

REGULAR ARTICLE

Salinity influences physiological traits of seven Sesame (*Sesamum indicum* L.) varieties

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Abstract

In the present investigation a pot culture experiment was conducted in order to estimate the effects of salt stress on some physiological traits in seven sesame varieties like PAIYUR-1, SVPR-1, TMV-3, TMV-4, TMV-5, VIR-1 and VIR-2. Young and fully matured leaves were taken from control and salinity treated plants on 15th Days After Treatment (DAT), 30th (DAT) and 45th (DAT) for all the experiments in different salinity (NaCl) concentrations of control, 40mM, 80mM, 120mM. During the experiments of photosynthetic enzymes, foliar nitrogen and ABA content were measured. Lower rate of decreased photosynthesis, photosynthetic enzymes activity, foliar nitrogen and ABA content was increased with increasing salinity level in leaves of all the seven sesame varieties on all the sampling days. On 45th DAT, significantly higher enhancement of photosynthetic enzymes activity, foliar nitrogen, ABA content was observed in TMV-3 with 120mM salinity by relative to control plants while lower enhancement was noticed in PAIYUR-1 with 120mM salinity by compared to control plants. Moderate enhancement of photosynthetic enzymes, foliar nitrogen, ABA content was monitored in the variety VIR-2 with 120mM salinity on 45th DAT compared to control plants. TMV-3 exhibited higher adaptive potential under salinity stress as judged by increased photosynthetic rate and activities of photosynthetic, foliar nitrogen, higher accumulation ABA when compared to variety TMV-4 and PAIYUR-1 was closely followed by VIR-1. Variety VIR-2 was followed by SVPR-1 and TMV-5.

Key words: ABA, DCPIP, RuBb carboxylase, salinity stress, sesame, foliar nitrogen, photosynthesis

Introduction

In irrigated agriculture, the salt stress is a major problem due to accumulation of salt from the irrigation water in the soil layers. All major plant processes are affected by salinity and thereby a growth reduction and yield deficiency occurs in crop plants (Munns, 2002). Salinity affects the crop productivity around the globe. Salinity affects both vegetative and reproductive phases of plants (Munns and Rawson, 1999). In the vegetative phase, it leads to the reduction in growth and

in reproductive phase, the main issue will be related to the decline in the yield.

Numerous studies are already carried out to evaluate the effects of salinity on all major crop plants. There are reports on the effect on NaCl stress on various crop plants like *Casuarina* (Desingh et al., 2006), maize (Gunes et al., 2007), cotton (Desingh, and Kanagaraj, 2007; Kanagaraj and Desingh, 2009), soybean (Weisany et al., 2012), pigeon pea (Manivannan et al., 2017) etc. Recently, we

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reported changes in growth, pigments and protein contents (Kanagaraj and Sathish, 2017a) and alterations in carbohydrate, lipid peroxidation and proline contents (Kanagaraj and Sathish, 2017b) in two horse gram (*Macrotyloma uniflorum* (Lam.) Verdc) varieties under salinity.

Sesame (*Sesamum indicum* L.) is one of the oldest cultivated plants in the world. In India, sesame has a wide geographic distribution extending over a range of environmental conditions. However, as other crops in India, sesame is also subjected to environmental stresses, particularly salinity. Although much information is available on the agronomic aspects of sesame, very little is known about the effects of salinity on physiological and biochemical aspects of sesame. The main objectives of the present study were to evaluate the photosynthetic potential, foliar nitrogen, and abscisic acid content to salinity responses of seven sesame varieties (*Sesamum indicum* L.) usually used for cultivation.

Materials and methods

Plant material and growth condition

The certified *Sesamum indicum* Lin. seeds (Variety: PAIYUR-1, SVPR-1, TMV-3, TMV-4, TMV-5, VIR-1 and VIR-2) were procured from Tamilnadu Agriculture University Coimbatore, Srivilliputhur, Virudhachalam and Tindivanam. Seeds with uniform size were selected and the plants were raised in pots containing red and clay soil and pH of the soil was 7.2 with EC of 0.2 dsm⁻¹. At 20 days, thinning was done to maintain three plants of uniform size in each pot.

