, 156) reported that foliar zinc treatment had a substantial beneficial influence on wheat grain production and its components, as well as grain quality. One of the most important variables affecting the protein content of wheat grain is the nutritional condition of the plant (157). In winter wheat, the element zinc is recognized to have a key role in grain protein synthesis and nitrogen absorption (111). Zinc has an impact on the structure of monomeric proteins, the composition of high molecular weight glutenin subunits, and the proportions of glutenin and gliadin in total proteins, all of which have an impact on wheat quality (115). The protein content of wheat flour might be improved by increasing the amount of zinc available in the soil (158).

2. AIM AND SCOPE OF THE STUDY

This study aims to evaluate the effects of salicylic acid and zinc foliar applications on the physiological characteristics, productivity, and quality of the wheat crop.

A shortage of water sources due to the low rainfall in Iraq and the region and a drop in the water level in rivers negatively affect growth and productivity indicators, which result in reducing the size of the plant, the leaf area, and the lack of yield. Also, among micronutrients, zinc deficiency is most common and widespread in wheat-growing regions as it is one of the micro-nutrients necessary for plant growth and completion of its life cycle. In addition, zinc deficiency is one of the widespread nutritional problems in Iraq and the region, so it is necessary to introduce new technology for seedling crops.

Plant breeders and farmers are racing against the clock, as the world's population continues to rise at a rapid rate, necessitating more food in exchange for shrinking amounts of arable land. Climate change, on the other hand, is posing a growing number of issues. During the growing seasons, temperature and greenhouse variables have impacted some new places, bringing drought and pests from one agricultural area to another. With the world's population growing, many scientists and researchers are researching non-traditional methods to increase agricultural production, as the world's first source of food, through the use of modern technologies to accelerate the growth of agricultural crops, and the introduction of some modifications to give it a greater ability to resist diseases and adapt to changing environmental conditions. Cereal crops are of fundamental importance in human life, as most of the world's population depends on grain for their food, which is estimated at more than 90% of the world's total population, and wheat is one of the basic crops in providing food. Therfor, research aims to find ways and ways to develop the cultivation of this crop.

Growth regulators and microeliments, have a significant role in the physiological processes that are related to plant growth and its final outcome. The growth and formation of the plant does not happen randomly, but rather it is controlled by plant hormones that make the plant sensitive to its environment and interact with it in order to reach a state of balance between the available growth factors for the plant and what carries predetermined genetic factors. Also, microeliments are important for the proper growth and development of crop plants. Therefore, the purpose of this treatment is to determine the effect of different concentrations of salicylic acid and zinc on some vegetative traits and the yield of grain and wheat seed quality.

3. MATERIALS AND METHODS

3.1. Conducting Places

The experiment was conducted in the fields of the Sulaimani Agricultural Research Center in the Bakrajo/Sulaymaniyah Governorate which is located at northern Iraq in the reign place category with the coordinates from GPS of 35° 32' 30" N and 45° 21' 00" E. and 745 meters above sea level. Cultivar (Sulaimani 2) was used in this study, which is soft wheat approved in Iraqi agriculture and one of the best bread wheat cultivar among farmers in iraq. The physical and chemical properties of the field soil are shown in Table (1). The experiment was carried out during the agricultural season 2020/2021. The amount of rain that fell this year in experiment place reached 378.7 mm, but the annual average rain fall in the region is 500 mm-750 mm.

Table 1. Soil texture in depth 0-26 cm

Soil texture	**Silty Clay**
Sand	4.23%
Silt	48.84%
Clay	46.93%
PH	7.88
EC ($ds.m^{-1}$)	0.18
N%	0.22
Zn (mg/kg)	280.0
Mn (mg/kg)	4.0
Available P (ppm)	9.162
Soluble K+ (mmol/l)	0.053
Soluble Ca+ (mmol/l)	1
O.M (mg/kg)	11.5

3.2. Agricultural Operations

The land was plowed with a digger plow (minimum tillage) and twice perpendicular, leveled and smoothed. The physical and chemical analysis of the field soil, which is indicated in Table (1), was conducted, mixing the seeds with the raxel pesticide for the purpose of combating smut. 350 grains were planted in each of the experimental unit lines, and the planting was carried out on 12/07/2020. NPK fertilizer (**15**: **15**: **15**) was added at a rate of 20 g per line by adopting 200 kg/ha for the purpose of reaching the fertilizer equally to the plants. Nitrogen fertilizer was added at a rate of 80 kg/ha (%N 46) at the beginning of the branching, all other agricultural operations of weeding and bush control were carried out in accordance with the recommendations of planting the crop.

3.3. The Design Used in the Experiment

A factorial design (R.C.B.D) randomized complete block design was used and with three replicates. Each replicate contains twelve experimental units on which the factorial coefficients are randomly distributed to match the studied factors. Each experimental unit contains six lines, the length of the line is 5 m, the distance between one line and another is 0.2 m. The area of the experimental unit is (6 x 0.2m x 5m = 6 m2). But four lines of them was harvested, so the harvested area was 4 m^2

3.4. Studied Factors

The first factor was spraying wheat plants with salicylic acid at four concentrations at the beginning of the tiller stage.

S0=zero	S2=200 ppm
S1=100 ppm	S3=300 ppm

The concentrations of salicylic acid were determined by dissolving 1 g of salicylic acid with ethylene alcohol and completing the solution to a liter by adding distilled water due to the difficulty of dissolving it directly with water and diluting the solution to the required concentration according to the equation

V1 * N1 = V2 * N2

Where N1 is the concentration of the original solution, and V1 is the volume of the original solution.

At the beginning of the tillering stage, the shoots were sprayed with salicylic acid at the specified concentrations immediately after preparation in the morning by a pressure sprayer on the plant until complete wetness. As for the control treatments, they were sprinkled with distilled water only.

The second factor spraying wheat plant with zinc (Zn) at the three concentrations at booting stage.

Z0=zero

Z1=50 ppm

Z2=100ppm

The zinc concentrate was dissolved in the form of zinc sulfate $ZnSO_4$ directly in distilled water. At the booting stage, the shoots were sprayed with zinc at the specified concentrations immediately after preparation in the morning by a pressure sprayer on the plant until complete wetness. As for the control treatments, they were sprinkled with distilled water only.

3.5. Studied Characters

For trait measurements, ten plants from each cultivar were chosen at random.

3.5.1. Physiological Characteristics

- **Plant Dry Matter (g/plant)**

It was measured by taking the parts of the sample (leaves, stems and ears) in the flowering stage. 10 plants per plot were dried at a temperature of 65 ° C for 48 hours until the weight was stable and converted to the weight of one plant.

- **The Percentage of Dry Matter**

It was the percentage of wet weight of plant before drying dividing by dry weight of it after drying in the flowering stage according to the following equation:

$$percentage\ of\ dry\ matter = \frac{dry\ weight}{wet\ weight} \times 100$$

- **Relative Growth Rate RGR (g/g/day)**

Relative growth rate RGR (g.g.day) according to (159) Calculate the relative growth RGR for a sample of plants in the time of difference between the first taking (flowering stage) and second taking sample (physiological maturity according to the following equation

$$RGR = \frac{lnw_2 - lnw_1}{T_2 - T_1}$$

Lin w1: natural logarithm of dry matter weight in time T1

Lin w2: natural logarithm of dry matter weight in time T2

(T2-T1): the differences of time by day between the time of taking first dry weight (T1) and the time of taking second dry weight (T2).

- **Chlorophyll Content in Flag Leaf**

It was estimated at the completion of flowering stage of flag leave of the main branches as an average of ten plants from each experimental by using the SPAD 502 device (160).

