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Research Article

Yield and component yield of onion (*Allium cepa* L.) effect of salicylic acid under drought stress in Indonesia

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Abstract
The use of salicylic acid as a resistance inducer agent in several plant species was well known. Salicylic acid has been believed to play an important role in inducing drought resistance. The use of salicylic acid and dryness in onion (*Allium cepa* L.) has never been studied. The present study aimed to ascertain how limited water supply and salicylic acid (SA) interact with onion (Allium cepa L.) yield and component yield traits. A completely randomized design (CRD) and two-factor treatment with three replications were employed in the investigation. Drought was the first factor (FC1(field capacity), FC2 (at 60% field capacity), FC3 (at 20% field capacity). The concentration of salicylic acid (SA) was the second component (0 mM, 0.5 mM, and 1 mM). The following parameters were measured: relative water content (RWC), water use efficiency (WUE), plant height, number of leaves, number of tillers, root length, chlorophyll content index (CCI), proline, bulb weight (bw), strawweight (w), bulb diameter, bulb production (bp), harvest index (hi), and bulb diameter. The results showed that tillers increased (7.0 to 10.0) as SA concentration increased at three levels of dryness. However, plant height (40.6 to 30.0cm) and the number of leaves (24.3 to 16.0) decreased as drought increased. Dryness in bulb weight, strawweight, bulb diameter, and bulb production could not be alleviated by the SA concentration. Salicylic acid 1 mM has been able to overcome drought up to 20% of field capacity as indicated by plant height and leaf area but was unable to prevent drought on bulb weight and tuber diameter. Thus, the concentration of salicylic acid given would help to overcome drought (water deficit) in shallot plants.

Keywords: Drought, Onion bulbs, Proline, Salicylic acid, Tiller

INTRODUCTION

Onions (*Allium cepa* L.) are shallow-rooted plants with maximum roots in about 20 cm of topsoil and only a few roots penetrate deep into the soil (Kusugak and Dasgan. 2017; Ghodke *et al*.,2018). Drought is a factor that significantly disrupts physiological processes in plants (inhibits germination, reduces growth, lowers yields, and interferes with key metabolic processes) (Maksimović *et al*., 2021; Megala *et al*., 2022). Its influence is more evident during the reproductive stage than other growth stages, and yields are significantly decreased (Atta *et al*., 2022; Rehman *et al*., 2021). The severity, duration, type of plant species, and stage of development affect how plants react to drought stress. When pressured by drought, the plants narrow their stomata to reduce further water loss (Manosjkumar *et al*., 2021)

Plants produce salicylic acid (SA), a hormone that functions as a signaling molecule to mitigate the detrimental effects of abiotic stressors like drought (Jini and Joseph, 2017). Two distinct processes, isochorismate synthase- and phenylalanine ammonia-lyase-dependent mechanisms, are used to biosynthesize SA from chorismate (Koo *et al*., 2020). Numerous studies have demonstrated that salicylic acid increases a plant's tolerance to biotic and abiotic stresses as well as growth indices like the fresh and dry weight of roots and shoots, leaf area, and other parameters. (Ratnarajah and Gnanachelvam, 2021). Researchers have paid more attention to this issue and made significant progress in reducing the negative effects of drought and increasing the production of drought-tolerant varieties (Seleiman *et al*., 2021). This study aimed to ascertain how drought stress and salicylic acid (SA) interacted to affect onion (*Allium cepa* L) growth, production, and physiological traits.

MATERIALS AND METHODS

Plant materials and growth conditions

From June to October 2022, the study was conducted at the Greenhouse and Plant Ecology and Production Laboratory of the Diponegoro University in Semarang's Faculty of Animal Husbandry and Agriculture. The research site is located at latitudes 6^o55'34" to 7^o07'04" in the south and 110^o16'20" to 110^o30'29" to the east and at an altitude of 125 meters above sea level with an average daily temperature of 22 to 34°C, air humidity of 75% and 3359 mm of annual rainfall.