Salinity treatments

The seedlings were divided into four groups. One group of seedlings was maintained under non-salinized conditions which served as control plants. The watering solution for control plants consists of tap water and one-fourth strength of Hoagland nutrients (Hoagland and Arnon, 1950) the three groups were salinized by irrigation daily to soil capacity (500 ml d⁻¹) with the nutrient medium containing 40 mM, 80 mM and 120 mM NaCl. All the plants used in this study were of comparable size. Young and fully matured leaves were taken from control and salinity treated plants on 15th Days After Treatment (DAT), 30th (DAT) and 45th DAT for all the experiments described below.

Photosynthesis

Photosynthesis was measured by following the method of (Sundar and Reddy, 2000). Values are expressed as nmol/gfw/s.

Rubp Carboxylase Activity (EC 4.1.1.39)

RuBP carboxylase activity was assayed by the method of (Lorimer et al., 1977). Values are expressed as μ moles/mgprotein/min.

Sucrose phosphate synthase activity (EC 2.4.1.14)

The enzyme sucrose phosphate synthase (SPS) was assayed by the method of (Sinha et al., 1977). The activity of SPS was expressed as μ mol/mgprotein/min

Dichlorophenol Indophenol (DCPIP) reduction

Isolation of chloroplast and photochemical activities were done by following the method of (Lilley et al., 1975). The values are expressed as μ mol/mgpro/min.

Foliar nitrogen content

The nitrogen content of the leaves was estimated according to Kjeldahl method using the KJEL PLUS System (Pelican, India) and as described by Chaitanya et al. (2001). The Nitrogen content was expressed as percentage of nitrogen per gram d.w.

Abscisic Acid

Extraction and quantification of ABA was done following Daie and Wyse, (1982) and as explained by Reddy et al. (2004). Values are expressed as μ g/gfw.

Statistical analysis

Data for each parameter analyzed by Two-Way ANOVA and significant differences between treatment mean and varieties were determined by using SPSS (version 15.0, SPSS, Chicago, IL, USA). Data are presented as the mean \pm SE of five independent determinations and significance was determined at the 95% confidence ($P \leq 0.05$) limits.

Results

Photosynthesis

The rate of photosynthesis in various sesame varieties under salinity stress on different DAT was shown in (Fig. 1). Under high (120mM) salinity, variety TMV-3 showed highest photosynthetic rate on 15th DAT (3.18 nmol/gfw/s), 30th DAT (3.14 nmol/gfw/s) and 45th DAT (3.06 nmol/gfw/s) relative to control plants (3.90 nmol/gfw/s, 3.98 nmol/gfw/s and 4.02 nmol/gfw/s, respectively), while lowest

photosynthetic rate was recorded in PAIYUR-1 on 15th DAT (1.88 nmol/gfw/s), 30th DAT (1.68nmol/gfw/s) and 45th DAT (1.35nmol/gfw/s) over the control plants (2.99nmol/gfw/s, 3.01nmol/gfw/s and 3.19nmol/gfw/s, respectively). Under 120mM salinity, moderate rate of photosynthesis was observed in the variety VIR-2 on 15th DAT (2.69 nmol/gfw/s), 30th DAT (2.58nmol/gfw/s) and 45th DAT (2.55nmol/gfw/s) compared to control plants (3.51nmol/gfw/s, 3.71nmol/gfw/s and 3.90nmol/gfw/s, respectively). Variety TMV-3 was closely followed by TMV-4 and PAIYUR-1 was followed by VIR-1. VIR-2 was followed by the varieties SVPR-1 and TMV-5.

RuBP carboxylase activity

Fig. 2 Shows the activity of RuBP carboxylase in leaves of seven sesame varieties under salinity stress on different sampling days. Highest RuBPcarboxylase activity was recorded in TMV-3 followed by TMV-4 on 45th

