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Effect of salicylic acid and zinc sulphate on morpho-physiological parameters and yield parameters of groundnut (*Arachis hypogaea* L.)

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Abstract
An investigation entitled "Effect of salicylic acid and zinc sulphate on morpho-physiological parameters and yield of groundnut (*Arachis hypogaea* L.)" was carried out at farm of Agril. Botany, College of Agriculture, Nagpur, during *Kharif* 2021. The experiment was arranged in randomised block design and replicated thrice consisting of twelve treatments of salicylic acid (50 ppm, 100 ppm, 150 ppm) and zinc sulphate (0.50% and 1.00%) when applied individually and as a treatment combination. The foliar spray at 30 and 50 DAS showed significant increase in all the growth parameters *i.e.*, plant height, number of secondary branches plant^{-1}, days to 50% flowering, days to maturity, total dry weight plant^{-1}, leaf area plant^{-1} and leaf area index, RGR, NAR and yield parameters such as number of the pods plant^{-1}, pod yield plant^{-1} (g), plot^{-1} (Kg), ha^{-1} (q), seed yield plant^{-1} (g), plot^{-1}(Kg), ha^{-1} (q), and Test weight (100 seed) and harvest index (%). Finally, it can be stated that spraying of plants with 150 ppm salicylic acid + 1.00% zinc sulphate and 100 ppm salicylic acid + 1.00% zinc sulphate at 30 and 50 DAS could be considered as the most suitable concentration and time to enhance the growth and yield of groundnut.

Keywords: Salicylic acid, zinc sulphate, foliar spray, B:C ratio, groundnut, morpho-physiological parameters, yield

Introduction

Groundnut belongs to family Leguminosae, genes *Arachis* and has chromosome number 2n=40. It is a day neutral plant, flowers are self-pollinated. Botanical name of groundnut is *Arachis hypogea* (L.). *Arachis hypogea* is derived from two Greek words "Arachis" meaning to legume and "hypogea" meaning below ground, referring to the formation of pods in the soil. Groundnut is one of the most important field legumes in India. Being an oil seed crop, it plays an important role in country's agricultural economy, on account of its versatile use in domestic and industrial fields. The major groundnut producing countries of world are India, China, USA, Brazil, Senegal and West Africa. India ranks second in production of groundnut after China.

Groundnut is cultivated as *Kharif*, *Rabi* and *Zaid* crop in India. Its cultivation in India is mainly confined to the States of Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Madhya Pradesh, Uttar Pradesh, Rajasthan, Punjab and Orissa. (Anonymous, 2020) [4]

As considering the importance of groundnut from nutrition and production aspect it becomes necessary to take production of groundnut crop with the aim of higher yield. The productivity of crop can be achieved with the help of physiological approaches by coordinating plant process to synthesize dry matter and partitioning its major quantum of effective yield contributing factors.

Materials and Methods

The field experiment was laid out in Randomized Block Design (RBD) with three replications consisting of twelve treatments comprising of different doses of salicylic acid and zinc sulphate. Three individual salicylic acid concentrations {50, 100 and 150 ppm- T_2 (Salicylic acid @ 50 ppm), T_3 (Salicylic acid @ 100 ppm), T_4 (Salicylic acid @ 150 ppm)}, two individual zinc sulphate concentrations {0.50 and 1.00% - T_5 (Zinc Sulphate @ 0.50%), T_6 (Zinc Sulphate @ 1.00%)} and six treatment combinations { T_7 (Salicylic acid @ 50 ppm + Zinc Sulphate @ 0.50%), T_8 (Salicylic acid @ 50 ppm +Zinc Sulphate @ 1.00%), T_9 (Salicylic acid @ 100 ppm + Zinc Sulphate @ 0.50%), T_{10} (Salicylic acid @ 100 ppm + Zinc Sulphate @ 1.00%), T_{11} (Salicylic acid @ 150 ppm + Zinc Sulphate @ 0.50%), T_{12} (Salicylic acid @ 150 ppm + Zinc sulphate @ 1.00%)} and one control (T_1- water sprays) were used for the experiment. PDKVG-335 cultivar of groundnut was used in investigation.

Seeds were sown at the rate of 100 to 125 kg ha^{-1} by dibbling method at a spacing of 45 cm x 10 cm on 26th June, 2021 after receiving the sufficient rainfall. After the germination, gap filling was completed on 5th July, 2021. Thinning was carried out after full emergence so as to maintain required number of plants $plot^{-1}$. Intercultural operations were also undertaken as and when required. Spraying of salicylic acid and zinc sulphate was done at 30 and 50 DAS with hand sprayer. Observations were recorded at different stages i.e., at 40, 60 and 80 DAS. The crop was kept free from disease and pest during the growth period. Harvesting in all treatments was undertaken after crop was matured.