Preparation of field

The experiment of onion (*Allium cepa* var Bima Brebes) employed a 3 x 3 factorial study with three replications of a completely randomized design (CRD). The first factor was drought, which was kept at bay by FC1 by keeping the soil moist (not dry), FC2 by maintaining a 60% medium field capacity, and FC3 by maintaining a 20% medium field capacity condition. The second factors were SA1, SA2, and SA3, which are salicylic acid concentrations of 0, 0.5, and 1 mM, respectively.

Drought stress was computed using % field capacity, 60% field capacity, and 20% field capacity. During the vegetative phase at 14 DAP and 21 DAP, the SA treatment was applied to the leaves by spraying (Sayyari *et al*., 2013). The recommended spraying volume was 25 ml per plant (Khandaker *et al*., 2011). In the morning, random leaf samples for relative leaf water content (RLWC) measurements were collected Leaf samples were taken on the 30th day after planting. RLWC (%) was calculated using the procedure Wu and Bao, 2011. Proline was measured using the technique of Purbajanti *et al*. (2017). The measured parameters included relative leaf water content, WUE, plant height, number of leaves, tillers, root length, chlorophyll content index, proline, and bulb.

Statistical analysis

One-way analysis of variance was used to assess the data, and then Tukey's test with a significance level of 5% was used to compare the means using Minitab 2017 software.

RESULTS

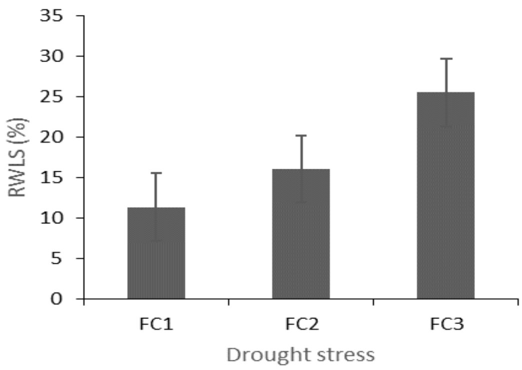
Relative Leaf Water Content and Water use efficiency

Salicylic acid had no meaningful effect, while the single factor limiting water did, and there was no interaction between the two. According to statistical data analysis, limited water and salicylic acid interaction had no appreciable effects on leaf water potential (Fig 1A). The most prevalent symptoms are water loss, photosynthetic inhibition, growth restriction, and cell membrane damage in plants under drought stress (Wan *et al*., 2021). The most important indicator for studies on drought stress is relative water content (RWC). Most genotypes exhibit an average relative moisture content (RWC) of 80–84% (Meher et al., 2018). With increasing drought stress, RWC declines. RWC permits the continuance of metabolic activity by osmotic adjustment and other drought adaption qualities when it can be maintained in cells and tissues. The leaves of plants with relatively low moisture content (RLWC) demonstrate diverse effects of water shortages on these plants due to competition between the top and bottom of the plant for the finest resources, resulting in stunted root development (Arefi *et al*., 2016). There is no interaction between the dryness factor (water deficit) and salicylic acid. The salicylic acid factor has a significant effect (Fig 1B). The ratio of carbon assimilated as biomass or grain produced per unit of water utilized by plants is known as water usage efficiency (WUE). WUE expands as the water deficit widens (Hatfield and Dold, 2018).

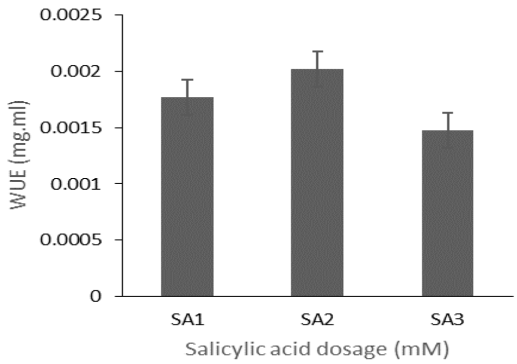
Growth of onion

Plant height exhibited a higher decline at FC3 (20% dry stress capacity) than at FC2 (60% dry stress) and not stressed (100% field capacity) (Fig.1C). The non-stressed plant reached its maximum height at 0 mM salicylic acid (40.66 cm). FC3 had the lowest height, whereas FC2 provided the same height between o, 0.5, and 1 mM. Due to the impact of water stress during the appropriate harvest season, the plant height for stress treatment was much lower than that without stress.

