Original Research Article

Effect of foliarly-treated salicylic acid on the yield of *Pennisetumglauca*

ABSTRACT

Pennisetumglauca is a worthy cereal crop in the world with multiple functions in staple food, feed, fodder and good source of energy. The phytohormone, salicylic acid (SA) plays an essential role in the improvement of productivity in bajra. Foliar exogenous application of SA is a simple and effective way to improve the yieldin the number, size and weight of *Pennisetumglaucum* seeds. The treatment of bajra plants with 3.0 mM salicylic acid (SA) increased the size, weight and number of seeds per single panicle and elevated the productivity. With the present study, it was proven that SA application was associated with the enhancement of productivity inbajra and the data suggests that SA - application inducedenhancement of productivity of bajragrown in drought stressed regions of Telangana.

Comment [C1]: This part of the sentence needs to be rewritten.

Comment [C2]: At the beginning of the sentence the general name of the plant should be mentioned.

Key Words: Bajra; panicle; salicylic acid; seed weight; yield

INTRODUCTION

Bajraor *Pennisetumglaucum* (L.) R.Br., belongs to grass (Poaceae) family,is cosmopolitan in distribution and widely cultivated in different parts of the world though it is native to West Africa. It is widely cultivated in tropical areas for its edible grains, stover, and fodder in various parts of the globe.The germplasm of both cultivated and wild bajra is conserved as 66,682 accessions in 97 gene banks in around 65 countries [1]. Bajra is a

predominant grain cereal and forage crop of Indian subcontinent and African regions. Bajrais one of the sixth most important cereal crops in the world production after wheat (*Triticumaestivum* L.), rice (*Oryzasativa* L.), maize (*Zea mays* L.), barley (*Hordeumvulgare* L.) and sorghum (*Sorghum bicolor* (L.) Moench). It is the second most sought after millet after sorghum. Bajra is the most widely grown staple food crop of majority of poor and small land holders in Asia and Africa and can be cultivated in sandy soils even in dry conditions [2]. In India, bajra is the fourth most widely cultivated food crop after rice, wheat and maize. It occupies nearly 7.4 million hectares with an average production of 9.13 million tonnes and productivity of 1237 kg/ha during 2017-2018 as reported by Directorate of Millets Development in 2019. The major bajra growing states in India are Rajasthan, Maharashtra, Uttar Pradesh, Gujarat and Haryana which produce nearly 90% of the total production of the country.

Bajra is a good source of energy as it comprises of carbohydrates, fat, ash, dietary, proteins, vitamins, fatty acids, fibres, iron and zinc and thus is a staple food for the millions of people. It generally comprises of 9-13% protein, though a large variation exists among genotypes wherein proteins ranging from 6-21% have been observed [3]. It is high in fibre around 1.2 g/100g and shows alpha-amylase activity when compared with other grains.

Comment [C3]: What do you mean?

Salicylic acid (SA)being very typical to its organic compound is water phobic in nature and is a phenolic compound which participates in the regulation of cell suspension cultures [4], flowering [5], seed germination [6], sulphur and nitrogen metabolism [7], photosynthesis [8]proline metabolism [9] etc. Application or supplementation of SA resulted in mitigating different abiotic stresses in plants such as drought [10-12], chilling [13-14], salinity stress [15-17], heavy metal tolerance [18-19], heat [20], UV radiation [21] etc. SA

Comment [C4]: The sentence is unclear.

can be supplemented to plants by foliar application [22], soil treatment [23] and was effective even when supplied by hydroponically [24]. In the present study, bajra seeds were used to investigate the yield quantity in the drought stressed regions of Telangana which is one of the most important crops all over the world. The present study was conducted to analyze the effect of foliarly-treated salicylic acid (SA) on the yield of bajra grown in drought stressed Telangana State, India.