DAT under 120mM salinity and it was 215.35 $\mu\text{molCO}_2/\text{mgpro}/\text{min}$ and 201.38 $\mu\text{molCO}_2/\text{mgpro}/\text{min}$, respectively, relative to control plants (279.22 $\mu\text{molCO}_2/\text{mgpro}/\text{min}$ and 275.48 $\mu\text{molCO}_2/\text{mgpro}/\text{min}$, respectively), whereas lowest RuBPcarboxylase activity was noted in the variety PAIYUR-1 followed by VIR-1 and it was 102.52 $\mu\text{molCO}_2/\text{mgpro}/\text{min}$ and 110.24 $\mu\text{molCO}_2/\text{mgpro}/\text{min}$, respectively, over the control plants (258.11 $\mu\text{molCO}_2/\text{mgpro}/\text{min}$ and 260.15 $\mu\text{molCO}_2/\text{mgpro}/\text{min}$, respectively). Moderate level of RuBPcarboxylase activity was observed in the variety VIR-2 (181.51 $\mu\text{molCO}_2/\text{mgpro}/\text{min}$) followed by SVPR-1 (172.36 $\mu\text{molCO}_2/\text{mgpro}/\text{min}$) and TMV-5 (157.63 $\mu\text{molCO}_2/\text{mgpro}/\text{min}$) compared to control plants (271.17 $\mu\text{molCO}_2/\text{mgpro}/\text{min}$, 268.14 $\mu\text{molCO}_2/\text{mgpro}/\text{min}$ and 263.36 $\mu\text{molCO}_2/\text{mgpro}/\text{min}$, respectively) under 120mM salinity on 45th DAT.

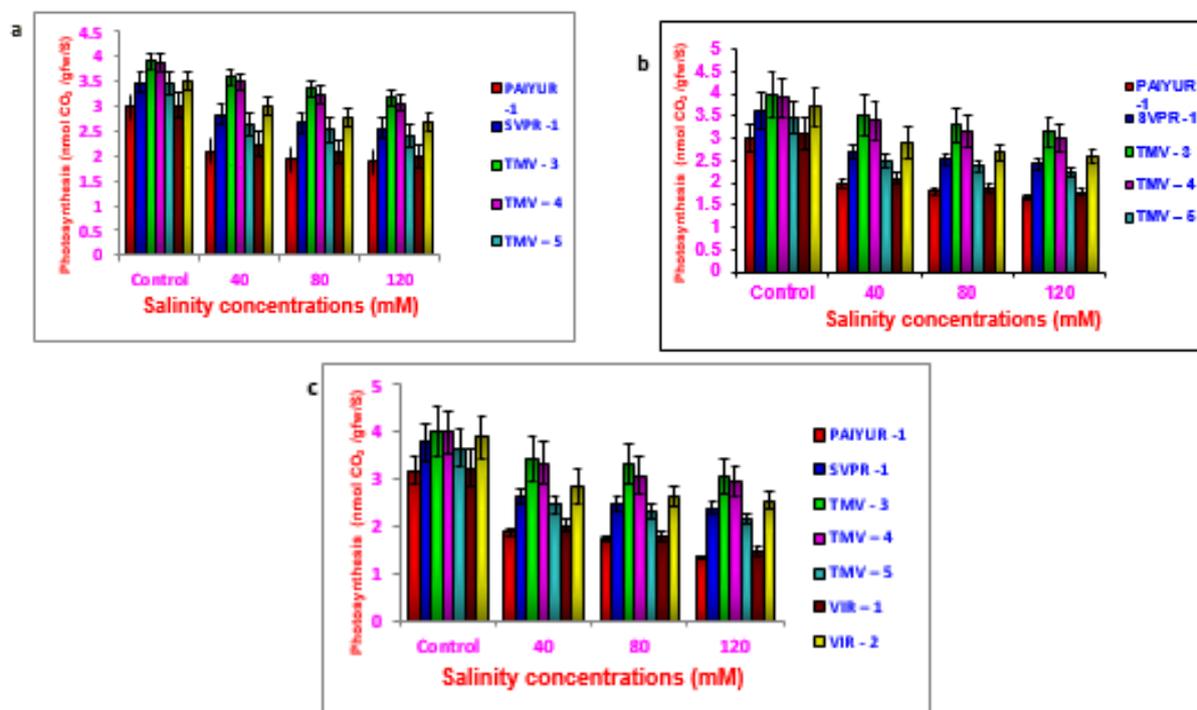


Fig. 1. Influence of varying levels of salinity stress on photosynthetic rate in leaves of seven sesame varieties on 15th DAT (a), 30th DAT (b) and 45th DAT(c). Each value represents mean \pm SE of five independent determinations ($p < 0.05$).

