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Effect of salicylic acid on growth, physiological traits, yield and water productivity of summer mungbean (*Vigna radiata* L. Wilczek) under different irrigation regimes

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ABSTRACT

To evaluate the efficacy of salicylic acid in improving water productivity under different irrigation regimes, a field experiment was carried out in 2019-20 and 2020-21 in a split plot design with three irrigation regimes i.e., irrigation water (IW) to cumulative pan evaporation (CPE) ratios of 0.3, 0.6 and 0.9 in main plots and foliar spray of salicylic acid (SA) at four concentrations i.e., 0, 0.5, 1.0 and 1.5 mM in sub plots. Frequency of irrigation significantly affected the morphological and physiological traits. However, foliar application of salicylic acid alleviated the effect of less frequent irrigation on plant height (4.6-10.3%), biomass (10.4%) and leaf area (1.0%). SA application improved the water status of plants with 9.2% higher relative water content as compared to control. Root mass density was higher in $I_{0.3}$ regime in the lower depths of soil profile as compared to $I_{0.6}$ and $I_{0.9}$, which further increased with salicylic acid application. The content of osmolytes was highest in $I_{0.3}$ which increased up to 34-36% with salicylic acid. Highest seed yield was recorded under $I_{0.6}$ regime and 1.5 mM SA but it was statistically at par with 1.0 mM SA. Water productivity was highest in the least irrigated regime (3.55 kg ha^{-1} mm^{-1}) and 1.0 mM SA (3.25 kg ha^{-1} mm). Foliar application of 1.0 mM SA can be considered as the effective for improving seed yield under all irrigation regimes with more pronounced effect in less frequent irrigation regime.

Keywords: Irrigation regimes, salicylic acid, summer mungbean, water productivity

INTRODUCTION

Mungbean (*Vigna radiata* L.) is one of the important legume crops cultivated in various regions of India. In addition to its nutritive value to humans, it also improves soil health through symbiotic nitrogen fixation. It is mainly grown as a *kharif* crop; but, with the development of short duration varieties, it became an ultimate option for summer season. During summer season, pre-sowing irrigation is must for germination and crop establishment and thereafter, monsoon rains fulfill the water requirement. However, inconsistent monsoon rains and high vapour pressure results in rapid depletion of stored soil moisture consequential in extreme water deficits and severe loss in mungbean yield (Kumar and Sharma, 2009). Therefore, supplemental irrigation is necessary as the temperature is high and relative humidity is low during crop season. This short duration crop requires 3-5 irrigations depending on the weather conditions (Ram *et al.* 2016). On the other hand, because of the depleting water supplies and increasing demand of the industries and urban areas, it is difficult to fulfil high irrigation water requirements. To increase the efficiency of available water use, proper irrigation scheduling is required which will provide water at stages that match the crop evapotranspiration and at critical growth stages. Water supply affects almost every plant process either directly or indirectly. Incidence of dry spell during plant life cycle affects various physiological and metabolic processes such as germination, growth, photosynthesis, respiration, nutrient uptake etc., resulting in yield loss. Water shortage perturbs normal turgor pressure; loss in turgidity may hinder the process of cell enlargement, thus reducing plant growth. Under limited available water, productivity can be improved by increasing the tolerance to drought stress in crop plants. Exogenous application of plant growth regulators is one of the approaches to impart tolerance to crop under water stress (Srivastava *et al.* 2016). Salicylic acid (SA) is one of the potential growth regulators, a signaling molecule in plants which affects plants' response to biotic and abiotic stresses. Previous studies show that SA provokes resistance to drought stress in cereals, pulses, oilseeds (Wakchaure *et al.* 2016, Razmi *et al.* 2017). Foliar application of SA enhanced the growth, photosynthesis and stomatal conductance (Habibi, 2012) and increased antioxidative

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enzymes and osmolytes under water stress (Sharma *et al.* 2017). It ameliorates the effects of drought on growth and photosynthesis by increasing proline content (Nazar *et al.* 2015). In view of importance of summer mungbean as a short duration, highly nutritive pulse crop and need for its improved water use efficiency and the role of salicylic acid in amelioration of abiotic stress, the present study was carried out with the objective of evaluating the efficacy of salicylic acid in improving water productivity of summer mungbean under different irrigation regimes.