3.5.2. Agronomic Characteristics

- **The Area of the Flag Leaf (cm^2)**

Flag leaf area was calculated from the flag leaf of the main stems as an average of ten plants at the completion of the flowering stage of each experimental unit. Leaf area of wheat crop can be measured according to (161) equation.

The area of the flag leaf (cm^2) = the length of the leaf (cm) x the maximum width of the leaf (cm) x 0.95.

- **Plant Leight (cm)**

The height of the plant (cm) (from the surface of the soil to the end of the spike without the awn) and it was calculated for the main tillers as an average of ten plants after reaching the stage of full flowering.

- **Spike Length (cm)**

The length of the spike was measured from of first basal spikelet to the top of spike without awn**.**

- **Number of Spike in (m^2)**

It was calculated after the stems formed on plants and for a distance of one meter in the stage of completion of flowering from all experimental units and then converted to an area of square meters in proportion

- **Number of Spikelets in a Spike**

Calculate as an average of ten spikes from each experimental unit randomly.

- **Number of Grain in Spike**

Calculated by taking ten spikes from each experimental unit, and the spike rate was calculated after threshing them by hand, counting them, and then returning them to the sample yield.

- **Weight of (1000) Grains (g)**

A random sample consisting of 1000 grains was taken from the grain yield of each experimental unit and its weight was measured using a sensitive electronic scale.

- **Grain Yield kg/ha**

Grain yield per unit area (kg/ha) was estimated from the sum of the area of the four harvested middle lines (4 x 5 m x 0.2 m = 4 m2) and converted to kg/ha.

- **Biological Yield kg/ha**

It is the weight of the total dry matter after harvesting (ears + straw), for the area of the four middle lines (4 x 5 m x 0.2 m = 4 m2) and converted to kg/ha.

- **Harvest Index**

It was calculated according to this equation.

$$HI = \left(\frac{GY}{DM}\right) \times 100$$

HI: harvest index

GY: grain yield kg.ha^{-1}

DM: total dry matter yield (grain + straw) kg.ha^{-1}

3.5.3. Qualitative Characteristics

- **Hectoliter**

It was obtained by laboratory devices for calculating hectoliters by taking the amount of grain yield of each experimental unit.

- **The Protein Content in Grain**

It was calculated using laboratory instruments that took the amount of grain yield of each experimental unit to calculate the protein content.

Not. All statistical analyses were performed using the ready-made program (SPSS statistic 26.0.0). The data was statistically examined using a two-way analysis of variance (ANOVA). The post-hoc test was Duncan. The confidence intervals are 95.0% and the significance level is 0.5. The Mean Square of all variables is shown in the table (Appendix 1, 2, and 3).

4. RESULTS

Results of foliar application of salicylic acid and zinc show positive on all studied characters. Most of them are significantly superior, while some studied characters are superior but not significantly so, according to the F test, as indicated in tables (2, 3,... 17) and details below.

The activation treatment (S3), which is the highest concentration of salicylic acid, was significantly superior to the other activation treatments in terms of relative growth rates, chlorophyll content of the flag leaf, spick length, the number of spikelets in the spike, the number of grains in the spike, weight of 1000 grains, the number of spikes in (m^2), biological yield, grain yield, protein content of grain and hectoliter. While it is also superior to the other activation treatments in terms of plant dry weight, dry weight percentage, plant height and harvest index, it is not significantly so. And the activation treatments (S2 and S1) had positive effects and were superior in most studied characteristics compared to the non-sprayed treatments, as shown in the tables (Appendix 1, 2, and 3).

The zinc spraying treatment (Z2), which was the maximum zinc concentration, was significantly superior to the other activation treatments in the relative growth rates, plant height, spick length, the number of spikelets in the spike, the number of grains in the spike, weight of 1000 grains, biological yield, grain yield, protein content of grain, and hectoliter. However, it is superior but not significantly to the other activation treatments in dry weight of plant, dry weight percentage, and harvest index. Also, activation treatment (Z1) had a positive effect and was superior in most studied characteristics compared to non-activation treatment, as shown in the tables (Appendix 1, 2, and 3).

The interaction between the foliar application of salicylic acid and zinc also showed a positive effect in most studied characters, especially in (S3Z2) treatments, which reached the highest level compared to all other arithmetic averages and gave a grain yield.

4.1. Weight of Dry Matter

The results of the analysis of variance in table (Appendix 1) show when spraying treatments with different concentrations of salicylic acid and zinc, and the interaction between them did not have a significant effect on the weight of the dry matter, while we notice positive effects when increasing both concentrations of salicylic acid and zinc.

Table 2. The effects of salicylic acid and zinc, as well as their interactions, on dry matter yield (g/plant).

Zn / SA	Z0	Z1	Z2	Effect of SA
S0	7.14 ab	7.04 ab	7.34 ab	7.18 b
S1	6.85 b	7.74 ab	7.67 ab	7.42 ab
S2	7.37 ab	7.26 ab	7.67 ab	7.43 ab
S3	7.51 ab	7.77 ab	7.93 a	7.73 a
Effect of Zn	7.22 b	7.45 ab	7.65 a	

With regards to the effect of salicylic acid in table (2), the highest level shown in (S3) that was treated with (300 ppm) and for zinc's effect, the highest level shown in (Z2) that was treated with (100 ppm). Also, the interaction between them (S3Z2) is superior compared to others.

4.2. Percentage of Dry Weight

The results of the analysis of the variance in table (Appendix 1) discovered that spraying treatments with varied concentrations of salicylic acid and zinc had no significant impact on the percentage of the dry matter.

Table 3. The effects of salicylic acid and zinc, as well as their interactions, on percentage of dry matter

Zn / SA	Z0	Z1	Z2	Effect of SA
S0	30.65 abc	30.36 abc	29.79 abc	30.27 a
S1	28.85 c	29.19 bc	31.55 a	29.86 a
S2	30.33 abc	30.37 abc	31.07 abc	30.59 a
S3	30.37 abc	31.13 ab	31.29 ab	30.93 a
Effect of Zn	30.05 a	30.26 a	30.92 a	

With regards to the effect of salicylic acid in table (3), the highest level shown in (S3) that was treated with (300 ppm) and for zinc's effect, the highest level shown in (Z2) that was treated with (100 ppm). While the highest level of the interaction between them is shown in (S1Z2).

4.3. Relative Growth Rate

The results of the analysis of variance in table (Appendix 1) show that spraying with salicylic acid and zinc had a significant effect on the relative growth rate, which gives an indication that the applications both affected the accumulation of dry matter during the period of wheat plant growth until physiology maturity. However, the interaction between them did not reach the level of significance according to the F test.

Table 4. The effects of salicylic acid and zinc, as well as their interactions, on relative growth rate (g/g/day)

Zn / SA	Z0	Z1	Z2	Effect of SA
S0	0.0060 b	0.0077 ab	0.0077 ab	0.0071 b
S1	0.0073 ab	0.0073 ab	0.0077 ab	0.0074 b
S2	0.0070 ab	0.0083 a	0.0090 a	0.0081 ab
S3	0.0080 ab	0.0090 a	0.0087 a	0.0086 a
Effect of Zn	0.0071 b	0.0081 a	0.0083 a	

With regards to the effect of salicylic acid in table (4), the highest level shown in (S3) that was treated with (300 ppm) and for zinc's effect, the highest level shown in (Z2) that was treated with (100 ppm). While, the interaction between them (S2Z2) and (S3Z1) are superior compared to others.

4.4. The Chlorophyll Content of the Flag Leaf

The results of the analysis of variance in table (Appendix 1) show that spraying with salicylic acid and zinc and the interaction between them had a significant effect on the content of the flag leaf of chlorophyll.