MATERIAL AND METHODS

Bajra seeds were procured from Natural Seeds Corporation, Madikonda, Warangal Urban district, Telangana State, India during the *Kharif* - 2014 and *Rabi* – 2015 seasons. One popularly used local variety of seeds viz., *Ananta* was employed in the present experiment work.SA (SD-fine) was procured from Dwarakamai Enterprises located in Hyderabad of Telangana State, India. Individual plots were prepared with a size of 10×10 m. The plots were uniformly mixed with twenty five kilograms of conventional compost. The bajraplants were grown in field (10×100 m - length and width) containing fresh sieved reddish soil mixed with organic manure. The seeds of bajra viz., variety *Ananta* were surface first sterilized with 0.5% (v/v) sodium hypochlorite and washed carefully with several changes of sterile distilled water to remove any additional sodium hypochlorite adhering to them. They were immersed for 24h in *Rhizobium* inoculums. Thirty Seeds of bajra were sown in each row keeping a gap of about 40 cm between each row and a total of twelve rows (treated nine rows for three different concentrations of SA and three rows as controls) were prepared in the field and totally 630 seeds were sown in 10×10 m well prepared plot. Germination of bajra seeds started around3-4 days after sowing. On the 7^{th} day (3-4 leaves stage) after the germination, approximately 75% of plants (ca. 470 individuals) were

UNDER PEER REVIEW

retained in the soil. Bajra crops were grown under natural day length and observed initiation of panicle in 4th week (22nd day onwards). Salicylic acid (SA) was supplied at six different concentrations viz., 0.5 mM, 1.0 mM, 2.0 mM, 3.0 mM, 3.5mM and 4.0 mM and three rows (total nine rows) were maintained for each concentration of SA in the bajra field. Three rows were maintained as controls which were supplemented with water. SA was supplemented as foliar spray to bajra crop and the spraying was done in the wee hours of the morning by using sprayers. Foliar application of SA was done thrice to bajra plants on 20th, 40th and 50th (from the day of sowing of seeds) whereas the untreated bajra controls were supplied with distilled water.

RESULTS

The effect of six concentrations of salicylic acid (SA) viz., 0.5 mM SA, 1.0 mM SA, 2.0 mM, 3.0mM SA, 3.5 mM SA and 4.0 mM SA on the reproductive growth were quantified as panicles/plant and length of panicle of bajra.

Comment [C5]: SA

Number of Panicles/Plant

Application of 3.0 mM concentration of SA caused a maximum raise in the production of number of panicles in bajra plants around 202.91%, followed by 2.0 mM concentration of SA which caused a raise of 186.41%, followed by 1.0 mM conc. of SA which caused a raise of 136.89% and 0.5 mM conc. of SA which caused a raise of 86.41% over water-treated control plants (Figure 1).

Comment [C6]: The figure is sufficient, there is noneed to present the content in this form.

UNDER PEER REVIEW

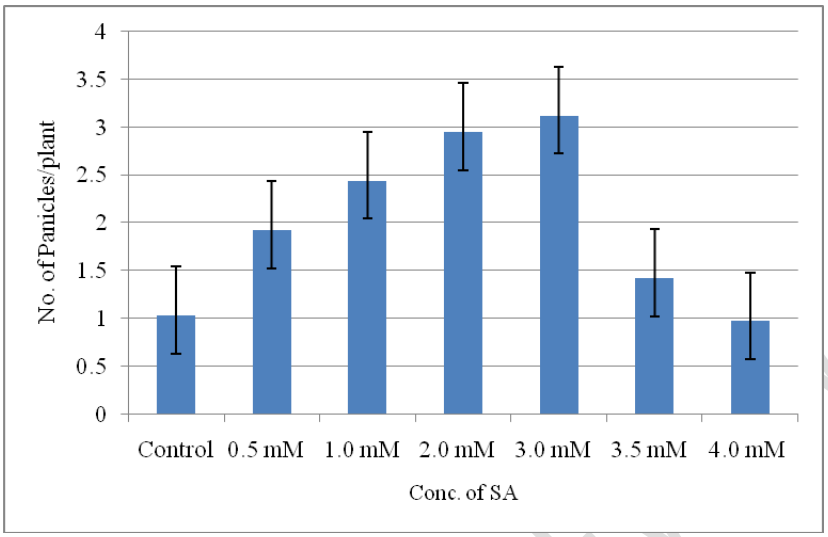

Figure 1. Salicylic Acid (SA) on the Number of Panicles/Plant (65th Day from Sowing) of Bajra Grown in Drought –Stressed Telangana State

*The results presented are the mean values of 9 replicates. One-way analysis of variance (ANOVA) was carried out and the differences were considered significant if p was ≤ 0.05.