MATERIALS AND METHODS

The experiment was conducted at Research Farm, Punjab Agricultural University, Ludhiana, Punjab (30°56' N latitude; 75°52' E longitude; 247 m altitude) located in the Indo–Gangetic Plains Region during summer season in 2019 and 2020. The soil of experimental site was primarily sandy loam textured, non-saline (EC 0.17-0.24 dS m^{-1}) and slightly alkaline (pH 7.9-8.2) in nature. The bulk density in different depths ranged from 1.50-1.55 g cm^{-3}. Water holding capacity of the soil was found out to be 14 – 16.5% on weight basis. The experimental soil was low in organic carbon which ranged from 0.36-0.56 per cent at different depths. Total rainfall recorded during crop season was 91.1 mm in 2019 and 72.4 mm in 2020; while evaporation was 634.8 mm and 571.7 mm in respective years. The experiment was laid–out in a split plot design with three irrigation regimes *i.e.*, irrigation water (IW) to cumulative pan evaporation (CPE) ratios of 0.3 ($I_{0.3}$), 0.6 ($I_{0.6}$) and 0.9 ($I_{0.9}$) in main plots and foliar spray of salicylic acid at four concentrations *i.e.*, 0 (Control), 0.5 ($SA_{0.5}$), 1.0 ($SA_{1.0}$) and 1.5 mM ($SA_{1.5}$) in sub plots with three replications and a total of 36 plots and each sub-plot measured 5 x 2.5 m. The number of post sowing irrigations in $I_{0.3}$, $I_{0.6}$ and $I_{0.9}$ were one, three and five and the amount of irrigation water applied was 60, 180 and 300 mm (60 mm each measured with Parshall flume), respectively. Foliar application of 0.5, 1.0 and 1.5 mM salicylic acid solutions was done on April 25, 2019 and May 10, 2020 in the respective plots while in SA_0 plots, no spray was done. Cultivar SML-668 was sown @ 25 kg ha^{-1} on 1st April in 2019 and 14th April in 2020 with heavy pre-sowing irrigation. Before sowing, the seed was treated with Captan @ 3g kg^{-1} of seed and inoculated with freshly prepared Rhizobium culture prepared at the time of sowing. Nitrogen (12.5 kg ha^{-1}) and phosphorus (39.54 kg ha^{-1}) were applied through urea and single super phosphate at the time of sowing. Differential irrigation was given from the first day of sowing. The crop was harvested on 11th and 25th June in 2019 and 2020, respectively.

Plant height and leaf area per plant were recorded at maturity form three plants randomly selected from each plot. Plant biomass was recorded by harvesting plants from 0.5 m row length in the second outermost row on either side of each plot and placed in oven at 65±2°C to measure the dry weight and final biomass was expressed in q ha^{-1}. Number of days from date of sowing to 50 per cent flowering stage were counted as days to 50% flowering. Relative water content was recorded using method given by Barrs and Weatherley (1962) from the 4th leaf from the top. Chlorophyll content was recorded with the help of chlorophyll meter (SPAD 502, Minolta) and the average of ten readings was reported as SPAD value. Normalized Difference Vegetation Index (NDVI) was estimated using GreenSeeker Hand Held Optical Sensor, NTech Industries, Inc. For dry matter partitioning, three plants were cut at ground level from each plot, excised into different parts and then oven dried to record their dry weights; dry matter partitioning towards different tissues was calculated. Total soluble sugars, proline content in leaves and protein content in seed were estimated by method of Dubois *et al.* (1956), Bates *et al.* (1973) and Lowry *et al.* (1951), respectively. For root mass density, the soil cores were collected at flowering stage at 15 cm depth increments to 90 cm soil depth using an auger of 5 cm inner diameter centered 5 cm away from the base of plant (Gajri *et al.* 1994). Root samples were washed in net cloth and cleaned thoroughly; dried in oven at 60°C and then weighed with the help of precise balance and the root mass density (root weight per unit volume of soil) was calculated. Seed yield was recorded from net area of 6.4 m^2 and computed as q ha^{-1}. Three plants were selected randomly to record data pertaining to yield attributes. Water productivity (kg ha^{-1} mm^{-1}) was calculated by dividing the grain yield (kg ha^{-1}) by total water use (total water use (mm) is the summation of total irrigation water applied; total rainfall received and profile water use). Statistical analysis of the experimental data was carried out using ANOVA procedures in OPSTAT software. The data presented is the average of two years (2019 and 2020). Differences between means were compared using least significant difference test (LSD) at 5% level ($p \leq 0.05$).