Sucrose phosphate synthase activity

Sucrose phosphate synthase (SPS) activity decreased with increasing salinity levels on all the sampling days in leaves of seven sesame varieties and it was shown in (Fig. 3). Significantly higher decrease of SPS activity was observed in variety PAIYUR-1 (13.52 $\mu\text{mol UDP/mgpro/min}$) followed by VIR-1 (14.85 $\mu\text{mol UDP/mgpro/min}$) on 45th DAT, under 120mM salinity stress, compared to control plants (32.10 $\mu\text{mol UDP/mgpro/min}$ and 32.34 $\mu\text{mol UDP/mgpro/min}$, respectively), while lower decrease of SPS activity was recorded in

the variety TMV-3 (24.88 $\mu\text{mol UDP/mgpro/min}$) followed by TMV-4 (24.02 $\mu\text{mol UDP/mgpro/min}$) relative to control plants (34.56 $\mu\text{mol UDP/mgpro/min}$ and 34.18 $\mu\text{mol UDP/mgpro/min}$, respectively). SPS activity moderately decreased in the variety VIR-2 (21.92 $\mu\text{mol UDP/mgpro/min}$) followed by SVPR-1 (20.15 $\mu\text{mol UDP/mgpro/min}$) and TMV-5 (18.34 $\mu\text{mol UDP/mgpro/min}$) under salinity stress of 120mM salinity, on 45th DAT relative to control plants (33.99 $\mu\text{mol UDP/mgpro/min}$, 33.63 $\mu\text{mol UDP/mgpro/min}$ and 32.45 $\mu\text{mol UDP/mgpro/min}$, respectively).

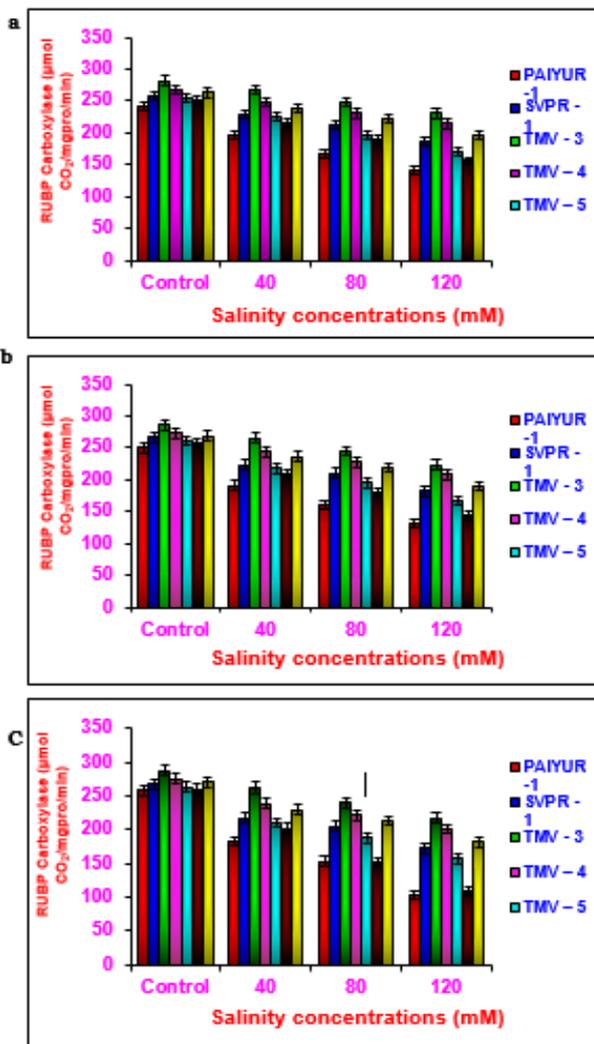


Fig. 2. Influence of varying levels of salinity stress on RuBP Carboxylase activity in leaves of seven sesame varieties on 15th DAT (a), 30th DAT(b) and 45th DAT(c). Each value represents mean \pm SE of five independent determinations ($p < 0.05$).