Length of Panicle

Treatment of 3.0 mM concentration of SA caused a maximum hike in the length of panicles in bajra plants around 48.52%, followed by 2.0 mM concentration of SA which caused a hike of 25.05%, followed by 1.0 mM conc. of SA which caused a hike of 19.88% and 0.5 mM conc. of SA which caused a hike of 14.61% over untreated control plants.The treatment of other two concentrations of SA viz., 3.5 mM and 4.0 mMdepicteddiminished length of panicles in bajra compared to the other four treatments mentioned above. Treatment of 3.5 mM concentration of SA caused a slight hike of around 2.73% where as 4.0 mM concentration of SA caused a diminution of around 12.79% in panicle length compared to water - treated controls (Figure 2).

Comment [C7]: The figure is sufficient, there is noneed to present the content in this form.

UNDER PEER REVIEW

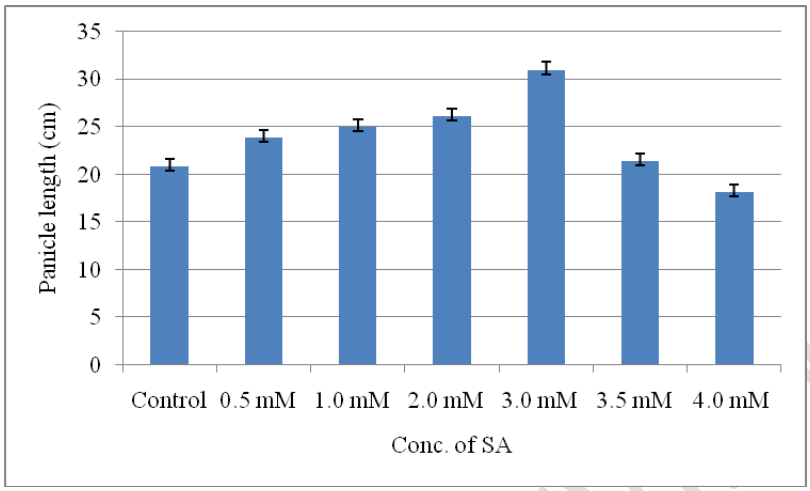

Figure 2. Salicylic Acid (SA) on the Length of Panicle (65th Day from Sowing) of Bajra Grown in Drought –Stressed Telangana State.
*The results presented are the mean values of 9 replicates. One-way analysis of variance (ANOVA) was carried out and the differences were consideredsignificant if p was ≤ 0.05.

The effect of six different concentrations of salicylic acid (SA) viz., 0.5mM, 1.0mM, 2.0 mM, 3.0 mM, 3.5 mM and 4.0mM on the yield of bajra was quantified as number of seeds/panicle and 1000 seeds weight on the 85th day after sowing.

Seeds/Panicle

The foliar application of six concentrations of salicylic acid (SA) viz., 0.5 mM, 1.0 mM, 2.0 mM, 3.0 mM, 3.5 mM and 4.0 mM did not show same result patterns (Figure 3). Application of 3.0 mM concentration of SA caused a maximum surge in the production of number of seeds per a panicle in bajra plants around 51.86%, followed by 2.0 mM concentration of SA which caused a surge of 43.19%, followed by 1.0 mM conc. of SA which caused a surge of 37.52% and 0.5 mM conc. of SA which caused a surge of 11.80% over untreated control plants.