RESULTS AND DISCUSSION

Growth traits: Irrigation significantly affected the growth traits viz., plant height, biomass and leaf area in summer mungbean with maximum value in the most frequent irrigation regime $I_{0.9}$ (63.2 cm, 47.3 t ha^{-1} and 743.9 cm, respectively) and minimum in least frequent irrigation regime (55.3 cm, 35.6 t ha^{-1} and 723.6 cm, respectively) (Table 1). Foliar application of salicylic acid alleviated the effect of less irrigation on plant height (4.63-10.3%), biomass (10.4%) and leaf area (1.0%). Deficit irrigation hinders the physiological processes like nutrient absorption, assimilation, photosynthesis and translocation of photoassimilates, which ultimately affects the plant growth by obstructing the cell division and enlargement (Mondal *et al.* 2018). Foliar spray of 1 and 2 mM SA resulted in significant improvement in different growth traits of onion over the control (Semida *et al.* 2017). Water stress induced early attainment of 50% flowering as depicted by 38.7 days in $I_{0.3}$ irrigation regime. While, the application of SA caused more delay in the appearance of 50% flowering with 42.2 days with $SA_{1.5}$ as compared to 39.5 in control. Salicylic acid might have reduced the effect of stress under limited water, hence causing delay in appearance of flowers. Hussen *et al.* (2019) also observed that days to 50% flowering were significantly affected by water stress.

Table 1: Effect of irrigation regimes and foliar application of salicylic acid on growth traits, yield and water productivity of mungbean (mean of 2 years)

	Plant height (cm)	Plant biomass (q ha^{-1})	Leaf area $plant^{-1}$ (cm^2)	Days to 50% flowering	Seed yield (t ha^{-1})	Water productivity (kg mm^{-1} ha^{-1})
Irrigation						
$I_{0.3}$	55.3	35.6	723.6	408.7	8.6	3.5
$I_{0.6}$	59.7	41.3	733.6	41.3	10.9	3.1
$I_{0.9}$	63.2	47.3	743.9	43.3	10.7	2.2
L.S.D. 5%	2.18	3.56	4.49	1.06	1.06	0.38
			SA treatments			
Control	56.0	39.1	730.5	39.5	9.2	2.6
$SA_{0.5}$	58.6	40.7	732.1	40.8	9.8	2.9
$SA_{1.0}$	61.1	42.7	735.6	41.9	10.6	3.2
$SA_{1.5}$	61.8	43.2	736.7	42.2	10.7	3.1
L.S.D. 5%	1.74	1.56	1.65	1.06	0.70	0.38

Physiological traits: The reduction in irrigation frequency significantly affected the physiological traits viz., leaf relative water content, chlorophyll content and NDVI (Table 2). The highest relative water content was observed in the most frequent irrigation regime $I_{0.9}$ (74.4%) followed by $I_{0.6}$ (68.4%) and $I_{0..3}$ (64.0%). Likewise, chlorophyll content reduced by 16.8 and 6.9% in $I_{0.3}$ and $I_{0.6}$ regimes as compared to $I_{0.9}$. Highest NDVI was obtained in the most frequent irrigation regime $I_{0.9}$ irrigation being statistically at par with $I_{0.6}$ but significantly higher than $I_{0.3}$. The reduction in chlorophyll content may be attributed to higher rate of degradation of chlorophyll than its biosynthesis under water stress (Bhupendra *et al.* 2018). Foliar application of 0.5, 1.0 and 1.5 mM SA increased relative water content by 2.9, 9.3, 6.4%, respectively, over control. Maximum chlorophyll level was observed with $SA_{1.5}$ (47.3) which was statistically at par with $SA_{1.0}$ (46.8) but significantly higher than $SA_{0.5}$ (45.2) and control (44.1). $SA_{1.5}$ resulted in the highest vegetative index (0.63) which was statistically at par with the vegetative index with $SA_{1.0}$ (0.58) followed by $SA_{0.5}$ (0.47) and control (0.39). Foliar application of salicylic acid improved the leaf relative water content and photosynthetic pigments in soybean under water deficit (Razmi *et al.* 2017). Increased NDVI, leaf area index, dry matter accumulation and grain yield with foliar priming of salicylic acid in late sown wheat was reported by Jatana *et al.* (2020). Partitioning of assimilates was lower towards pods and more towards leaf in $I_{0.3}$, whereas in $I_{0.6}$ and $I_{0.9}$, dry matter was translocated more towards pod than leaf and stem, thus forming a basis for reduction in seed yield under $I_{0.3}$ regime (Fig. 1). Under $I_{0.3}$, the control treatment showed a higher partitioning coefficient in leaf; while $SA_{0.5}$, $SA_{1.0}$ and $SA_{1.5}$ depicted higher pod partitioning coefficient. Kumar and Sharma (2009) also observed that under drought, more assimilates were diverted to vegetative parts, while well watered plants partitioned towards reproductive parts in mungbean.