Table 5. The effects of salicylic acid and zinc, as well as their interactions, on the chlorophyll content of flag leaf

Zn / SA	Z0	Z1	Z2	Effect of SA
S0	43.03 c	44.60 abc	44.37 bc	44.00 b
S1	43.73 bc	44.97 ab	43.73 bc	44.14 b
S2	44.33 bc	45.40 ab	44.63 bc	44.36 ab
S3	44.60 abc	45.17 ab	46.30 a	45.36 a
Effect of Zn	43.93 b	45.03 a	44.76 a	

With regards to the effect of salicylic acid in table (5), the highest level shown in (S3) that was treated with (300 ppm) and for zinc's effect, the highest level shown in (Z1) that was treated with (50 ppm). Also, the interaction between them (S3Z2) is superior compared to others.

4.5. Flag Leaf Area (cm^2)

The results of the analysis of variance in table (Appendix 1) showed that the application of salicylic acid and zinc and the interaction between them had a significant effect on the area of the flag leaf.

Table 6. The effects of salicylic acid and zinc, as well as their interactions, on the flag leaf area (cm^2)

Zn / SA	Z0	Z1	Z2	Effect of SA
S0	36.10 c	37.13 abc	37.03 abc	36.76 b
S1	36.63 bc	36.63 bc	37.50 abc	36.92 b
S2	37.93 ab	37.53 abc	37.90 ab	37.79 a
S3	36.60 bc	38.63 a	38.47 a	37.90 a
Effect of Zn	36.82 b	37.48 ab	37.73 a	

With regards to the effect of salicylic acid in table (6), the highest level shown in (S3) that was treated with (300 ppm) and for zinc's effect, the highest level shown in (Z2) that was treated with (100 ppm). Also, the interaction between them (S3Z1) is superior compared to others.

4.6. Plant Height (cm)

It was found from the analysis of variance in table (Appendix 2) that the effect of spraying zinc was significant, while the spraying with salicylic acid and the interaction between them had no significant effect on this trait. However, increasing zinc concentrations has a positive effect on plant height.

Table 7. The effects of salicylic acid and zinc, as well as their interactions, on the plant height (cm)

Zn / SA	Z0	Z1	Z2	Effect of SA
S0	97.10 b	99.60 ab	99.60 ab	99.77 a
S1	99.33 ab	98.70 ab	99.60 ab	99.21 a
S2	97.27 b	101.23 ab	102.30 a	100.27 a
S3	98.77 ab	101.97 a	101.07 ab	100.60 a
Effect of Zn	98.12 b	100.38 a	100.64 a	

With regards to the effect of zinc in table (7), the highest level shown in (Z2) that was treated with (100 ppm). Also, the interaction between them (S2Z2) is superior compared to others.

4.7. Spike Length (cm)

The results of the analysis of variance in table (Appendix 2) showed that spraying wheat plants with salicylic acid and zinc and the interaction between them had a significant effect according to the F test on the length of spike.

Table 8. The effects of salicylic acid and zinc, as well as their interactions, on the spike length **(cm)**

Zn / SA	Z0	Z1	Z2	Effect of SA
S0	9.75 c	9.77 c	10.43 ab	9.99 b
S1	10.01 bc	10.26 abc	10.48 ab	10.25 ab
S2	10.22 abc	10.52 ab	10.78 a	10.51 a
S3	10.40 ab	10.57 ab	10.63 a	10.53 a
Effect of Zn	10.06 b	10.28 b	10.58 a	

With regards to the effect of salicylic acid in table (8), the highest level shown in (S3) that was treated with (300 ppm) and for zinc's effect, the highest level shown in (Z2) that was treated with (100 ppm). Also, the interaction between them (S2Z2) is superior compared to others

4.8. Number of Spike in (m^2)

The results of the analysis of variance in table (Appendix 2) showed that the foliar application of salicylic acid had a significant effect on the total number of spikes. While spraying of zinc and the interaction between factors did not reach the level of significance according to the F test.

Table 9. The effects of salicylic acid and zinc, as well as their interactions, on the number of spike in (m^2)

Zn / SA	Z0	Z1	Z2	Effect of SA
S0	416.33 a	425.67 a	421.67 a	421.22 b
S1	435.00 a	452.00 a	440.33 a	442.44 a
S2	430.66 a	438.33 a	443.33 a	437.44 ab
S3	437.00 a	454.00 a	454.00 a	448.33 a
Effect of Zn	429.75 a	442.50 a	439.83 a	

With regards to the effect of salicylic acid in table (9), the highest level shown in (S3) that was treated with (300 ppm) and for zinc's effect, the highest level shown in (Z1) that was treated with (50 ppm). While the highest level of the interaction between them is shown in (S3Z1) and (S3Z2).

4.9. Number of Spikelets in a Spike

The table of analysis of variance (Appendix 2) showed that the spraying with salicylic acid and zinc, and the interaction between them, had a significant effect on the number of spikelets in a spike

Table 10. The effects of salicylic acid and zinc, as well as their interactions, on the number of spikelets in a spike

SA \ Zn	Z0	Z1	Z2	Effect of SA
S0	20.54 c	20.57 c	21.82 a	20.97 b
S1	20.75 bc	21.11 abc	21.33 abc	21.07 b
S2	20.54 c	21.28 abc	21.72 a	21.18 ab
S3	21.49 ab	21.44 ab	21.88 a	21.61 a
Effect of Zn	20.83 b	21.10 b	21.69 a	

With regards to the effect of salicylic acid in table (10), the highest level shown in (S3) that was treated with (300 ppm) and for zinc's effect, the highest level shown in (Z2) that was treated with (100 ppm). Also, the interaction between them (S3Z2) is superior compared to others.

4.10. Number of Grains in a Spike

The results of the analysis of variance in table (Appendix 2) showed that the foliar application salicylic acid and zinc and the interaction between them had a significant effect on the number of grains in a spike of wheat.

Table 11. The effects of salicylic acid and zinc, as well as their interactions, on the number of grains in a spike

Zn / SA	Z0	Z1	Z2	Effect of SA
S0	52.35 e	53.50 de	56.15 abc	54.00 b
S1	53.55 de	54.28 cde	55.32 a-d	54.38 b
S2	53.86 de	54.44 bcd	56.44 ab	54.91 ab
S3	55.06 a-d	55.54 a-d	56.81 a	55.80 a
Effect of Zn	53.71 b	54.44 b	56.18 a	

With regards to the effect of salicylic acid in table (11), the highest level shown in (S3) that was treated with (300 ppm) and for zinc's effect, the highest level shown in (Z2) that was treated with (100 ppm). Also, the interaction between them (S3Z2) is superior compared to others.

4.11. The Weight of Thousand Grains (gm)

It was found from the analysis of variance in table (Appendix 3) that the effect of the application of salicylic acid and zinc, and the interaction between them, had significant effect on the weight of a thousand grains in wheat plants.

Table 12. The effects of salicylic acid and zinc, as well as their interactions, on the weight of thousand grains (gm)

Zn / SA	Z0	Z1	Z2	Effect of SA
S0	30.29 bc	30.68 bc	31.22 ab	30.73 b
S1	30.76 bc	30.49 bc	30.82 bc	30.69 b
S2	29.68 c	30.70 bc	31.32 ab	30.57 b
S3	31.15 abc	31.30 ab	32.53 a	31.66 a
Effect of Zn	30.47 b	30.79 b	31.47 a	

With regards to the effect of salicylic acid in table (12), the highest level shown in (S3) that was treated with (300 ppm) and for zinc's effect, the highest level shown in (Z2) that was treated with (100 ppm). Also, the interaction between them (S3Z2) is superior compared to others

4.12. Biological Yield (kg/ha)

It was shown from the analysis of variance in table (Appendix 3) that spraying wheat plants with salicylic acid and zinc had a significant effect on the biological yield, while the interaction between them had no significant effect.