The application of other two concentrations of SA viz., 3.5 mM and 4.0 mMdepicted varying patterns not following the gradual surging.nApplication of 3.5 mMconcentration of

UNDER PEER REVIEW

SA was caused a slight surge of 5.64% but application of 4.0 mM concentration of SA lessenedby 11.81% in the production of seeds in bajra plants.

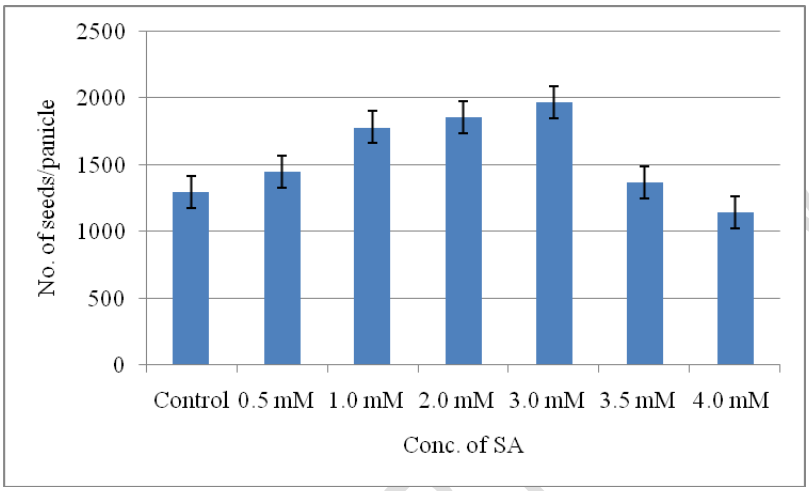

Figure 3. Salicylic Acid (SA) on the Seeds/ Panicles (85th Day from Sowing) of Bajra Grown in Drought –Stressed Telangana State
*The results presented are the mean values of 9 replicates. One-way analysis of variance (ANOVA) was carried out and the differences were considered significant if p was ≤ 0.05.

1000 Seed Weight

The four treatments of salicylic acid (SA) viz., 0.5 mM, 1.0 mM, 2.0 mM and 3.0 mM substantially raised the 1000 seed weight per panicle in bajra plants (Figure 4). Treatment of 3.0 mM concentration of SA caused a maximum raise in the seed weight in bajra plants around 52.84%, followed by 2.0 mM concentration of SA which caused a raise of 39.18%, followed by 1.0 mM conc. of SA which caused a raise of 32.9% and 0.5 mM conc. of SA which caused a raise of 22.23% over untreated control plants. The treatment of the above four concentrations of SA viz., 0.5 mM, 1.0 mM, 2.0 mM and 3.0 mM resulted in better 1000 seed weight in bajra plants.

UNDER PEER REVIEW

The application of other two concentrations of SA viz., 3.5 mM and 4.0 mMdepicted in gradual reduction of 1000 seed weight in bajra plants compared to the above mentioned treatments. Application of 3.5 mM concentration of SA was caused a slight raise of 4.39% but 4.0 mM concentration of SA caused a decline in the 1000 seed weight of bajra crop by 3.89%.

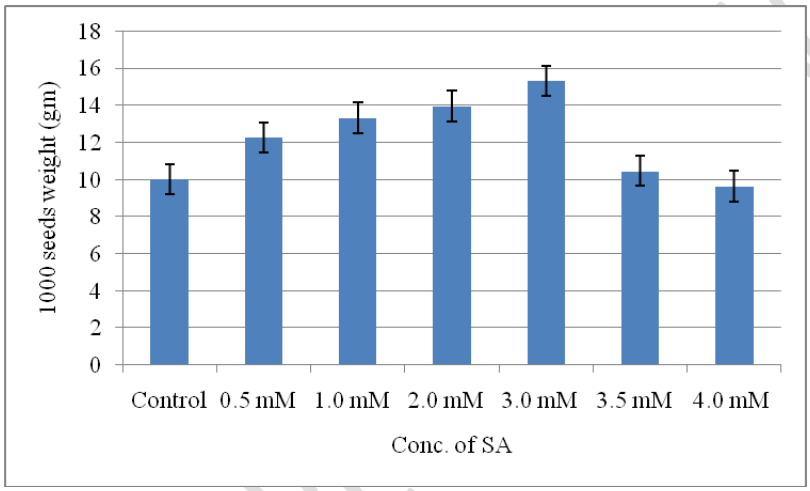

Figure 4.Salicylic Acid (SA) on the 1000 Seed Weight (85th Day from Sowing) of Bajra.