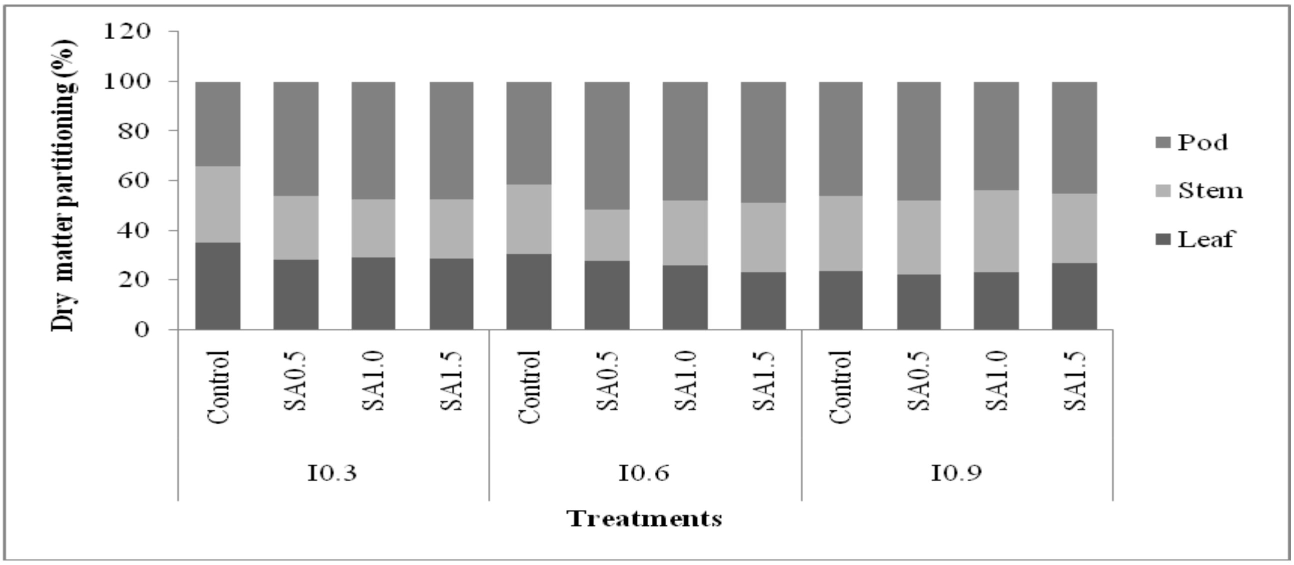

Fig. 1: Effect of irrigation regimes and foliar application of salicylic acid on dry matter partitioning coefficient (%) in summer mungbean at maturity

Osmolytes and seed protein: The content of osmolytes viz., total soluble sugars and proline was significantly higher under $I_{0.3}$ than $I_{0.6}$ and $I_{0.9}$ (Table 2). Foliar application of SA enhanced the sugar content with maximum accumulation in $SA_{1.5}$ treated plants and the effect was more pronounced under $I_{0.3}$ regime with 34-36% increase as compared to frequent irrigation (15-17% increase). Similar trend was observed with maximum proline content with $SA_{1.5}$ (2.3 mg/g DW) which was statistically higher than $SA_{1.0}$ (2.0 mg g^{-1} DW), $SA_{0.5}$ (1.5 mg g^{-1} DW) and control (1.3 mg g^{-1} DW). Maity and Bera (2009) reported an increase in sugar content with salicylic acid application in black gram. Accumulation of sugars and free proline is important for enhancing osmotic stress tolerance in plants (Tatar and Gevrek 2008). The seed quality in terms of protein content was also significantly affected by irrigation regimes and salicylic acid.