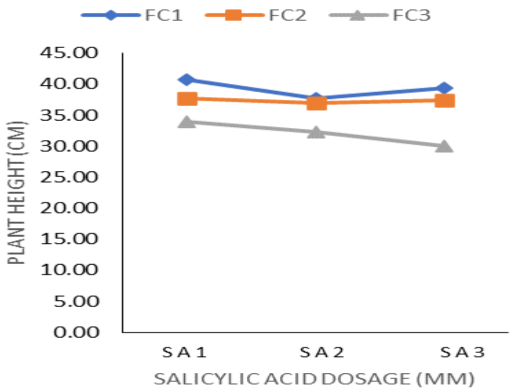
At FC3 dry stress, the number of leaves decreased by FC2, but the reduction was less (Fig. 1D). According to the study's findings on root length characteristics, plants that were not subjected to dry stress (100 percent field capacity) saw a rise in root length that grew abruptly at a concentration of 0.5 mM and then gradually at a dosage of 1 mM (Table 1). The pattern of stressed plants rose at 0.5% salicylic acid concentration and reduced somewhat in 1 mM (FC2) salicylic acid or decreased dramatically in stress weight (FC3) under mild (FC2) or severe (FC3) stress. The ANOVA findings revealed no discernible interaction between



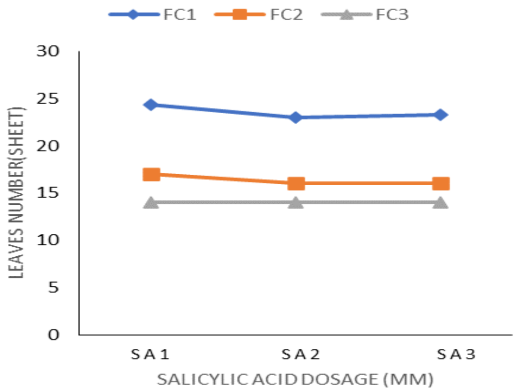
A. *Relative water content effect of drought stress*



B. *Water use efficiency effect of salicylic acid*



C. *Plant height*



D. *Leaves number*

Fig. 1 A-C. *Relative water content, water use efficiency, plant height, and number of leaves of onion due to drought treatment and salicylic acid*

Table 1. Tiller number, root length, chlorophyll content index (CCI), and proline of onion due to drought treatment and salicylic acid

Field capacity	**Treatment salicylic acid**	**Tillers number**	**Root length Cm**	**CCI**	**Proline $\mu g.mL^{-1}$.**
FC1	SA1	6.0[e]	2.00[f]	54.13[a]	0.11[b]
FC1	SA2	8.0[b]	6.00[d]	56.83[a]	0.08[f]
FC1	SA3	8.0[b]	4.00[h]	53.43[a]	0.05[h]
FC2	SA1	8.0[b]	8.00[c]	52.40[a]	0.07[g]
FC2	SA2	7.0[cd]	10.00[a]	48.83[a]	0.04[i]
FC2	SA3	6.3[de]	8.00[c]	45.40[a]	0.08[e]
FC3	SA1	10.0[a]	9.00[b]	38.86[a]	0.12[a]
FC3	SA2	7.33[bc]	10.00[a]	38.46[a]	0.08[d]
FC3	SA3	2.0[f]	5.00[e]	52.50[a]	0.09[c]
	LSD	0.278	0.00	8.73	0.00
FC1		7.3 [a]	4.00 [c]	54.80[a]	0.08[b]
FC2		7.1 [a]	8.66[a]	48.87[ab]	0.06[c]
FC3		6.4 [b]	8.00[b]	43.27[b]	0.10[a]
	LSD	0.008	0.00	8.67	0.00
	SA1	8.0 [a]	6.33 [b]	48.46[a]	0.10[a]
	SA2	7.4 [b]	8.66[a]	48.04[a]	0.06[c]
	SA3	5.4 [c]	5.67[c]	50.44[a]	0.07[b]
	LSD	0.137	0.00	4.30	0.00
Source					
Field capacity(FC)		*	*	*	*
Salicylate(SA)		*	*	Ns	*
FC*SA		*	*	Ns	*