The morpho-physiological observations *viz*., plant height, number of secondary branches $plant^{-1}$, days to maturity, total dry weight $plant^{-1}$, leaf area $plant^{-1}$ and leaf area index were recorded at 40, 60 and 80 DAS. Days to flower initiation, days to 50% flowering, days to maturity were also recorded. Similarly, RGR and NAR were calculated at 40-60 and 60-80 DAS. Observations on yield and yield contributing parameters like, number of pods $plant^{-1}$, pod yield $plant^{-1}$ (g), $plot^{-1}$ (Kg), ha^{-1} (q), seed yield $plant^{-1}$ (g), $plot^{-1}$(Kg), ha^{-1} (q), and Test weight (100 seed) were also recorded. Harvest Index was also worked out. The observed data were analysed statistically using analysis of variance at 5% level of significance (Panse and Sukhatme, 1967) [11].

Results and Discussion

Plant height

Plant height is an important character of the vegetative phase and indirectly influences the yield components. It is the shortest vertical distance between the upper boundary of the main photosynthetic tissue on a plant and the stem or shoot base from the ground level.

At 80 DAS, data regarding plant height was found significant. The range of plant height was recorded 26.41 cm to 32.25 cm. However, the treatment T_{12} (Salicylic acid @ 150 ppm + Zinc sulphate @ 1.00%) was found significantly superior over the treatment T_1 (control) and other treatments; followed by treatment T_{10} (Salicylic acid @ 100 ppm + Zinc Sulphate @ 1.00%), T_{11} (Salicylic acid @ 150 ppm + Zinc Sulphate @ 0.50%), T_8 (Salicylic acid @ 50 ppm +Zinc Sulphate @ 1.00%), T_9 (Salicylic acid @ 100 ppm + Zinc Sulphate @ 0.50%) and T_7 (Salicylic acid @ 50 ppm + Zinc Sulphate @ 0.50%). Whereas, the treatments T_2 (Salicylic acid @ 50 ppm), T_3 (Salicylic acid @ 100 ppm), T_4 (Salicylic acid @ 150 ppm), T_5 (Zinc Sulphate @ 0.50%), T_6 (Zinc Sulphate @ 1.00%) were found at par with control.

The increase in photosynthetic activity, chlorophyll formation, nitrogen metabolism, and auxin content in the plant might be the reason for increase in plant height.

The above observations are similar with the findings of Ali and Mahmoud (2013) [1]. The results showed that the interaction between salicylic acid (150 ppm) and zinc nutrient (500 ppm) had a significant effect on plant height in mungbean. Similarly, Shemi *et al.*, (2021) [13] reported that the spraying application of 140 mg l^{-1} SA, 4 g l^{-1} Zn and 11.5 g l^{-1} GB improved growth parameters such as plant height (cm) in maize.

Number of secondary branches $plant^{-1}$

Branches are the sites of the leaves, flower and pod formation. Hence, they are closely associated with the photosynthetic activity and yield of plant. So, number of branches is a desirable attribute for higher biomass production and yield.

At 80 DAS, data regarding number of secondary branches $plant^{-1}$ was found significant. The range of number of secondary branches $plant^{-1}$ was recorded 4.82 to 7.89. However, the treatment T_{12} (Salicylic acid @ 150 ppm + Zinc sulphate @ 1.00%) was found significantly superior over the treatment T_1 (control) and other treatments; followed by treatment T_{10} (Salicylic acid @ 100 ppm + Zinc Sulphate @ 1.00%), T_{11} (Salicylic acid @ 150 ppm + Zinc Sulphate @ 0.50%), T_8 (Salicylic acid @ 50 ppm +Zinc Sulphate @ 1.00%), T_9 (Salicylic acid @ 100 ppm + Zinc Sulphate @ 0.50%) and T_7 (Salicylic acid @ 50 ppm + Zinc Sulphate @ 0.50%). Whereas, the treatments T_2 (Salicylic acid @ 50 ppm), T_3 (Salicylic acid @ 100 ppm), T_4 (Salicylic acid @ 150 ppm), T_5 (Zinc Sulphate @ 0.50%), T_6 (Zinc Sulphate @ 1.00%) were found at par with control.

Application of salicylic acid and zinc sulphate along with RDF increase the metabolic activities of auxins and also synthesis of nitrate reductase enzyme in the leguminous crop increased the availability of other nutrients and accelerated the translocation of photo-assimilates.

Similar results were obtained by Ali and Mahmoud (2013) [1]. The results showed that the interaction between salicylic acid (150 ppm) and zinc nutrient (500 ppm) had a significant effect on number of secondary branches $plant^{-1}$ in mungbean. Whereas, Kesarkar *et al.*, (2022) [7] revealed that, foliar application of zinc sulphate @ 1.0% significantly improves the number of secondary branches $plant^{-1}$ in safflower.