Table 2: Effect of irrigation regimes and foliar application of salicylic acid on physiological traits, osmolytes and seed protein content in mungbean (mean of 2 years)

	Leaf relative water content (%)	Chlorophyll content (SPAD value)	NDVI	Total soluble sugars (mg g^{-1} DW)	Proline content (mg g^{-1} DW)	Total seed protein (mg g^{-1} DW)
Irrigation						
$I_{0.3}$	64.0	42.2	0.47	17.2	2.1	60.0
$I_{0.6}$	68.4	46.1	0.54	16.7	1.8	64.4
$I_{0.9}$	74.4	49.3	0.55	15.6	1.5	68.9
L.S.D. 5%	2.92	1.14	0.03	0.86	0.16	2.08
			SA treatments			
Control	65.0	44.1	0.39	15.2	1.3	62.2
$SA_{0.5}$	67.9	45.2	0.47	16.1	1.5	63.6
$SA_{1.0}$	71.9	46.8	0.58	17.2	2.0	65.5
$SA_{1.5}$	70.8	47.3	0.63	17.8	2.3	66.4
L.S.D. 5%	2.59	1.99	0.05	0.79	0.14	1.09

Root mass density: Irrigation influenced the root mass density with higher values in $I_{0.6}$ and $I_{0.9}$ regimes in the upper 0-30 cm layer than $I_{0.3}$ (Fig. 2). However, below 30 cm, the root mass density was highest in $I_{0.3}$. Salicylic acid application increased the root mass density at all the depths with highest effect of $SA_{1.5}$. Higher root mass density under least irrigated regime may be attributed to the response of plant to stress as root forages water in the deeper soil layers. Karande *et al.* (2019) also observed higher root weight under the less frequent irrigation treatment. Hegazi and El-Shraiy (2007) also reported positive effects of salicylic acid on root weight in soybean.