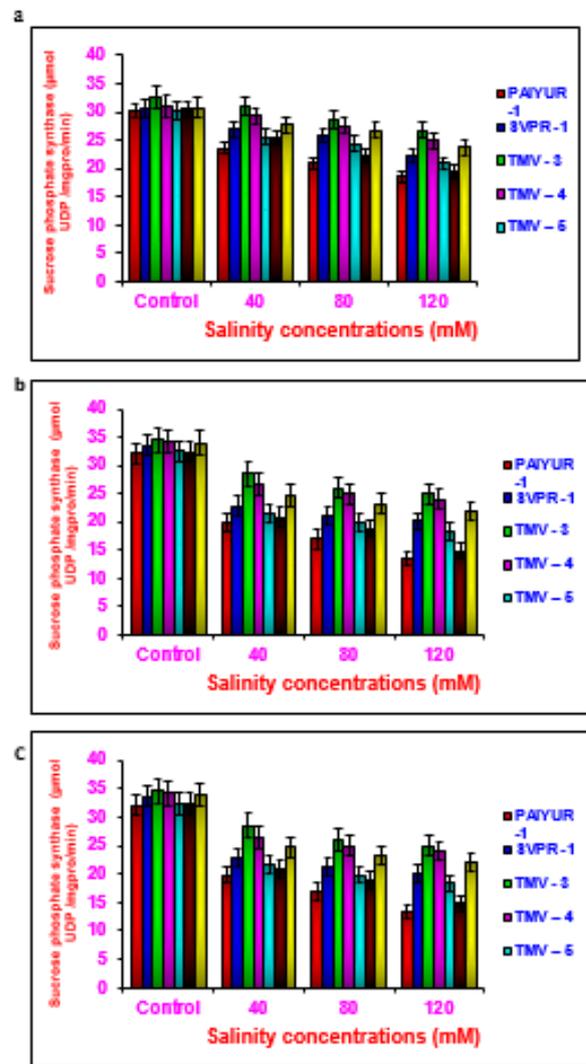


Fig. 3. Variation of sucrose phosphate synthase activity in leaves of sesame varieties on 15th DAT (a), 30th DAT(b) and 45th DAT (c) in the presence of different NaCl concentration. Each value represents mean \pm SE of five independent determinations ($p < 0.05$).

DCPIP Reduction

DCPIP reduction was studied under salinity stress on different sampling days in seven sesame varieties and it was shown in the (Fig. 4). Higher 'DCPIP reduction' was recorded in the variety TMV-3 followed by TMV-4 on 45th DAT under 120mM salinity stress and it was 125.82 $\mu\text{mol/mgpro/min}$ and 118.65 $\mu\text{mol/mgpro/min}$, respectively, over the control plants (163.58 $\mu\text{mol/mgpro/min}$ and 161.27 $\mu\text{mol/mgpro/min}$, respectively), while lower 'DCPIP reduction' was measured in the variety PAIYUR-1 (66.54 $\mu\text{mol/mgpro/min}$) followed by VIR-1 (72.46 $\mu\text{mol/mgpro/min}$) relative to control plants (148.53 $\mu\text{mol/mgpro/min}$ and 152.11 $\mu\text{mol/mgpro/min}$, respectively). Moderate level of 'DCPIP reduction' was observed in the variety VIR-2 (108.72 $\mu\text{mol/mgpro/min}$) followed by SVPR-1 (108.82 $\mu\text{mol/mgpro/min}$)

and TMV-5 (98.64 $\mu\text{mol/mgpro/min}$) compared to control plants.

Foliar nitrogen content

Under salinity stress, foliar nitrogen content decreased on all the sampling days in seven sesame varieties and it was shown in (Fig. 5). On 45th DAT with 120mM salinity stress, higher nitrogen content was recorded in the variety TMV-3 (0.26%) followed by TMV-4 (0.24%) relative to control plants (0.34% and 0.33%, respectively), while lowest protein content was monitored in variety PAIYUR-1 (0.13%) followed by VIR-1 (0.15%) over the control plants (0.28% and 0.29%, respectively). On 45th DAT with 120mM salinity stress, protein content was moderately present in the variety VIR-2 followed by SVPR-1 and TMV-5 and it was 0.21%, 0.19% and 0.18%, respectively when compared to respective control plants.