Table 13. The effects of salicylic acid and zinc, as well as their interactions, on the biological yield (kg/ha)

SA \ Zn	Z0	Z1	Z2	Effect of SA
S0	13458 b	13333 b	13500 b	13431 b
S1	13500 b	13583 ab	14333 a	13806 ab
S2	13500 b	13958 ab	14333 a	13931 a
S3	13958 ab	13917 ab	14083 ab	13986 a
Effect of Zn	13604 b	13698 b	14063 a	

With regards to the effect of salicylic acid in table (13), the highest level shown in (S3) that was treated with (300 ppm) and for zinc's effect, the highest level shown in (Z2) that was treated with (100 ppm). Also, the interaction between them (S1Z2) and (S2Z2) are superior compared to others.

4.13. Grain Yield (kg/ha)

The results of the analysis of variance in table (Appendix 3) show that spraying wheat plants with salicylic acid and zinc and the interaction between them had a significant effect on the grain yield.

Table 14. The effects of salicylic acid and zinc, as well as their interactions, on the grain yield (kg/ha)

SA \ Zn	Z0	Z1	Z2	Effect of SA
S0	4300 e	4366 de	4506 cd	4390 c
S1	4562 abc	4457 cd	4548 bc	4522 b
S2	4386 de	4573 abc	4685 ab	4548 b
S3	4606 abc	4591 abc	4713 a	4637 a
Effect of Zn	4464 b	4497 b	4613 a	

With regards to the effect of salicylic acid in table (14), the highest level shown in (S3) that was treated with (300 ppm) and for zinc's effect, the highest level shown in (Z2) that was treated with (100 ppm). Also, the interaction between them (S3Z2) is superior compared to others.

4.14. Harvest Index

The results of the analysis of variance in table (Appendix 3) show that spraying treatments with different concentrations of salicylic acid and zinc did not have a significant effect on the harvest index.

Table 15. The effects of salicylic acid and zinc, as well as their interactions, on the harvest index

SA \ Zn	Z0	Z1	Z2	Effect of SA
S0	31.95 a	32.76 a	33.38 a	32.70 a
S1	33.45 a	32.83 a	31.80 a	32.89 a
S2	32.49 a	32.66 a	32.70 a	32.62 a
S3	33.00 a	33.05 a	33.60 a	33.22 a
Effect of Zn	32.73 a	32.82 a	32.87 a	

With regards to the effect of salicylic acid in table (15), the highest level shown in (S3) that was treated with (300 ppm) and for zinc's effect, the highest level shown in (Z2) that was treated with (100 ppm). While the highest level of the interaction between them is shown in (S3Z2).

4.15. Hectoliter

It was found from the analysis of variance in table (Appendix 3) that the effect of the application of salicylic acid and zinc, and the interaction between them, had significant effect on the wheat grain hectoliter

Table 16. The effects of salicylic acid and zinc, as well as their interactions, on the hectoliter

SA \ Zn	Z0	Z1	Z2	Effect of SA
S0	74.63 cd	75.20 bcd	75.73 abc	75.19 c
S1	76.07 ab	75.90 ab	76.30 ab	76.09 Ab
S2	74.40 d	76.33 ab	76.07 ab	75.60 bc
S3	76.17 ab	76.33 ab	76.77 a	76.42 a
Effect of Zn	75.32 b	75.94 a	76.22 a	

With regards to the effect of salicylic acid in table (16), the highest level shown in (S3) that was treated with (300 ppm) and for zinc's effect, the highest level shown in (Z2) that was treated with (100 ppm). Also, the interaction between them (S3Z2) is superior compared to others.

4.16. The Protein Content in Grain

The results of the analysis of variance in table (Appendix 3) indicate that wheat plant foliar application with salicylic acid and zinc and the interaction between them had a significant effect on the protein content of grains.

Table 17. The effects of salicylic acid and zinc, as well as their interactions, on the protein content of grains

Zn / SA	Z0	Z1	Z2	Effect of SA
S0	13.20 c	13.50 ab	13.37 bc	13.36 b
S1	13.37 bc	13.50 bc	14.03 abc	13.63 ab
S2	13.33 bc	13.90 abc	14.10 abc	13.78 ab
S3	13.57 bc	14.20 ab	14.57 a	14.11 a
Effect of Zn	13.37 b	13.78 a	14.02 a	

With regards to the effect of salicylic acid in table (17), the highest level shown in (S3) that was treated with (300 ppm) and for zinc's effect, the highest level shown in (Z2) that was treated with (100 ppm). Also, the interaction between them (S3Z2) is superior compared to others.

5. DISCUSSION

During the vegetative development stage of the wheat plant, salicylic acid can be applied as a spray. It is an important phenolic that is found all across the plant world. Also, it was discovered to be an endogenous regulator in plants when it was shown to be involved in a variety of physiological processes in plants. Salicylic acid has physiological functions in plants throughout their lives and is important in controlling their growth and production (162). Zinc is a necessary component for plant growth. It was revealed that it has a function in improving the efficiency of photosynthetic product transfer from manufacturing sites to the remainder of the plant. And many recerch indicated that both of them (salicylic acid and zinc) have positive effect on physiological characteristics, productivity and quality of the wheat crop. Zinc plays a critical role in increasing wheat yields (163).

The arithmetic averages according to table (2), where we find an increase in the weight of dry matter when treated with concentration (100 ppm) of salicylic acid in treatment (S2) reached (7.42 gm.plant) compared to non-spraying (S0) which was (7.18 gm.plant), followed by treatment (S2) which reached (7.43 gm.plant) when sprayed with (200 ppm) and treatment (S3) which reached (7.73 gm.plant) when sprayed with (300 ppm). It is believed that the increase in dry weight results from the fact that salicylic acid treatment works to increase the regulation and distribution of dry matter from the source to the downstream, and its inhibition of the formation of abscisic acid ABA and the association with amino acids, which makes plants resistant to marginal environmental conditions and increases the absorption of nutrients such as phosphorous and nitrogen (69).

According to the zinc foliar application effects, the same results were shown in table (2) that dry weight increased from 7.22 gm.plant non-sprayed with zinc to 7.45, and 7.65 gm.plant respectively by spraying zinc with (50 ppm and 100 ppm) concentrations. The reason for this may be due to an increase in the leaf area when sprayed with zinc and the contribution of this trait to an increase in the plant’s ability to photosynthesis rates and the absorption of water and nutrients, which are positively reflected on the yield and its components. This is consistent with what was found by (164,165).

It also appears from table (2) that the interaction between the effects of spraying with salicylic acid and zinc did not reach the level of significance according to the F test, which observed enhanced dry weight in the interaction of the highest concentration treatment (S3Z2) compared to lower concentrations and non-spraying treatments.

The increase in dry matter in the spraying treatments, especially in the (S3Z2) treatment, may be due to the expansion of the root system in a short time, as salicylic acid leads to an increase in the speed of cell division and cell number, which is reflected in the contribution to the increase in the efficiency of absorption of water and nutrients and what accompanies it in increasing the production of nutrients through photosynthesis, reaching the stage of food sufficiency at an early age compared to no treatment, according to the interpretations of (166, 36). But the unreached level of significance according to the F test in this study is due to the need to spray more than one stage in the plant growth period.

The results of the arithmetic averages in table (3) indicated an increase in the percentage of dry matter when spraying the vegetative total of plants with the highest concentration (300 ppm) of salicylic acid (S3), which gave the highest rate of 30.93% compared to non-spraying or spraying with lower concentration. The increase in dry matter yield at this stage may be due to the active role of salicylic acid in stimulating and encouraging plant growth. On cell division, stimulating enzymes, and synthesis of nucleic acids and protein, this increases the accumulation of dry matter according to the increase in the rate of photosynthesis (167, 168).