*The results presented are the mean values of 9 replicates. One-way analysis of variance (ANOVA) was carried out and the differences were considered significant if p was ≤ 0.05.

DISCUSSION

The present research study focussed on the application of salicylic acid (SA) on the yiels of bajra plant. Earlier researchers also observed the potentiality of SA in improvenment of crop growth and yield. Asghari and Aghdam[25] observed that exogenous treatment of SA increased fruit formation and overall productivity in different horticultural plants. Abdel-Salam [26]opined that exogenous application of SA in combination with few micronutrients to grapevine depicted improved yield parameters like cluster weight, berry weight and

quantity of berry juice. Application of SA alleviated the salinity stress of *Rosmarinusofficinallis* L. by modifying the chemical composition, gene expression and bioactivity of plant secondary metabolites in terms of specific major essential oils components causing reductions in α-pinene, β-pinene, and cineole along with sharp increases in linalool, camphor, borneol, and verbenone[27]. Tahjib-Ul-Arif et al [28] reported that exogenous treatment of SA enhanced the yield parameters in *Zea mays* by enhancement of photosynthetic attributes and antioxidant capacity. Mohamed et al. [29]observed the effect of salicylic acid foliar spray at 3 mM concentration level which increased the vegetative growth, number of flower clusters in strawberry (*Fragaria* × *ananassa*Duch) cultivars, and different studies were also proved the yield increases in many plant species after exogenous application of salicylic acid [30-33].

CONCLUSION

The foliar application of six different concentrations of salicylic acid (SA) viz., 0.5 mM, 1.0 mM, 2.0 mM, 3.0 mM, 3.5 mM and 4.0 mM did not depict similar result patterns on the yield of bajraquantified in terms of number of seeds/panicle and 1000 seeds weight. Four out of the six treatments of salicylic acid (SA) viz., 0.5 mM, 1.0 mM, 2.0 mM and 3.0 mM substantially surged the production of the yield (number of seeds/panicle and 1000 seeds weight of bajra. Application of 3.0 mM concentration of SA caused a maximum surge in the yield of bajra plants followed by 2.0 mM, 1.0 mM and 0.5 mM conc. of SA. The application of other two concentrations of SA viz., 3.5 mM and 4.0 mM exhibited varying patterns not following the gradual surging. Application of 3.5 mM concentration of SA caused a slight surge but 4.0 mM concentration of SA caused a decrease in yield of bajra plants.