Days to flower initiation

Data revealed that days to flower initiation was seen non-significant from observations because foliar sprays of salicylic acid and zinc sulphate were given after this stage.

Days to 50% flowering

Early flowering has been induced by salicylic acid concentrations because this stimulating agent accelerates biosynthesis of secondary metabolites. SA as a manager of blooming time, interacts with both photo-period dependent pathways and self-governing pathways. Salicylic acid stimulated initiation of flowers subsequently involves in the physiological process. The molecular mechanism of SA engaged in the bud stimulating behaviour; as SA is considered as an endogenous hormone with phenolic compositions, by the reason metabolism of indole-3-acetic acid can be shifted in presence of phenolic chemicals.

Data revealed that days to 50% flowering significantly reduced; as the concentration of salicylic acid and zinc sulphate increased. Also combine effect of salicylic acid and zinc sulphate significantly reduced the days to 50% flowering. Foliar application of salicylic acid and zinc sulphate at concentrations of 150 ppm and 1.00% respectively exhibited best results among all treatments. The range of days to 50% flowering is 35.81 DAS (Control) to 31.22 DAS (Salicylic acid @ 150 ppm + Zinc sulphate @ 1.00%).

Nitrate reductase is the key enzyme related to flowering process. The increased nitrate reductase activity by the application of salicylic acid might be the reason for early flowering induction. Reduced Indole-3-acetic Acid Oxidase (IAAO) activity and increased auxin content also contributed to early flowering, which was achieved by salicylic acid treatment. Salicylic acid in sesame reduced the number of flowering days as reported by Uma Devi (1998) [14] and Manikandan and Sathiyabama (2014) [8] in sesame and finger millet respectively. (Sathish Kumar *et el.,* 2018) [12]

Similar results found with Sathish Kumar *et el.,* (2018) [12]. Results showed that foliar application of salicylic acid 40 ppm twice at pre and post flowering stage of crop growth significantly reduced the days to 50% flowering in finger millet (*Eleusine coracana* (L.) Gaertn.) and also Kesarkar *et al.,* (2022) [7] revealed that, foliar application of zinc sulphate @ 1.0% significantly improves the days to 50% flowering (days) in safflower (*Carthamus tinctorius* L.).

Days to maturity

The data on days to maturity indicated a difference among the treatments. Early maturity was observed with foliar application of salicylic acid and zinc sulphate at treatment T_{12} (Salicylic acid @ 150 ppm + Zinc sulphate @ 1.00%), T_{10} (Salicylic acid @ 100 ppm + Zinc Sulphate @ 1.00%), T_{11} (Salicylic acid @ 150 ppm + Zinc Sulphate @ 0.50%), T_8 (Salicylic acid @ 50 ppm +Zinc Sulphate @ 1.00%), T_9 (Salicylic acid @ 100 ppm + Zinc Sulphate @ 0.50%), T_7 (Salicylic acid @ 50 ppm + Zinc Sulphate @ 0.50%) as compared with treatment T_1 (control) and other treatments. The increased nitrate reductase activity by the application of salicylic acid might be the reason for the induction of early maturity. (Sathish Kumar *et el.,* 2018) [12]

However, data regarding days to maturity in groundnut cultivar PDKVG-335 was found non-significant.

Total dry weight plant^{-1} (g)

Total dry matter production, its distribution and partitioning are integral part of growth and development over the entire growth period and is directly related to seed yield. Dry matter is an important criterion. It determines source sink relationship and depends upon the net gain in processes on anabolism and catabolism of plant.

Significant and gradual increase (40-80 DAS) was noticed regarding dry matter production at different stages of observations. The data recorded about dry matter production was subjected to statistical analysis and found significant.

At 40, 60 and 80 DAS, data regarding total dry weight plant^{-1} was found significant. The range of total dry weight plant^{-1} at 80 DAS was recorded highest among other two days of observation i.e., 11.13 g to 37.61 g. However, the treatment T_{12} (Salicylic acid @ 150 ppm + Zinc sulphate @ 1.00%) was found significantly superior over the treatment T_1 (control) and other treatments; followed by treatment T_{10} (Salicylic acid @ 100 ppm + Zinc Sulphate @ 1.00%), T_{11} (Salicylic acid @ 150 ppm + Zinc Sulphate @ 0.50%), T_8 (Salicylic acid @ 50 ppm +Zinc Sulphate @ 1.00%), T_9 (Salicylic acid @ 100 ppm + Zinc Sulphate @ 0.50%) and T_7 (Salicylic acid @ 50 ppm + Zinc Sulphate @ 0.50%). Whereas, the treatments T_2 (Salicylic acid @ 50 ppm), T_3 (Salicylic acid @ 100 ppm), T_4 (Salicylic acid @ 150 ppm), T_5 (Zinc Sulphate @ 0.50%), T_6 (Zinc Sulphate @ 1.00%) were found at par with control.