With regard to spraying zinc, it has a positive effect, as we find in the treatment of plants at level (Z1) with concentration of (50ppm) increased in the percentage of dry weight which reached 30.26%, followed by the treatment of (Z2) with a concentration of (100ppm), which reached the highest level and reached 30 92%. As, (169) found that all zinc treatments enhanced the fresh and dry weight of wheat shoots, as well as their length, as compared to the control. It also found the same result for the interaction between the effect of foliar application salicylic acid and zinc, which reached 31.29% in (S3Z2) and we see the highest level in (S1Z2), which reached 31.55%, but in spite of this increase, none reached the level of significance according to the F test.

The arithmetic averages in Table (4) indicate the superiority of spraying the foliar 300 ppm with salicylic acid (S3) in giving it the highest rate of 0.0086 g. $g^{-1}.day^{-1}$ and the (R.G.R) decreased by decreasing the concentration of (S2) treatment by spraying the shoots with 200 ppm with salicylic acid, as it reached 0.0081 g. $g^{-1}.day^{-1}$ and decreased to 0.0074 g. $gm^{-1}.day^{-1}$ in (S1) treatment with spraying 100ppm salicylic acid. While the lowest (R.G.R) was in treatment (S0) with non-spraying, which reached 0.0071 g. $g^{-1}.day^{-1}$. The increase in the (R.G.R) between the beginning of the elongation phase when treating the foliage with salicylic acid is due to the effective role in stimulating growth by being hormonally balanced (auxins and cytokinins) and to the increase in chlorophyll content in the leaves (Table 5.) and the increase in the relative water content and the increase in the ability of the plant to absorb nutrients, which increases the efficiency of the plant in the possibility of converting toxic hydrogen peroxide into water, which helps the plant to perform vital functions during the period of low temperatures (68, 71). These results are consistent with what was mentioned by (37) as they indicated an increase in the (R.G.R) by spraying the vegetative mass with salicylic acid.

Table (4) shows the similar results based on the impacts of zinc foliar application. The (R.G.R) increased by spraying with 100ppm zinc, which reached 0.0087 g. $g^{-1}.day^{-1}$ as it is the highest level compared to the lowest concentration application and non-sprayed treatments. (170) observed similar results, reporting that zinc fertilizer improved the dry matter yield of wheat plants. (169) also reported that the growth of fresh and dry weight of wheat shoots and their length were increased more or less in all zinc applications as compared to control. Despite not reaching the interaction between spraying the acid and zinc to the level of significant in (R.G.R), we note the positive effects of applied treatment and most of the data are enhanced by increasing the concentration of both acid and zinc or if compared to control.

The arithmetic shown in table (5) showed that spraying wheat plants with salicylic acid had a significant effect on the flag leaf content of chlorophyll, as a significant increase of 44.14 SPAD was achieved in the 100 ppm activation treatment for spraying with 100 ppm on the foliar application (S1). The chlorophyll content of the leaves increased when the concentration of salicylic acid was increased to the 200 ppm foliar spray treatment and it reached 44.36 SPAD. It also increased significantly by increasing the concentration of acid to 45.36 SPAD in (S3) compared with the non-spraying treatment. The spray treatment led to an increase in the chlorophyll content in the leaves because salicylic acid has a role in increasing the growth of cells and increasing their number due to the increase in the accumulation of metabolites in the tops of the developing ones, which leads to an increase in the rates of mitosis and an increase in the effectiveness of DNA and RNA (171). Acid has a role in increasing the proportion of antioxidants, especially when exposed to abiotic stresses, including catalase, which has a role in protecting the enzyme Ribulase 1-5 phosphate carboxylase, and plastids, and the effect of oxidative H2O2 by activating its activity and converting it to water (172). Salicylic has a role in lowering the concentration of ABA, inhibiting the representation of ethylene leading to aging, raising the efficiency of photosynthesis and increasing the concentration of gibberellins, auxins and cytokinins (173). Therefore, it contributed to improving plant growth by increasing the accumulation of dry matter and increasing the relative growth rates and crop growth. These results are consistent with what was found (37) in yellow corn, who indicated that the activation with salicylic acid spraying on the shoot increases the chlorophyll content in the leaves of treatment plants.

In addition, it mentions in table (5) the effect of zinc spraying in Z1 and Z2 that the flag leaf content of chlorophyll increased significantly as it reached 45.03 and 44.76 SPAD compared with control. These results are consistent with what was mentioned (174). They indicated increasing chlorophyll in the content of wheat plant leaves by spraying the vegetative mass with zinc. (84, 175, 83) showed that zinc is required for photosynthesis and respiration, and a lack of it lowers photosynthetic rate, chlorophyll concentration, carbonic anhydrase activity, and protein production. Moreover, foliar application of Zn increased photosynthesis rate and SPAD value in wheat leaves under drought stress (150).

It is also noted that the interaction between the activation factors salicylic acid and zinc was significant, and that the highest rate of chlorophyll content in S3Z2 which is reached 46.30 SPAD comparing to other treatments. Therefore, application of salicylic acid and zinc may be an important measure for enhancing chlorophyll contain in leafs and it led to improving the yield and quality of wheat.

From the results of the arithmetic averages in table (6), it is noted that the spraying treatment increased by 100 ppm with salicylic acid (S1), and the area of the flag leaf was 36.92 cm^2, followed by the spraying treatment with 200 ppm on the vegetative total with salicylic acid (S2), and the area of the flag leaf was 37.79 cm^2, and also reached the highest level when treating with 300 ppm in treatment (S3), which is 37.90 cm^2. While the non-spray treatment (S0) gave the lowest average leaf area, with a significant difference of 36.76 cm^2, that salicylic acid leads to an improvement in phenotypic and physiological characteristics because it leads to an increase in the relative growth rate, crop growth rate and the accumulation of dry matter in the different stages of growth, for its contribution to increasing cell division rates, increased DNA and RNA activity, decreased ABA concentration, and inhibited ethylene metabolism, raising the efficiency of photosynthesis, increasing plant hormones, and increasing the percentage of antioxidants when exposed to environmental stresses (171, 176). These results are consistent with what was found by (36) on the pea plant.

The results of the arithmetic averages of the flag leaf area in table (6) show that the sprayed treatments with zinc led to a significant increase in this trait, as it gave the highest rate for the trait that reached 37.73cm^2 in the treatment of spraying the vegetative part of the wheat plant with 100 ppm (Z2) and reached 37.48 cm^2 in the teat with 50 ppm (Z1) compared to control (Z0), which is 36.82 cm^2. Flag leaf area and other growth metrics are likely to have improved because of a rise in amino acids, which are key components in the growth of leaf area. Firouzi M. 2005 claims that foliar Zn spraying enhances flag leaf area by lengthening and widening the leaves when auxin levels rise.

It was also shown that the interaction between the activation factors salicylic acid and zinc was significant, as evidenced by the table (6) the highest rate of the area of the flag leafs in (S3Z1) which is reached 38.63 cm2 next to it (S3Z2) which is reached 38.47 cm2, while flag leaf area is 36.10 cm2 in non-spray treatment (S0Z0). Therefore, application of salicylic acid and zinc may be an important factor for increasing leaf area, and it has led to improvements in the biological yield and grain yield of wheat due to increasing the area unit and efficiency of photosynthesis in leaves.