UNDER PEER REVIEW

REFERENCES

1. Santosh, K., Pattanshetti, Upadhyaya, H.D., Dwivedi, S.L., Vetriventhan, M. and Reddy, K.N. 2016. Pearl Millet. pp. 253-289. *In*: Singh, M., Upadhyaya, H.D. (eds.), Genetic and genomic resources for grain cereals improvement. Academic Press, Elsevier (pp. 384).
2. Tako, E., Redd, S.M., Budiman, J., Hart, J.J. and Glahn, R.P. 2015. Higher iron pearl millet (*Pennisetumglaucum* L.) provides more absorbable iron that is limited by increased polyphenolic content. Nutrition Journal 14:11.
3. Manning, K., Pelling, R., Higham, T., Schwenniger, J.-L., Fuller, D.Q. 2011. 4500-year old domesticated pearl millet (*Pennisetumglaucum*) from the Tilemsi Valley, Mali: new insights into an alternative cereal domestication pathway. Journal of Archaeological Science 38:312-322.
4. Dean, J.V., Mohammed, L.A. and Fitzpatrick, T. 2005. The formation, vacuolar localization, and tonoplast transport of salicylic acid glucose conjugates in tobacco cell suspension cultures. Planta 221:287-296.
5. Jin, J.B., Jin, Y.H., Lee, J. et al. 2008. The SUMO E3 ligase, AtSlZ1, regulates flowering by controlling a salicylic acid-mediated floral promotion pathway and through effects on FLC chromatin structure. The Plant Journal 53:530-540.
6. Lee, S., Kim, S.-G. and Park, C.-M. 2010. Salicylic acid promotes seed germination under high salinity by modulating antioxidant activity in *Arabidopsis*. New Phytologist 188: 626-637.
7. Nazar, R., Iqbal, N., Syeed, S. and Khan, N.A. 2011. Salicylic acid alleviates decreases in photosynthesis under salt stress by enhancing nitrogen and sulphur assimilation and antioxidant metabolism differentially in two mung bean cultivars. Journal of Plant Physiology 168:807-815.
8. Mateo, A., Funck, D., Muhlenbock, P., Kular,B., Mullineaux , P.M. and Karpiniski , S. 2006. Controlled levels of salicylic acid are required for optiomal photosynthesis and relox homeostasis. Journal of Experimental Botany 57:1795-1807.
9. Saruhan, N., Saglam, A. and Kadioglu, A. 2012. Salicylic acid pre-treatment induces drought tolerance and delays leaf rolling by inducing antioxidant systems in maize

UNDER PEER REVIEW

genotypes. Acta Physiologiae Plantarum 34: 97-106.Doi: 10.1007/S11738-011-0808-7.

10. Alam, M., Hasanuzzaman, M., Nahar, K. and Fujita, M. 2013. Exogenous salicylic acid ameliorates short-term drought stress in mustard (*Brassica juncea* L.) seedlings by up-regulating the antioxidant defence and glyoxalase system. Australian Journal of Crop Science 7:1053-1063.
11. Karim, S., Aronsson, H., Ericson, H., Pirhonen, M., Leyman, B., Welin, B., Mantyla, E., Palva, E.T., Dijck, P.V. and Holmstrom, K. 2007. Improved drought tolerance without undesired side effects in transgenic plants producing trehalose. Plant Molecular Biology 64: 371-386.
12. Nazar, R., Umar, S., Khan, N.A. and Sareer, O. 2015. Salicylic acid supplementation improves photosynthesis and growth in mustard through changes in proline accumulation and ethylene formation under drought stress. South African Journal of Botany 98:84–94.
13. Mutlu, S., Karadago-Glu,-O., Atici, O. And Nalbantoglu, B. 2013. Protective role of salicylic acid applied before cold stress on antioxidative system and protein patterns in barley apoplast. Boilogicae Plantarum 57: 507-513.Doi: 10.1007/S10535-013-0322-4.
14. Baninaiem, E., Mirzaaliandastjerdi, A.M., Rastegar, S. and Abbaszade, Kh. 2016. Effect of pre- and postharvest salicylic acid treatment on quality characteristics of tomato during cold storage. Advances in Horticultural Sciences 30(3): 183.
15. Fayez. K.A. and Bazaid, S.A. 2014. Improving drought and salinity tolerance in barley by application of salicylic acid and potassium nitrate. Journal of Saudi Society of Agricultural Science 13: 45-55.
16. Khan, M.S., Akther, T., Mubarak, A.D. and Hemalatha, S. 2019. An investigation on the role of salicylic acid alleviate the saline stress in rice crop (*Oryza sativa* L.). Biocatalysis and Agricultural Biotechnology 10:10-27.
17. Miura, K. and Tada, Y. 2014. Regulation of water, salinity, and cold stress responses by salicylic acid. Frontiers in Plant Sciences 5:4. Doi: 10.3389/Fpls.2014. 00004.