The increase in total dry matter is mainly ascribed to optimum utilization of solar radiation, higher assimilates production and its conversion to starch.

Similar results found with Meena *et al.* (2020) [9]. The result showed that application of salicylic acid 200 ppm at flowering and siliqua formation stage significantly increased dry matter plant^{-1} (58.10 g) in Indian mustard (*brassica juncea*) whereas, Kesarkar *et al.,* (2022) [7] revealed that, foliar application of zinc sulphate @ 1.0% significantly improves the total dry matter plant^{-1} (g) safflower (*Carthamus tinctorius* L.).

Leaf area plant^{-1} (dm^{-2})

Leaf area of plant denotes the activity of photosynthesis by regulating the interception of sunlight. There was continuous increase in leaf area over time from vegetative to maturity. Development of leaf area is a decisive factor of yield of the particular crop.

At 40, 60 and 80 DAS, data regarding leaf area plant^{-1} was found significant. The range of leaf area plant^{-1} at 80 DAS was recorded 5.77 dm^{-2} to 8.69 dm^{-2}. However, the treatment T_{12} (Salicylic acid @ 150 ppm + Zinc sulphate @ 1.00%) was found significantly superior over the treatment T_1 (control) and other treatments; followed by treatment T_{10} (Salicylic acid @ 100 ppm + Zinc Sulphate @ 1.00%), T_{11} (Salicylic acid @ 150 ppm + Zinc Sulphate @ 0.50%), T_8 (Salicylic acid @ 50 ppm +Zinc Sulphate @ 1.00%), T_9 (Salicylic acid @ 100 ppm + Zinc Sulphate @ 0.50%), T_7 (Salicylic acid @ 50 ppm + Zinc Sulphate @ 0.50%). Whereas, the treatments T_2 (Salicylic acid @ 50 ppm), T_3 (Salicylic acid @ 100 ppm), T_4 (Salicylic acid @ 150 ppm), T_5 (Zinc Sulphate @ 0.50%), T_6 (Zinc Sulphate @ 1.00%) were found at par with control.

Due to foliar spray of salicylic acid and zinc sulphate at concentrations of 150 ppm and 1.00% respectively exhibited best results among all treatments.

Hence, it can be concluded that when salicylic acid as a growth regulator and zinc sulphate as a micronutrient applied through foliar spray, might have accelerated the metabolic and physiological activities of the plant and put up more growth by assimilating more amount of major nutrients and ultimately increased the leaf area plant^{-1} in the present investigation.

Similar results were obtained with AL-Mafargy *et al*. (2020) [2]. The results show that the treatment combination of Zn 100 mg l^{-1} and SA 150 mg l^{-1} shows highest leaf area plant^{-1} (20.57 cm^2) of cherry tomato plant. Similarly, Shemi *et al.* (2021) [13] reported that that the spraying application of 140 mg l^{-1} SA, 4 g l^{-1} Zn and 11.5 g l^{-1} GB improved growth parameter such as leaf area plant^{-1} (cm^2) in both (well-watered and water deficit) soil conditions in maize.

Leaf area index (LAI)

The leaf area index is an important factor determining the dry matter production of a crop and subsequently the yield. The leaf area index at 40, 60 and 80 DAS was significantly influenced by the foliar spray of salicylic acid and zinc sulphate. Among the treatments; T_{12} (Salicylic acid @ 150 ppm + Zinc sulphate @ 1.00%) exhibited best results among all treatments.

Similar results found with Gowthami and Rama Rao (2014) [6]. The experiment revealed that foliar application of zinc sulphate @ 1% significantly improves leaf area index when compared to control in soybean. Also, Sathish Kumar *et el.*, (2018) [12] revealed that foliar application of salicylic acid 40 ppm twice at pre and post flowering stage of crop growth significantly increased leaf area index (LAI) in finger millet (*Eleusine coracana* (L.) Gaertn.) and also Kesarkar *et al.*, (2022) [7] revealed that, foliar application of zinc sulphate @ 1.0% significantly improves the leaf area index in safflower (*Carthamus tinctorius* L.).

Growth analysis

Growth analysis is a mathematical expression of environmental effects on growth and development of crop plants. This is a useful tool in studying the complex interactions between the plant growth and the environment.

The basic principle that underlies in growth analysis depends on two values (1) total dry weight of whole plant material per unit area of ground and (2) the total leaf area of the plant per unit area of ground.