Numbers followed by the same letter in the same column are not significantly different at 5 %

light stress and various salicylic acid dosages in CCI (Table 1). Salicylic acid dosage and various dry stresses had a great impact on CCI outcomes. The maximum CCI value for dry stress with a single factor was at FC1, which was reduced by 10.82% at FC2 and decreased by 21.04% at FC3. For salicylic acid as a single factor, there was a decrease of 8% at a dose of 0.5 mM and an increase of 4.08% due to the administration of 1 mM salicylic acid. The findings demonstrated that proline levels fell under FC1 circumstances from 0 to 0.5 mM salicylic acid concentration, which then rose to 1 mM salicylic acid concentration (Table 1). The proline level rose from 0 to 0.5 mM salicylic acid concentration in the FC2 dry stress condition before decreasing to 1 mM salicylic acid concentration.

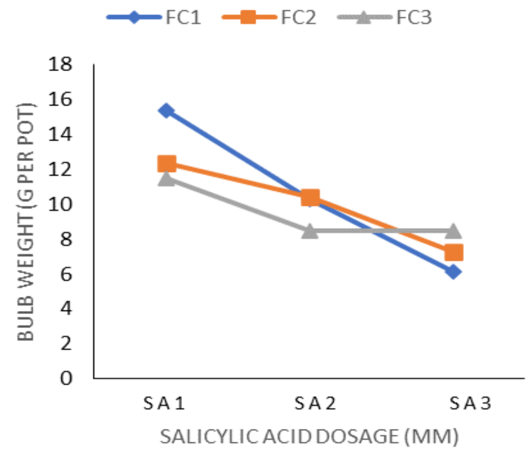
The plant height, the number of tillers, root length, and CCI for stress treatment were significantly lower than those without stress due to the influence of water stress during the proper harvest season. In the high-stress treatment, the lowest plant height was observed (Gebretsadkan *et al*., 2019). Regulators successfully enhanced plant height and leaf count compared to yields, and the percentage increase in plant height and leaf count reached 10% and 12% by regulators (Shirzadi *et al*., 2020). A minimum of one leaf and a maximum of seven leaves per leaf branch (Abderabi *et al*., 2018). Similar findings were made by Santos *et al*. (2021), who used a concentration of 75% to verify higher tillering capacity and higher leaf fresh weight. Although the maximum penetration of shallot roots is at 0.76 m, the largest shallot roots were found above 0.18 m, and only a small proportion are found deeper than 0.31 m (Hanci and Cebeci., 2014). Drought causes a variety of reactions in plants, including changes in cell metabolism, decreased growth rates, and changes in yield. It is important to understand how plants' biochemical and molecular responses to drought affect their ability to defend themselves against water constraints (Purbajanti *et al*., 2017). Salicylic acid can affect physiological processes such as seed germination, stomatal closing, chlorophyll production, protein synthesis, and photosynthesis (Hasson and Alduljabbar, 2019). Furthermore, proline accumulation is an important physiological index of plant response to drought stress and other types of stress. Proline levels continued to increase in the FC3 dry stress environment until the concentration of salicylic acid reached 1 Mm. Dry stress causes an increase in proline levels (Purbajanti *et al*., 2017). Administration of 1.5 mM salicylic acid under 70% drought stress increased lettuce (*Lactuca sativa*) plant height, leaf number, while 25% drought stress increased proline concentrations (Wang *et al*., 2015). Treatment of exogenous salicylic acid can increase the activity of antioxidant enzymes and plant tolerance to biotic and abiotic stress conditions (Min *et al*., 2018).