The arithmetic averages showed in the table (7) an increase in the height of plants with the salicylic acid application treatment with 300 ppm in (S3) on the shoot and it gave 100.60 cm compared with each of the treatment (S2) and (S1) that were sprayed with lower concentrations of acid, which gave 101.88 and 100.64 cm, respectively, and with the treatment of inactivation (S0), which gave 99.77 cm. This is due to the role of salicylic acid, especially in the concentration of spraying 300 ppm on the vegetative system in its ability to modify the osmosis of leaf cells and increase their ability to draw water from the roots even in insufficient water, and increase the enzyme catalase, which has the ability to analyze 1000 hydrogen peroxide molecules per second and convert them into a water molecule, which helps the plant to carry out its vital functions under environmental stress conditions (72), it works to increase and regulate the dry matter from the source to the estuary, increasing the division of cells and their number, and this is reflected in the increase the accumulation of dry matter and the increase in the relative growth rate and the growth rate of the crop, which is reflected in its superiority in the height of the plant (55).

As indicated, according to the effect of zinc foliar application in table (7), the plant height of wheat significantly increased and reached 100.64 cm high in (Z2) with 100ppm concentration reached 100.38 cm high in (Z1) with 50ppm. This is compared with control (Z0), which was 98.12 cm high. Increased plant height might be due to micronutrient participation in several physiological processes such as enzyme activation, electron transport, chlorophyll production, and stomatal control, among others, resulting in increased dry matter (177, 178). These results are consistent with what was found (146). It was revealed that plant height of wheat was significantly affected by foliar application of zinc.

But the interaction between the effects of spraying with salicylic acid and zinc did not reach the level of significance according to the F test, despite that it showed an increase in its average plant height by increasing the concentrations of acid and zinc, especially in (S2Z2), which reached the highest level of plant height 102.30 cm compared with all other treatments.

Salicylic acid foliar application has been shown in table (8) to have a positive effect on spike length in wheat plants as it reached the rate of highest length in (S3) treatment when sprayed with a concentration of 300 ppm it is 10.53 cm shorter than treatment (S2), which was sprayed with a concentration of 200 ppm and gave 10.51 cm. Following that is (S1), which was sprayed with 100 ppm and gave 10.25 cm, while the non-sprayed treatment gave the lower length of 9.99 cm. According to (179), salicylic acid therapy changed the plant's nutritional balances. They noted that exogenous administration of SA resulted in a substantial boost in plant growth in both saline and non-saline environments. Also, it agrees with the results of (180) that they showed the effects of foliar application of salicylic acid on spike length of wheat plants.

The spike length in wheat plants, also shown in table (8), increased significantly as a result of zinc foliar application and reached 10.58 cm as treated with the highest concentration of 100 ppm in (Z2). This is compared with a lower concentration of 50 ppm which reached 10.28 cm in (Z1) and a non-activation treatment (Z0) which gave a 10.06 cm length of spike. These results are in agreement with those reported by (177), who indicate an increase in spike length by the application of zinc. The interaction between the application of salicylic acid and zinc was also significant, with the longer rate of the wheat spike (S2Z2) reaching 10.78 cm, while the highest treat concentration (S3Z2) was lower and reached 10.63 cm. But it showed positive effects in most treatments by increasing the interaction concentration of both factors, and the shortest spikes were observed in control treatment (S0Z0), which gave a 9.75 cm length.

From the arithmetic averages of the number of spikes in m^2 shown in Table (9), it shows the superiority of the activation coefficients in the number of spikes, as the activation treatments (S3) and treatment (S1) gave the highest average spike for the number of spikes, which amounted to 448.33 and 442.44 spikes, respectively, compared to the lowest number of spikes in the (S2) and non-spray treatment (S0) which amounted to 437.44 and 421.22 spikes, that the increase in the number of spikes in the activation coefficients is associated with the number of fertile strands, which comes due to the hormonal balance of auxins, gibberellins and auxins as a result of treatment with salicylic acid and to its role in increasing the absorption of water and mineral elements and inhibiting the effectiveness of ethylene which helps in the trend towards reproductive growth to withstand the conditions of marginal factors and raises the efficiency of photosynthesis and protects the plastids from the influence of biological stresses, which worked to improve the studied traits that have to do with increasing the number of spikes or including increasing the dry matter carrier, relative growth rates, yield, chlorophyll content and the surface area of the flag leaf (173) that its contribution to increasing the above growth characteristics contributes to the development of the spike from the branches, as the adequacy of the metabolites in the stage of emergence and early development of the branches reduces competition among them and increases the percentage of spike-bearing spikes (166).

The results of the arithmetic averages in table (9) showed an increase in the number of spikes when spraying the vegetative total of plants with (50 ppm) of zinc (Z1), which gave the highest number 442.50 spike compared to (Z2) treatment and non-spraying treatment. It may not reach the level of significance because (181) indicated that the number of spikes in wheat is determined in the early stages of the plant's life, in the period of budding and spike formation. Also (8) indicated that the number of spikes/m^2 in wheat plants is the component of the yield most affected by the addition of zinc, especially the method of adding zinc to the soil and when adding zinc to the soil and spraying together. While the interaction between the factors reached 454 spikes in both treatments (S3Z1) and (S3Z2), which are the highest concentration treatments compared to the lowest concentration interaction and control. This increase indicated that the number of spikes in wheat plants had responded to changes in activation coefficients.

The results of the arithmetic averages in table (10) show the registration of the activation factor (S3), spraying the shoot with 300 ppm, the highest average number of spikelet per spike reached 21.61spikelet, superior to the activation treatments. Spraying the foliage total of 200 ppm and 100 ppm in (S2) and (S1) treatment, which 21.18 and 21.07 spikelet respectively, while the lowest was the non-activated plants, which gave 20.97 spikelet in spikes. It is believed that the increase in the number of spikelet is due to the role of salicylic acid in increasing the relative water content and reducing the water saturation deficit under drought conditions. It also has a role in increasing the absorption of water and mineral elements and inhibiting ethylene, which helps flower growth and increase drought tolerance and the increase in the number of flower origins as a result of the increase in growth characteristics, including the yield of dry matter in the two growth stages that were studied, the rate of crop growth, the relative growth rate and the height of the plant, which is reflected in the increase in the number of spikelet in the spike, especially in the activation treatment (S3). It agrees with the results of (55) and with what was indicated by (182), who indicated an increase in the number of spikelets in the spike when treated by soaking the seeds or spraying the plant with salicylic acid.

Table (10) shows the effect of zinc foliar treatment on the number of spikelets in a wheat spike, which increased significantly and reached 21.69 spikelets when treated with the highest concentration of 100 ppm in (Z2). This compared with the lowest concentration of 50 ppm, which reached 21.10 spikelets in (Z1) and non-spraying (Z0), which gave 20.83 spikelets in spikes. The number of spikelets per spike is an essential element that directly influences wheat crop production. It immediately impacts the grain yield of any wheat plot due to its direct effect on the quantity of grains per spike. These results are consistent with (183) findings. He discovered that applying zinc to wheat in the form of zinc sulfate increases the number of spikelets per spike.

The interaction between the activation variables salicylic acid and zinc was also demonstrated to be significant, as indicated in the table (10) that the highest number of spikelets in the spike in (S3Z2) reached 21.88 spikelets, and we notice the enhancing most of the interaction treatment by increasing factors concentration. As a result, application of salicylic acid and zinc may be an important factor for increasing the number of spikelets in a wheat spike, and it led to improving the yield of the wheat crop due to increasing the number of grains in spike.