The total dry weight (w) is usually measured as the dry weight of various plant parts *viz.*, leaves, stems and reproductive structures. The measure of leaf area (a) includes the area of other organs *viz.*, stem petioles, flower bracts, awns and pods that contain chlorophyll and contribute substantially to the overall photosynthesis of the plants.

RGR-(Relative growth rate) (g g^{-1} day^{-1})

Considering all the treatments, significantly maximum RGR was recorded in treatment T_{12} (Salicylic acid @ 150 ppm + Zinc sulphate @ 1.00%) *i.e.*, 0.0469 g g^{-1} day^{-1} at 40-60 DAS and 0.0767 g g^{-1} day^{-1} at 60-80 DAS.

At 40-60 and 60-80 DAS trend of relative growth rate was same and significantly higher RGR was observed in treatment T_{12} (Salicylic acid @ 150 ppm + Zinc sulphate @ 1.00%) when compared with treatment T_1 (control) and other treatments; followed by treatments T_{10} (Salicylic acid @ 100 ppm + Zinc Sulphate @ 1.00%), T_{11} (Salicylic acid @ 150 ppm + Zinc Sulphate @ 0.50%), T_8 (Salicylic acid @ 50 ppm +Zinc Sulphate @ 1.00%), T_9 (Salicylic acid @ 100 ppm + Zinc Sulphate @ 0.50%) and T_7 (Salicylic acid @ 50 ppm + Zinc Sulphate @ 0.50%). Whereas, the treatments T_2 (Salicylic acid @ 50 ppm), T_3 (Salicylic acid @ 100 ppm), T_4 (Salicylic acid @ 150 ppm), T_5 (Zinc Sulphate @ 0.50%), T_6 (Zinc Sulphate @ 1.00%) were found at par with control.

Similar results obtained with Gowthami and Rama Rao (2014) [6]. The results revealed that foliar application of zinc sulphate @ 1% significantly improves relative growth rate when compared to control in soybean. Whereas, Sathish Kumar *et el.*, (2018) [12] reported that foliar application of salicylic acid 40 ppm twice at pre and post flowering stage of crop growth significantly increased relative growth rate (g g^{-1} day^{-1}) in finger millet (*Eleusine coracana* (L.). Similarly, Kesarkar *et al.*, (2022) [7] revealed that, foliar application of zinc sulphate @ 1.0% significantly improves the relative growth rate safflower (*Carthamus tinctorius* L.).

Net assimilation rate (g dm^{-2} day^{-1})

The NAR is a measure of the amount of photosynthetic product going into plant material *i.e.*, it is the estimate of net photosynthetic carbon assimilated by photosynthesis minus the carbon lost by respiration. The NAR can be determined by measuring plant dry weight and leaf area periodically during growth and is commonly reported as grams of dry weight increase per square centimetre of leaf surface per week. This is also called as unit leaf rate because the assimilatory area includes only the active leaf area in measuring the rate of dry matter production. (Anonymous 2011) [3]

After analysing all the treatments under study, significantly maximum NAR was recorded in treatment T_{12} (Salicylic acid @ 150 ppm + Zinc sulphate @ 1.00%) *i.e.*, 0.0630 g dm^{-2} day^{-1} at 40-60 DAS and 0.1879 g dm^{-2} day^{-1} at 60-80 DAS.

At 40-60 and 60-80 DAS trend of net assimilation rate was same and significantly higher NAR was observed in treatment T_{12} (Salicylic acid @ 150 ppm + Zinc sulphate @ 1.00%) when compared with treatment T_1 (control) and other treatments; followed by treatments T_{10} (Salicylic acid @ 100 ppm + Zinc Sulphate @ 1.00%), T_{11} (Salicylic acid @ 150 ppm + Zinc Sulphate @ 0.50%), T_8 (Salicylic acid @ 50 ppm +Zinc Sulphate @ 1.00%), T_9 (Salicylic acid @ 100 ppm + Zinc Sulphate @ 0.50%) and T_7 (Salicylic acid @ 50 ppm + Zinc Sulphate @ 0.50%). Whereas; the treatments T_2 (Salicylic acid @ 50 ppm), T_3 (Salicylic acid @ 100 ppm), T_4 (Salicylic acid @ 150 ppm), T_5 (Zinc Sulphate @ 0.50%), T_6 (Zinc Sulphate @ 1.00%) were found at par with control.

A field experiment was conducted by Gowthami and Rama Rao (2014) [6] and studied the effect of foliar application of potassium, boron and zinc on growth analysis and seed yield in soybean. Results revealed that foliar application of zinc sulphate @ 1% significantly improves net assimilation rate in soybean. Similarly, Sathish Kumar *et el.*, (2018) [12] reported that foliar application of salicylic acid 40 ppm significantly increased net assimilation rate in finger millet (*Eleusine coracana* (L.) Gaertn). Whereas, Kesarkar *et al.*, (2022) [7] reported that, foliar application of zinc sulphate @ 1.0% significantly improves the net assimilation rate in safflower

(*Carthamus tinctorius* L.).