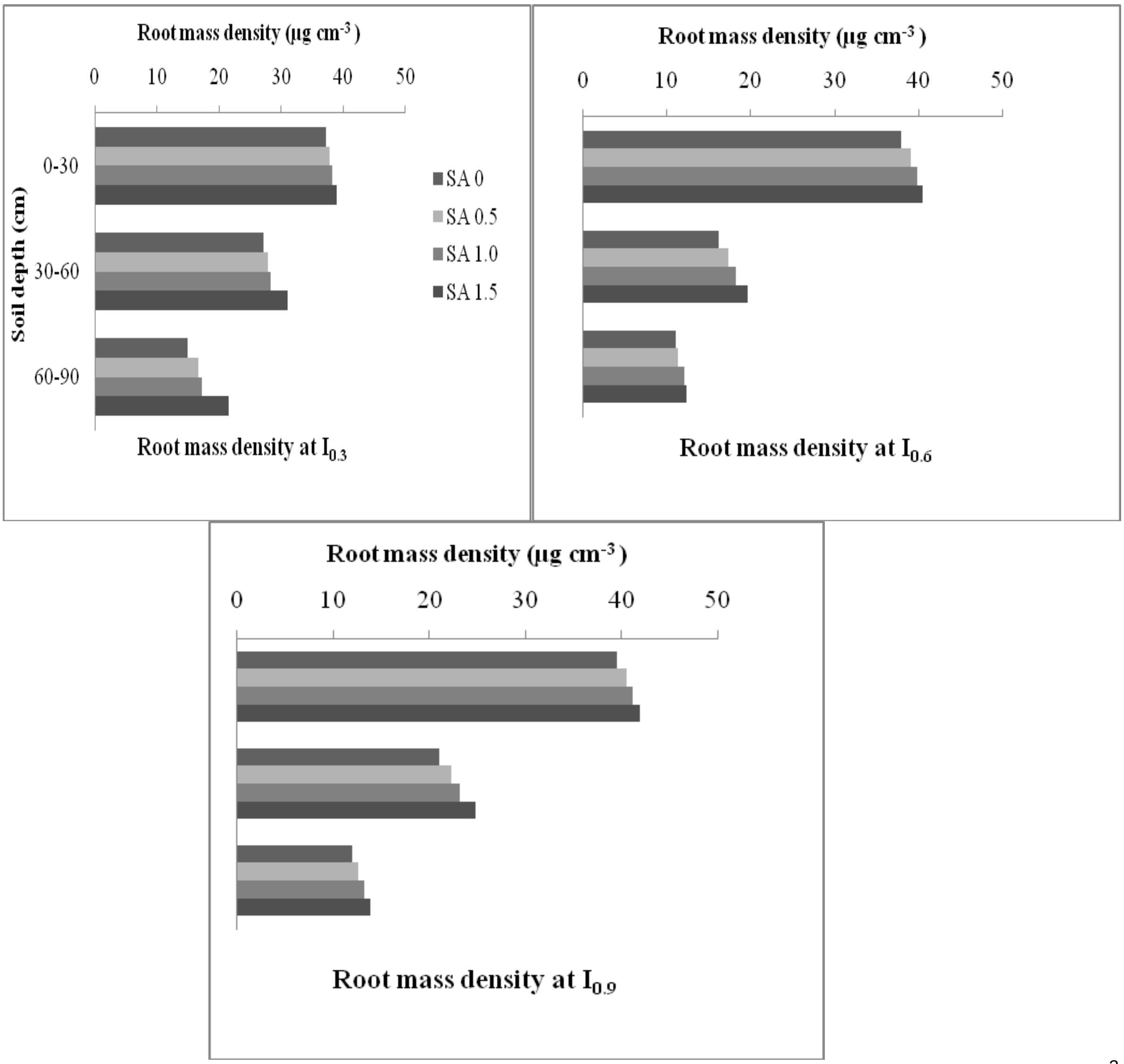

Fig. 2: Effect of irrigation regimes and foliar application of salicylic acid on root mass density (µg cm^{-3}) in summer mungbean at flowering stage

Seed yield and water productivity: Seed yield increased by 26.9% from $I_{0.3}$ to $I_{0.6}$, but more frequent irrigation regime $I_{0.9}$ resulted in fall of seed yield by 2.0% than $I_{0.6}$ (Table 1). Thus, $I_{0.6}$ irrigation schedule can be considered optimum as further increase in irrigation could not translate into seed yield. These results are in parity with the findings of Ram *et al.* (2016) who reported significantly higher seed yield with three irrigations than two irrigations but statistically at par with four irrigations in summer mungbean. Maximum yield was observed with 1.5 mM SA (10.7 q ha^{-1}) which was non-significant as compared to that at 1.0 mM (10.6 q ha^{-1}), but significantly higher than 0.5 mM (9.8 q ha^{-1}) and control (9.2 q ha^{-1}). Thus, 1.0 mm SA application can be considered more effective for improving seed yield under all the irrigation regimes. The beneficial effects of SA application have also been reported by Majeed *et al.* (2016) in mungbean under drought stress. Highest water productivity (3.5 kg ha^{-1} mm^{-1}) was obtained under $I_{0.3}$ irrigation schedule followed by $I_{0.6}$ (3.1 kg ha^{-1} mm^{-1}) and $I_{0.9}$ (2.2 kg ha^{-1} mm^{-1}). Maximum water productivity was observed with $SA_{1.0}$ which was statistically at par with $SA_{1.5}$ and $SA_{0.5}$ but significantly higher than the control (Table 1). Kahlon *et al.* (2021) also observed higher water productivity at less frequent irrigation in mungbean and related to efficient use of applied water and relatively more grain yield per unit water applied. Application of salicylic acid increased WUE in onion under deficit irrigation (Semida *et al.* 2017).

It may be concluded from the results that foliar application of salicylic acid was effective in mitigating the effect of water deficit by maintaining the plant water status in terms of relative water content and increased content of osmolytes. Also, the effect of salicylic acid on yield was more pronounced in $I_{0.3}$ regime, so salicylic acid can be utilized under water scarcity for improving growth and yield.

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