Yield and component of yield

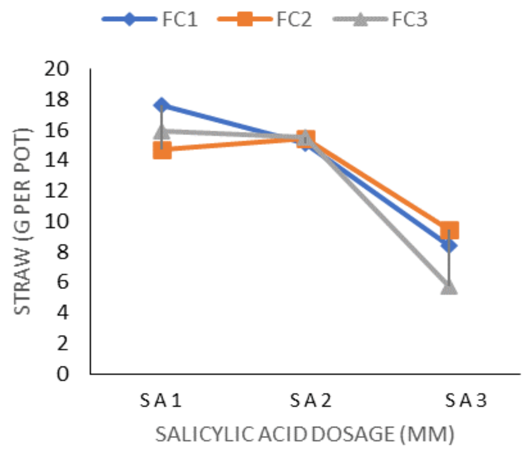
According to the findings, bulb weight declined under FC1 and FC2 circumstances from 0 to 0.5 mM salicylic acid concentration and then dropped to 1 mM salicylic acid concentration. The bulb weight decreased to 0.5 mM salicylic acid concentration at dry stress FC3 and then rose to 1 mM salicylic acid concentration (Fig. 2A). According to the findings, straw weight declined under FC1 circumstances from 0 to 0.5 mM salicylic acid concentration before rapidly decreasing to 1 mM salicylic acid concentration. Strawweight grew marginally to a salicylic acid concentration of 0.5 mM under conditions of dry stress FC2 and FC3, then abruptly declined to a salicylic acid concentration of 1 Mm (Fig 2B). The relationship between dehydration stress and PGR on plant fresh weight is quite large; so when there is no stress or only mild stress, the regulator has no impact, but when the stress is severe dehydration, it occurs (Shirzadi *et al*., 2020). In shallots, glutathione plays an important role in metabolic processes that lead to taste and aroma precursors. This is why the stress-related increase in onion glutathione will also change the taste of onions. (Romo-P'erez *et al*., 2021).

The findings demonstrated that bulb diameter output dropped significantly from 0 to 1 mM salicylic acid concentration in the FC1 , FC2, and FC3 conditions (Fig 2C). The outcomes demonstrated that bulb production under FC1 conditions decreased from 0 to a concentration of 1 mM salicylic acid (Fig 2D). In the dry stress condition of FC2, bulb production increased slightly to 0.5 Mm salicylic acid concentration and then decreased sharply to 1 mM salicylic acid concentration. Meanwhile, at dry stress FC3, bulb production decreased at 0.5 mM salicylic acid concentration, which then decreased sharply to 1 Mm salicylic acid concentration. Water stress during the formation and maturation stages did not significantly impact shallot bulb production or the effectiveness of water use. The bulb stage has the highest sensitive index, followed by the developmental stage, and is relatively low in the formation and maturation stages (Idaryani *et al*., 2021). However, drought production metrics remain dominant because production parameters sensitive to droughts, such as tuber weight, diameter, straw, and SA production cannot adapt (Marlina *et al*., 2021).