UNDER PEER REVIEW

18. Krantev, A., Yordanova, R., Jarda, T., Szalai, G. and Popova, L. 2008. Treatment with salicylic acid decreases the effect of cadmium on photosynthesis in maze plants. Journal of Plant Physiology 165(9):920-931.
19. Ahmad, B., Jaleel, H., Sadiq, Y., Khan, M.M.A. and Shabbir, A. 2018. Response of exogenous salicylic acid on cadmium induced photosynthetic damage, antioxidant metabolism and essential oil production in peppermint. Journal of Plant Growth Regulation 86:273–286.
20. Khan, M.I.R., Iqbal, N., Masood, A., Per, T. S., and Khan, N.A. 2013. Salicylic acid alleviates adverse effects of heat stress on photosynthesis through changes in proline production and ethylene formation. Plant Signaling and Behavior 8:E26374. doi:10.4161/Psb.26374.
21. Bandurska, H. and Cieslak, M. 2013. The interactive effect of water deficit and UV-B radiation on salicylic acid accumulation in barley roots and leaves. Environmental and Experimental Botany 94:9-18.
22. Chen, Z., Zheng Z., Haung, J., Lai, Z. and Fan, B. 2009. Biosynthesis of salicylic acid in plants. Plant Signaling and Behaviour 4:493-496.
23. Arfan, M. 2009. Exogenous application of salicylic acid through rooting medium modulates ion accumulation and antioxidant activity in spring wheat under salt stress. International Journal of Agricultural Biology 11:437-442.
24. Janda, T., Szalai, G., Tari, I. andPaldi,E. 1999. Hydroponic treatment with salicylic acid decreases the effect of chilling injury in maize (*Zea mays*) plants. Plant 208:175-180.
25. Asghari, M. and Aghdam, M.S. 2010: Impact of salicylic acid on post harvest physiology of horticultural Crops. Trends in Food Science and Technology 21:502-509.
26. Abdel-Salam, M.M. 2016. Effect of foliar application of salicylic acid and micronutrients on the berries quality of "*Bez El Naka"* local grape cultivator. Middle East Journal of Applied Science 6(1):178-188.
27. El-Esawi, M.A., Elansary, H.O., El-Shanhorey, N.A., Abdel-Hamid, A.M., Ali, H.M. and Elshikh, M.S. 2017. Salicylic acid-regulated antioxidant mechanisms and gene

UNDER PEER REVIEW

expression enhance rosemary performance under saline conditions. Frontiers in Physiology 8:716.

28. Tahjib-Ul-Arif, M., Siddiqui, M.N., Sohag, A.A.M., Sakil, M.A., Rahman, M.M., Polash, M.A.S., Mostofa, M.G. and Tran, L.-S.P. 2018.Salicylic acid-mediated enhancement of photosynthesis attributes and antioxidant capacity contributes to yield improvement of maize plants under salt stress. Journal of Plant Growth Regulation 37:1318–1330.
29. Mohamed, R.A., Abdelbaset, A.-K. andABd-Elkader, D.Y. 2018. Salicylic acid effects on growth, yield, and fruit quality of strawberry cultivars. Journal of Medicinally Active plants 6(2): 1-11.
30. El-Tayeb, M.A. 2005. Response of barley grains to the interactive effect of salinity and salicylic acid. Plant Growth Regulation 45:215-224.
31. Khodary, S.E.A. 2004. Effect of salicylic acid on the growth, photosynthesis and carbohydrate metabolism in salt-stressed maize plants. Journal of Agricultural Biology 6: 5-8.
32. Larque-Saavedra, A. and Martin-Mex, R. 2007. Effect of salicylic acid on the bio-productivity of plants. In: S. Hayat and A. Ahmed (eds.), Salicylic acid: a plant harmone. Sping Publishers, Dordrecht, The Netherlands. pp. 15-23.
33. Yildirim, E., Turab, E. and Guvenc, M. 2008. Effect of foliar salicylic acid application on growth, chlorophyll and mineral content of cucumber grown under salt stress. Journal of Plant Nutrition 31:593-612.

UNDER PEER REVIEW