The arithmetic averages of the number of grains of the spike shown in Table (11) that the activation treatment (S3) spraying the shoot with 300 ppm with salicylic acid was significantly superior and gave the highest number of grains in the spike, which amounted to 55.80 grains, with a significant difference with the activation treatments (S2)and (S1) spraying the foliage with 200 ppm and 100 ppm with acid, in which the grain rate reached 54.91 and 54.38 grains respectively, while the lowest number of grains observed in the non-sprayed treatment was 54.00 grains. These results were consistent with the increase in the growth characteristics that were studied (dry matter accumulation, relative growth rates, chlorophyll concentration, flag leaf area, and yield) and shown in the previous tables due to the role of salicylic acid in improving them, which produces Insufficient photosynthesis products, which is reflected in the lack of competition between the developing plant parts, which results in completed lateral spikelet (184), because the number of fertile florets and the growth rate of spikelet, which is associated with an increase in the net photosynthesis products achieved by the active role of salicylic acid in it, led to an increase in the number of spike grains, especially in the activation treatment (S3). These results are consistent with those of (185, 186) they indicated an increase in the number of spike grains in the wheat crop in the activation treatments with salicylic acid.

Spraying the vegetative total of wheat plants with zinc in table (11) showed a significant difference in the number of grains in the spike., as it gave the highest number of grains for the trait that reached 56.18 grains in the treatment of application of the vegetative part with 100 ppm (Z2), compared to treating with 50 ppm (Z1), which reached 54.44 grains, and the lowest number of grains in the control (Z0) treatment was 53.71 grains. The fact that the number of spikelets per spike and the number of grains per spike are closely related is a well-known fact. The number of grains per spike will grow as the number of spikelets per spike increases. Zinc participation in processes like pollination and fertilization, as well as its direct impact on the production of pollen tubes, results in an increase in grain setting. Low grain development in wheat is caused by zinc deficiency, which results in inadequate pollination and fertilization. These findings are consistent with those of (187), who discovered that foliar zinc treatment during the lateral development phases of wheat significantly increases the number of grains per spike.

As shown in table (11), the interaction between the activation factors salicylic acid and zinc was also significant. The greatest number of grains in the wheat spike in (S3Z2) reached 56.81 grains, which is the highest treatment concentration, and it indicated the positive effects of most treatments by increasing the interaction concentration of both factors. And the lowest number of grains per spike was observed in the non-sprayed treatment (S0Z0), which gave 52.35 grains.

It is noticed from the arithmetic averages of the weight of thousand grains shown in Table (12) that spraying wheat plants with 300 ppm salicylic acid has a significant effect, as it reached the highest weight of 31.66 gm in treatment (S3), but the other treatments did not have a positive effect on increasing the concentration of acid that is observed in activation treatments (S1 and S2) that gave 30.69 gm and 30.57gm respectively, compared to non-activation treatment (S0) which gave 30.37 g. This result is consistent with what was mentioned by (188), who indicated that salicylic acid has an important and effective role in increasing and regulating the distribution of dry matter from source to estuary even in conditions of abiotic stress and increases the efficiency of the plant in exploiting the available growth factors, so may be the weight of a thousand grains was not affected in all activation treatment. Although the activation coefficients were outperformed by the number of spikes/m2 and the number of grains per spike, and a slight increase in the weight of one thousand grains, especially in the (S3) treatment, which contributed to an increase in the yield of grains, according to these data.

Zinc spraying on vegetative total of wheat plants showed in table (12) a significantiy increased in the average weight of 1000 grains, as we found in the (Z2) treatment with the highest concentration (100 ppm), which reached 31.47 g, followed by the treatment of (Z1) with a lower concentration (50 ppm), which reached 30.79 g, while non-sprayed plants (S0) gave 30.47 g. That is a lower weight of a thousand grains. Zinc is required for growth hormone production, starch creation, and maturation, all of which contribute to seed weight gain (189). These results and interpretations are in agreement with (183), who determined that zinc treatment raised 1000-grain weight substantially. The interaction between the application of salicylic acid and zinc also has significant effects. As notice, the greatest weight of grain is in the treatment (S3Z2) and reaches 32.53 g, which is treated with the highest interaction concentration, and it shows in the positive effects in most treatments by increasing the interaction concentration of both factors, while the lowest weight of grain is observed in the control treatment (S0Z0), which gave 30.29 g.

It appears that the arithmetic averages shown in table (13) have a significant effect of the application treatments with salicylic acid on the biological yield, as the activation treatment by spraying the shoots with 300 ppm (S3) was significantly superior to 13986 kg/ha and superior to the activation treatment (S2) by spraying the vegetative total with 200 ppm significantly, amounting to 13931 kg/ha, while the treatment (S1) that sprayed with 100 ppm amounting 13806 kg/ha and non-activation gave the lowest biological yield amounting 13431 kg/ha. This is a reflection of the role of salicylic acid in exploiting the available resources for growth and increasing the photosynthesis efficiency of plants treated under environmental stress conditions, which was reflected in the studied growth characteristics, especially in treatment (S3), which the increasing dry matter yield and outperformed in the (R.G.R) and yield and increasing the area of flag leaf and an increase in the average number of total spikes as indicated in previous studied tables, and these results are consistent with what (182) found.

According to zinc spraing, that observed in table (13), increased significantly in the weight of biological yield, as a result of spraying it with a concentration of 100 ppm in (Z2) treatment on wheat plants, which reached 14063 kg/ha, while application plants with 50 ppm zinc in (Z1) treatment reached 13698 kg/ha and the lowest weight was in non-sprayed plants that gave 13.604 kg/ha. Zinc may enhance biological yield by increasing photosynthesis, early growth, and nitrogen fixation. These findings are consistent with the findings of (183), which showed that applying zinc to wheat at stages of development increases biological yield. Regardless of not reaching the interaction between spraying the acid and zinc to the level of significant weight of biological yield, we can observe the positive effects of application on plants in the treatments (S1Z2) and (S2Z2) where they reach the same weight 14333 kg/ha, which is the highest rate as compared to other treatments.

The arithmetic averages shown in Table (14) showed that the application treatments with salicylic acid had a significant effect on the grain yield, as the activation treatment (S3) outperformed by spraying the plants with 300 ppm, which gave the highest grain yield, reaching 4637 kg/ha with a significant increase compared to the activation treatment (S2) that spraying the plants with

200 ppm salicylic acid, which gave a grain yield of 4548 kg/ha and the activation treatment (S1) that spraying the plants with 100 ppm, which gave 4522 kg/ha, while the control treatment gave 4390 kg/ha grain yield. This resulted in the accumulation of dry matter during the different stages of growth, as the weight of the dry matter increased in the stages of elongation, heading stage, and biological yield. This may be due to the nature of phenolic salicylic acid that works to regulate ion uptake, hormonal balance and stomata movement (38). It helps convert toxic hydrogen peroxide into water that is used by the plant to carry out its physiological functions during the growth period under conditions of biological stress (72). Also, salicylic acid, especially in the S3 treatment, appears to have an important role in reducing the negative effects of borderline conditions as well as having the opposite effect of ABA growth inhibitor (41), or through its role in increasing the levels of auxins and cytokinins, which encourages vegetative growth and increases the ability of treated plants to branch and give the number of spikes per unit area. Increasing the absorption of NPK nutrients and contributing to the formation of plastids, which led to an increase in the chlorophyll content of the leaves and an increase in the area of the flag leaf. And it has a role in increasing the percentage of gibberellins that have a role in the flowering process in combination with Anthesin and the production of the flowering hormone Florigen, thus urging plants to flower early and form a larger number of flowers (71). It had a role in increasing the number of spikelets and the number of spike grains accordingly. In addition to its ability to absorb nutrients and increase their transport during the stages of floret formation and grain filling, this ensured that a high rate of grain weight was given despite the increase in yield components. This increase was caused by the role of salicylic acid in activating growth characteristics and components. The result contributed to the superiority in the relative growth rate and grain yield by activation treatments with salicylic acid. These results are in agreement with (182, 190), who all indicated an increase in grain yield when treated with salicylic acid either by soaking the seeds or spraying the shoots.