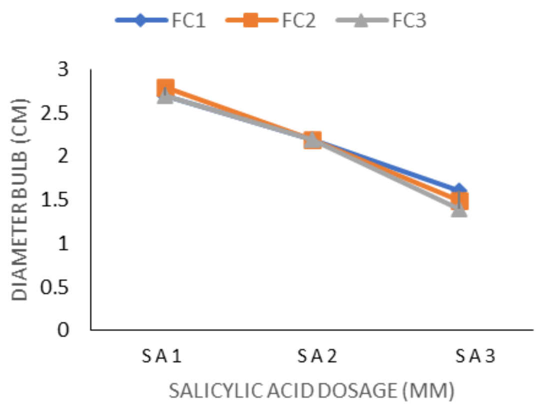
The harvest index is the yield sharing between economic crops and biological yields, which can describe the assimilation efficiency of the distribution of economic returns and the ability to accommodate photosynthesis (Ansar *et al*., 2019). The results showed the highest harvest index at FC1, which was not significantly different from FC2 but significantly different from FC3 (Fig 2E). Furthermore, the highest harvest index was at the concentration of 0 mM salicylic acid, which was significantly different at concentrations of 0.5 and 1 Mm (Fig 2F).

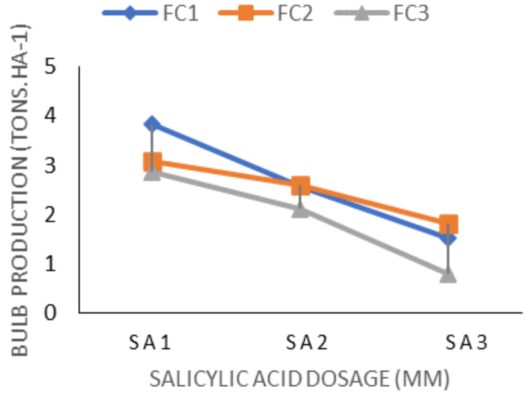


A. *Bulb weight*



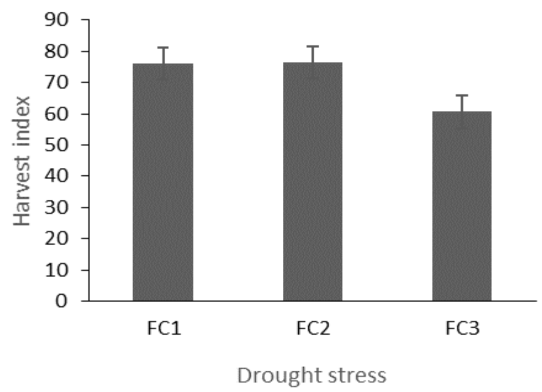
B. *Strawweight*

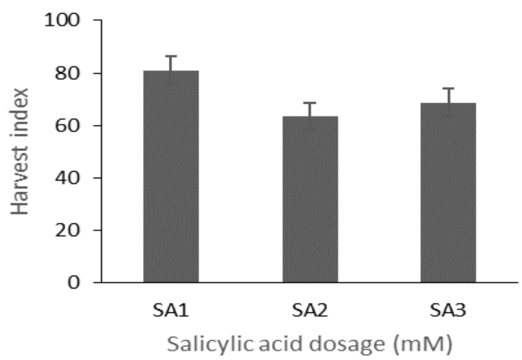




C. *Diameter of bulb*

D. *Bulb production*





E. *Harvest index due to drought stress*

F. *Harvest index due to salicylic acid*

Fig.2 A-F. *Bulb weight, straw weight, bulb diameter, bulb production and harvest index of onion due to drought treatment and salicylic acid*

Conclusion

Salicylic acid (SA), a hormone that acts as a signaling molecule to mitigate the negative impacts of abiotic stresses like drought, is produced by plants. In the present study, the non-stressed plant reached its maximum height (40.66 cm) at 0 mM salicylic acid. FC3 had the lowest height, whereas FC2 provided the same height between 0, 0.5, and 1 mM. Salicylic acid consumption and various dry stresses had a great impact on CCI outcomes. The maximum CCI value for dry stress with a single factor was at FC1. Bulb weight, bulb diameter and bulb production decreased as field capacity decreased and salicylic acid increased. Salicylic acid could not maintain shallot weight loss due to reduced field capacity.

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Conflict of interest

The authors declare that they have no conflict of interest.

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