Yield and yield contributing parameters

Seed yield and its related parameters in groundnut were influenced by the application of growth regulators and plant micronutrients which have different influence on the allocation of assimilates between vegetative and reproductive organs. In general crop yield depends on the accumulation of photo-assimilates during the growing period and way they are partitioned between desired storage organs of the plants.

Seed yield plant^{-1} (g), plot^{-1} (Kg)

Seed yield is influenced by morpho-physiological parameters such as plant height, number of secondary branches, days to flower initiation, days to 50% flowering, days to maturity, total dry weight, leaf area, number of pods per plant and 100 seed weight which are considered yield contributing parameters. Seed yield plant^{-1} (g), plot^{-1} (Kg), ha^{-1} (q) are combined effect of yield contributing parameters and physiological efficiency of plant during present investigation.

Source-sink relation contributes to seed yield. It includes phloem loading at source (leaf) and unloading at sink (seed) by which the economic part will be getting the assimilates synthesized by photosynthesis. Partitioning of the assimilates in the plant during reproductive development is important for flower, fruit and seeds. Thus, crop yield can be increased either by increasing the total dry matter production or by increasing the proportion of economic yield (harvest index) or both. (Gardener *et. al.,* 1988)

Data indicated that, seed yield plant^{-1} (g), was found significant. The range of seed yield plant^{-1} (g) was recorded 6.48 g to 8.49 g. However, the treatment T_{12} (Salicylic acid @ 150 ppm + Zinc sulphate @ 1.00%) was found significantly superior over the treatment T_1 (control) and other treatments; followed by treatment T_{10} (Salicylic acid @ 100 ppm + Zinc Sulphate @ 1.00%), T_{11} (Salicylic acid @ 150 ppm + Zinc Sulphate @ 0.50%), T_8 (Salicylic acid @ 50 ppm +Zinc Sulphate @ 1.00%), T_9 (Salicylic acid @ 100 ppm + Zinc Sulphate @ 0.50%), T_7 (Salicylic acid @ 50 ppm + Zinc Sulphate @ 0.50%). Whereas, the treatments T_2 (Salicylic acid @ 50 ppm), T_3 (Salicylic acid @ 100 ppm), T_4 (Salicylic acid @ 150 ppm), T_5 (Zinc Sulphate @ 0.50%), T_6 (Zinc Sulphate @ 1.00%) were found at par with control.

Seed yield plot^{-1} (Kg) was found significant. The range of seed yield plot^{-1} (Kg) was recorded 0.89 Kg to 1.16 Kg. However, the treatment T_{12} (Salicylic acid @ 150 ppm + Zinc sulphate @ 1.00%) was found significantly superior over the treatment T_1 (control) and other treatments; followed by treatment T_{10} (Salicylic acid @ 100 ppm + Zinc Sulphate @ 1.00%), T_{11} (Salicylic acid @ 150 ppm + Zinc Sulphate @ 0.50%), T_8 (Salicylic acid @ 50 ppm +Zinc Sulphate @ 1.00%), T_9 (Salicylic acid @ 100 ppm + Zinc Sulphate @ 0.50%) and T_7 (Salicylic acid @ 50 ppm + Zinc Sulphate @ 0.50%). Whereas, the treatment T_2 (Salicylic acid @ 50 ppm), T_3 (Salicylic acid @ 100 ppm), T_4 (Salicylic acid @ 150 ppm), T_5 (Zinc Sulphate @ 0.50%), T_6 (Zinc Sulphate @ 1.00%) were found at par with control.

From the above data it is revealed that foliar spray of salicylic acid and zinc sulphate at concentrations of 150 ppm and 1.00% respectively exhibited best results among all treatments.

Similar results were obtained with Ali and Mahmoud (2013) [1]. The results showed that foliar application of salicylic Acid (SA) enhanced significantly (p<0.05) seed weight plant^{-1} and seed yield ha^{-1} as compared with control (untreated plants) and the superiority was due to the high SA concentration (150 ppm). Significant (p<0.05) increases in all above mention traits were also occurred with foliar application of zinc (400 or 500 ppm) in mungbean. Whereas, Kesarkar *et al.*, (2022) [7] reported that, foliar application of zinc sulphate @ 1.0% significantly improves the seed yield plot^{-1} (Kg) in safflower (*Carthamus tinctorius* L.). Similarly, Monga and Kumar (2022) [10] reported that application of salicylic acid @ 100 ppm significantly increased number of grains spike^{-1}, grain yield (q ha^{-1}) wheat (*Triticum aestivum* L.).