From the arithmetic averages shown in Table (14), grain yield in wheat plants also increased significantly as a result of zinc foliar application. As a result of spraying plants with 100 ppm zinc in (Z2) treatment, the grain yield reached

4613 kg/ha, which is the highest rate, while application plants with 50 ppm zinc in (Z1) treatment reached 4497 kg/ha, which is the lowest weight seen in non-sprayed plants that gave 4464 kg/ha. Increased grain yield due to the direct role of zinc in the formation of the amino acid tryptophan, which gives rise to the hormone indole acetic acid (IAA), which is required for cell elongation and increased growth, as well as the role of zinc in the formation of chlorophyll, amino acids, carbohydrates, and increasing the vitality of pollen, all of which lead to an increase in growth characteristics by increasing zinc concentrations that are added by spraying on the plant, as indicated by (191). Moreover, the interaction between the application of salicylic acid and zinc significantly increased in treatment (S3Z2), reaching 4713 kg/ha, which is the highest rate of grain yield. Additionally, it showed positive effects in most treatments by increasing the interaction concentration of both factors, while the lowest weight was observed in the non-sprayed treatment (S0Z0), which was 4300 kg/ha.

As shown in table (15), the foliar application of salicylic acid on wheat plants had a positive effect, which was noticeable in enhancing the level of harvest index in treatments with the highest concentration of acid, reaching %33.22 in (S3) treatment compared to the lowest treated concentration used and non-sprayed plants. Zinc spraying on wheat plants enhances the level of harvest index by using the highest concentration in treatment (Z2) and reaching a %32.87 that compared to the lowest treated concentration used and non-spraying treatment. Also, results of interaction between the effect of spraying salicylic acid and zinc reached %33.60, which is the highest level in treatment (S3Z2) compared to other treatments and control, nonetheless, despite this increase, none of them reached the level of significance according to the F test.

Hectoliter mass, also known as bushel mass, particular test mass, or hectoliter weight in some countries, is the weight of a standard volume of grain and is thought to be a measure of grain bulk density and soundness (192). The hectoliter weight is an essential indication of wheat's physical quality and has long been used to predict wheat flour production. The arithmetic averages in table (16) showed that the weight of hectoliter was significantly superior by spraying the shoots of plants with 300 ppm of salicylic acid in treatment (S3) and gave the highest weight, which amounted to 76.42 kg/hl, compared with the activation treatments (S2) and (S1) that sprayed with 200 ppm and 100 ppm with acid, which reached 75.60 kg/hl and 76.09 kg/hl respectively, while the lowest weight seen in the non-sprayed as gave 75.19 kg/hl. This result is due to the positive effects of salicylic acid on the physiological and morphological processes in wheat plants, which significantly enhance the qualitative and quantitative properties of this crop's grain.

Results in table (16) zinc spraying on vegetative total of wheat plants showed a significant difference in the weight of hectoliter, as notice in the (Z2) treating with highest concentration (100ppm) raised in the weight which reached 76.22 followed by the treatment of (Z1) which sprayed with (50ppm) zinc, and reached to 75.94 kg/hl, while non-sprayed plants (S0) gave 75.32 kg/hl. Results showed that foliar application of zinc increased seed yield and its quality compared with control, which led to increase hectoliter and it is agree with that found by (77). Also, the interaction between salicylic acid and zinc was also significantly enhanced and had a positive effect by increasing the concentration of factors in weight of hectoliter, which is the highest level observed in treatment (S3Z2) that reached 76.77 kg/hl, as compared to other treatments and control.

As shown in table (17), spraying wheat plants with salicylic acid had a significant effect on the protein content in the seeds. Treatment (S3) was outperformed by spraying 300 ppm with salicylic acid, and the protein contained in seeds reached %14.11, which is the highest level compared with treatments (S2) and (S1) that were sprayed with 200 ppm and 100 ppm of acid, which reached %13.78 and %13.63 respectively, while the lowest percentage of protein in seeds seen in (S0) amounted to %13.36. These results were in line with those of (193), who found when compared to the control, all salicylic acid treatments resulted in significant increases in grain nitrogen and protein content, and there were also significant variances across treatments.

The protein content in wheat seeds also increased significantly as a result of zinc spraying on total vegetative, which reached %14.02 when treated with the highest concentration of 100 ppm zinc (Z2), while spraying plants with 50 ppm zinc (Z1) reached %13.78 proteins, and the non-spraying treatment (Z0) gave %13.37 proteins. According to Potarzycki and (194), plants with a zinc deficiency of 5.8% lower the rate of protein synthesis and protein content dramatically. These results agree with (195), who found that adding zinc to grains improves grain protein content substantially.

It is also noted that the interaction between spraying salicylic acid and zinc was significant in the trait of protein contained in seeds, as the highest percentage of protein was seen in treatment (S3Z2), which reached %14.57 compared to other treatments. The lowest protein content in seeds was observed in control treatment (S0Z0), which gave %13.20.

6. CONCLUSIONS AND RECOMMENDATIONS

We conclude from this study that the application of both salicylic acid and zinc by spraying on the vegetative parts is necessary to improve the physiological characteristics, productivity, and quality of the wheat crop, and the increase in the concentration of each is the best way to obtain the highest level of quantitative and qualitative characteristics of the wheat crop.

Foliar application of salicylic acid has positive effects, especially in treatment (S3) that activates with the highest concentration (300 ppm), which is superior significantly in chlorophyll content of the flag leaf, spick length, the number of spikelets in the spike, the number of grains in the spike, weight of 1000 grains, the number of spikes, biological yield, grain yield, protein content of grain and hectoliter. Furthermore, it outperforms the other activation treatments in terms of dry weight of the plant, dry weight percentage, plant height, and harvest index, but not significantly.

Foliar application of zinc has positive effects, especially in treatment (Z2) that activates with the highest concentration (100 ppm), which is superior significantly in relative growth rates, plant height, spick length, the number of spikelets in the spike, the number of grains in the spike, weight of 1000 grains, biological yield, grain yield, protein content of grain and hectoliter. Also, it is superior but not significantly to the other activation treatments in dry weight of plant, dry weight percentage, and harvest index.

Therefore, it is necessary to treat the wheat crop with a growth regulator, which we used salicylic acid and a microelement like zinc, especially in these lands that are suffering from zinc deficiency. These activations lead to improved wheat seed quality and enhanced grain yield.

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8. APPENDICES

Appendix 1

Source of Difference	Mean Square				
	Weight of dry matter	Dry matter percentage	Relative growth rate	Chlorophyll content	Flag leaf area
S	0.471^{ns}	1.873^{ns}	3.806*	3.513*	3.094*
Z	0.567^{ns}	2.476^{ns}	4.778*	3.997*	2.656*
SZ	0.323^{ns}	2.015^{ns}	2.270^{ns}	2.198*	1.879*
Error	0.238	1.310	1.104	0.801	0.746

Appendix 2

Source of Difference	Mean Square				
	Plant height	Spike length	No. of spike in (m^2)	No. spikelet in spike	No. of grain in spike
S	6.722^{ns}	0.591**	120.102*	0.705*	5.506*
Z	23.094*	0.719**	542.694^{ns}	2.309**	19.380**
SZ	8.409^{ns}	0.323**	460.694^{ns}	0.756**	5.451**
Error	4.507	0.095	362.649	0.194	1.188

Appendix 3

Source of Difference	Mean Square					
	W.1000 grain	Biological yield	Grain yield	Harvest index	Hectoliter	Protein content
S	2.791*	562934.028*	93598.148**	0.685^{ns}	2.645**	0.890*
Z	3.146*	703559.028*	73646.694**	0.65^{ns}	2.553**	1.295*
SZ	1.448*	371646.149^{ns}	48141.172**	0.913^{ns}	1.559**	0.549*
Error	0.613	179174.558	7170.149	1.137	0.444	0.232