The highest per cent increase in yield (31.33%) over control was observed by the application of 150 ppm salicylic acid + 1.00% zinc sulphate as a foliar spray at 30 and 50 DAS. Next to this treatment foliar spray of 100 ppm salicylic acid + 1.00% zinc sulphate also enhanced the yield by (27.09%) over control.

Harvest index (%)

Data were found statistically significant. Significantly maximum harvest index was recorded in T_{12} (Salicylic acid @ 150 ppm + Zinc sulphate @ 1.00%) when compared with treatment T_1 (control) and other treatments; followed by treatment T_{10} (Salicylic acid @ 100 ppm + Zinc Sulphate @ 1.00%), T_{11} (Salicylic acid @ 150 ppm + Zinc Sulphate @ 0.50%), T_8 (Salicylic acid @ 50 ppm +Zinc Sulphate @ 1.00%), T_9 (Salicylic acid @ 100 ppm + Zinc Sulphate @ 0.50%), T_7 (Salicylic acid @ 50 ppm + Zinc Sulphate @ 0.50%). Whereas, the treatments T_2 (Salicylic acid @ 50 ppm), T_3 (Salicylic acid @ 100 ppm), T_4 (Salicylic acid @ 150 ppm), T_5 (Zinc Sulphate @ 0.50%), T_6 (Zinc Sulphate @ 1.00%) were found at par with control.

Similar results were obtained with Sathish Kumar *et el.*, (2018) [12]. Results showed that foliar application of salicylic acid 40 ppm twice at pre and post flowering stage of crop growth recorded maximum harvest index (29.10%) in finger millet (*Eleusine coracana* (L.) Gaertn.). Whereas, Meena *et al.* (2020) [9] reported that spray of salicylic acid 200 ppm at flowering and siliqua formation stage significantly increased harvest index (32.44%) in Indian mustard (*brassica juncea*). Similarly, Shemi *et al.* (2021) [13] reported that the spraying application of 140 mg l^{-1} SA, 4 g l^{-1} Zn, and 11.5 g l^{-1} GB improved yield and its components such as harvest index (%) in both (well-watered and water deficit) soil conditions in maize. Similarly, Kesarkar *et al.*, (2022) [7] reported that, foliar application of zinc sulphate @ 1.0% significantly improves the harvest index (%) in safflower (*Carthamus tinctorius* L.)

Table 1: Effect of salicylic acid and zinc sulphate on plant height, number of secondary branches, days to flower initiation, days to 50% flowering, days to maturity, total dry weight, leaf area and leaf area index in groundnut.

Treatments	Plant height (cm)			Number of secondary branches plant^{-1}			Days to flower initiation	Days to 50% flowering	Days to maturity	Total dry weight plant^{-1} (g)			Leaf area plant^{-1} (dm^{-2})			Leaf area index		
	40 DAS	60 DAS	80 DAS	40 DAS	60 DAS	80 DAS				40 DAS	60 DAS	80 DAS	40 DAS	60 DAS	80 DAS	40 DAS	60 DAS	80 DAS
T1(Control)	15.32	23.31	26.41	2.08	3.86	4.82	21.73	35.81	113.74	2.31	4.34	11.13	1.29	4.77	5.77	0.29	1.06	1.28
T2 (Salicylic acid @ 50 ppm)	16.00	23.99	24.96	2.34	4.05	5.02	21.47	35.21	113.47	2.48	4.9	14.21	1.34	5.22	6.28	0.3	1.16	1.4
T3 (Salicylic acid @ 100 ppm)	16.22	24.21	26.94	2.99	4.61	5.58	21.07	34.79	113.28	2.57	5.14	16.36	1.39	5.22	6.31	0.31	1.16	1.4
T4 (Salicylic acid @ 150 ppm)	17.24	25.23	27.63	3.1	4.79	5.75	21.4	34.13	113.07	2.65	5.88	19.32	1.46	5.27	6.37	0.32	1.17	1.42
T5 (Zinc Sulphate @ 0.50%)	17.02	25.01	27.31	2.94	4.47	5.44	20.4	34.44	112.77	2.84	6.81	25.22	1.66	6.39	7.11	0.37	1.42	1.58
T6 (Zinc Sulphate @ 1.00%)	17.72	25.71	28.79	3.85	4.99	5.96	21.53	33.83	112.62	2.88	7.04	28.29	1.76	6.38	7.23	0.39	1.42	1.61
T7 (Salicylic acid @ 50 ppm + Zinc Sulphate @ 0.50%)	18.29	26.27	29.01	3.61	4.41	5.38	21.53	33.17	112.35	2.78	6.53	23.11	1.63	5.63	6.98	0.36	1.25	1.55
T8 (Salicylic acid @ 50 ppm +Zinc Sulphate @ 1.00%)	20.17	28.15	30.55	3.71	4.94	5.9	20.6	32.33	111.22	2.91	7.23	30.21	1.84	6.33	7.17	0.41	1.41	1.59
T9 (Salicylic acid @ 100 ppm + Zinc Sulphate @ 0.50%)	19.73	27.71	30.45	3.6	5.84	6.81	21.8	32.87	111.49	2.84	6.81	25.22	1.72	6.21	7.08	0.38	1.38	1.57
T10 (Salicylic acid @ 100 ppm + Zinc Sulphate @ 1.00%)	21.21	29.19	31.93	4.26	6.26	7.22	21.6	31.97	110.2	3.15	7.9	34.12	1.88	6.65	8.18	0.42	1.48	1.82
T11 (Salicylic acid @ 150 ppm + Zinc Sulphate @ 0.50%)	20.88	28.86	31.6	4.2	5.91	6.87	21.53	32.29	110.62	3.12	7.7	32.12	1.85	6.61	7.44	0.41	1.47	1.65
T12 (Salicylic acid @ 150 ppm + Zinc Sulphate @ 1.00%)	21.53	29.51	32.25	4.37	6.93	7.89	21.4	31.22	110.15	3.18	8.11	37.61	1.93	7.25	8.69	0.43	1.61	1.93
SE (m) +	1.084	1.083	2.142	0.259	0.476	0.476	0.306	2.3	2.6028	0.16	0.42	1.35	0.09	0.36	0.49	0.02	0.08	0.11
CD at 5%	3.178	3.18	6.283	0.761	1.395	1.395	--	6.745	--	0.47	1.24	3.96	0.26	1.04	1.45	0.06	0.23	0.32

Table 2: Effect of salicylic acid and zinc sulphate on RGR, NAR, Seed yield plant-1 (g), Seed yield plot-1 (Kg), Per cent increase over control, Harvest index (%),

Treatments	Relative Growth Rate (g g^{-1} day^{-1})		Net Assimilation Rate (g dm^{-2} day^{-1})		Seed yield plant^{-1} (g)	Seed yield plot^{-1} (kg)	Per cent increase over control	Harvest index (%)	B : C ratio
	40-60 DAS	60-80 DAS	40-60 DAS	60-80 DAS					
T1(Control)	0.0317	0.0471	0.0382	0.0646	6.48	0.89	-	29.51	1.99
T2 (Salicylic acid @ 50 ppm)	0.0343	0.0533	0.0424	0.0812	6.95	0.92	3.35	30.47	2.05
T3 (Salicylic acid @ 100 ppm)	0.035	0.058	0.0444	0.0976	7.13	0.95	6.76	31.11	2.12
T4 (Salicylic acid @ 150 ppm)	0.0399	0.0595	0.0544	0.1158	7.37	0.98	10.17	32.09	2.19
T5 (Zinc Sulphate @ 0.50%)	0.0437	0.0655	0.0568	0.1393	7.70	1.00	12.70	31.63	2.26
T6 (Zinc Sulphate @ 1.00%)	0.0444	0.0697	0.0585	0.157	7.76	1.05	18.60	32.21	2.41
T7 (Salicylic acid @ 50 ppm + Zinc Sulphate @ 0.50%)	0.0425	0.0631	0.06	0.1359	7.79	1.03	16.05	32.59	2.33
T8 (Salicylic acid @ 50 ppm +Zinc Sulphate @ 1.00%)	0.0454	0.0715	0.0598	0.1703	8.12	1.09	22.87	34.17	2.49
T9 (Salicylic acid @ 100 ppm + Zinc Sulphate @ 0.50%)	0.044	0.0649	0.0567	0.1432	7.92	1.07	20.33	32.82	2.42
T10 (Salicylic acid @ 100 ppm + Zinc Sulphate @ 1.00%)	0.0458	0.0737	0.0629	0.1778	8.42	1.13	27.09	36.49	2.58
T11 (Salicylic acid @ 150 ppm + Zinc Sulphate @ 0.50%)	0.0442	0.0723	0.061	0.1757	8.32	1.10	24.55	35.83	2.50
T12 (Salicylic acid @ 150 ppm + Zinc Sulphate @ 1.00%)	0.0469	0.0767	0.063	0.1879	8.49	1.16	31.33	38.61	2.66
SE (m) ±	0.0028	0.0028	0.0054	0.0149	0.19	0.05	-	1.74	
CD at 5%	0.0081	0.0082	0.0158	0.0436	0.56	0.15	-	5.11	

B:C ratio in groundnut

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