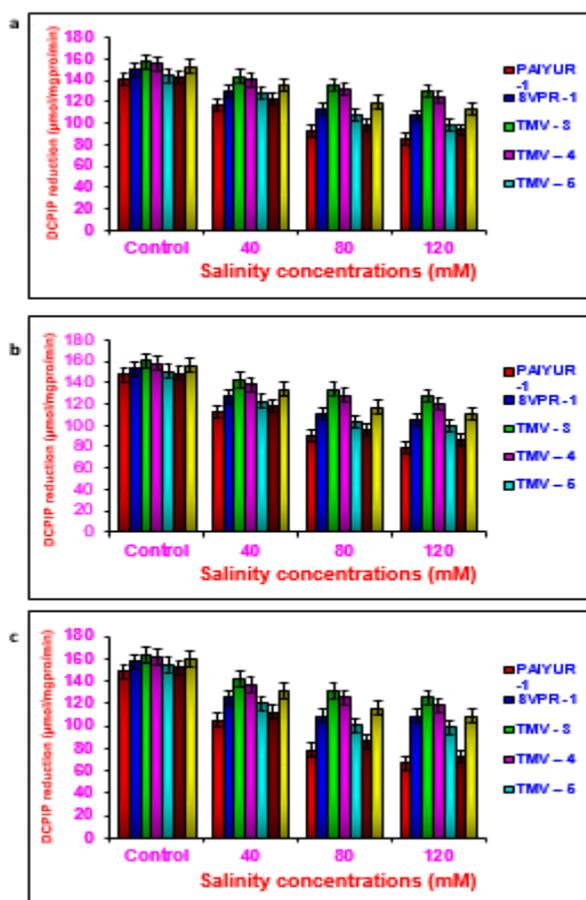


Fig. 4. Varying salinity stress effects on DCPIP reductions of sesame varieties on 15th DAT (a), 30th DAT (b) and 45th DAT (c). Each value represents mean \pm SE of five independent determinations ($p < 0.05$).

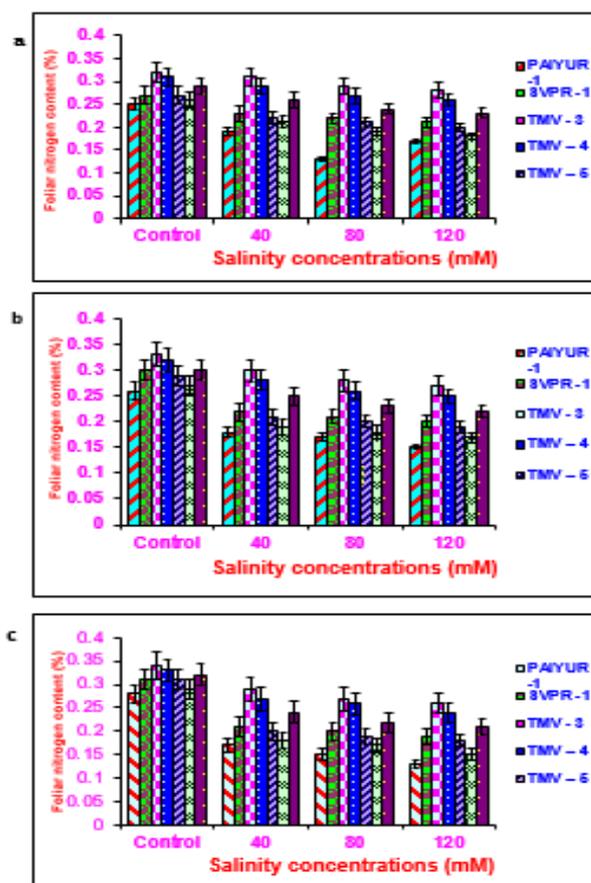


Fig. 5. Influence of varying levels of salinity stress on foliar nitrogen content in leaves of seven sesame varieties on 15th DAT (a), 30th DAT (b) and 45th DAT (c). Each value represents mean \pm SE of five independent determinations ($p < 0.05$).

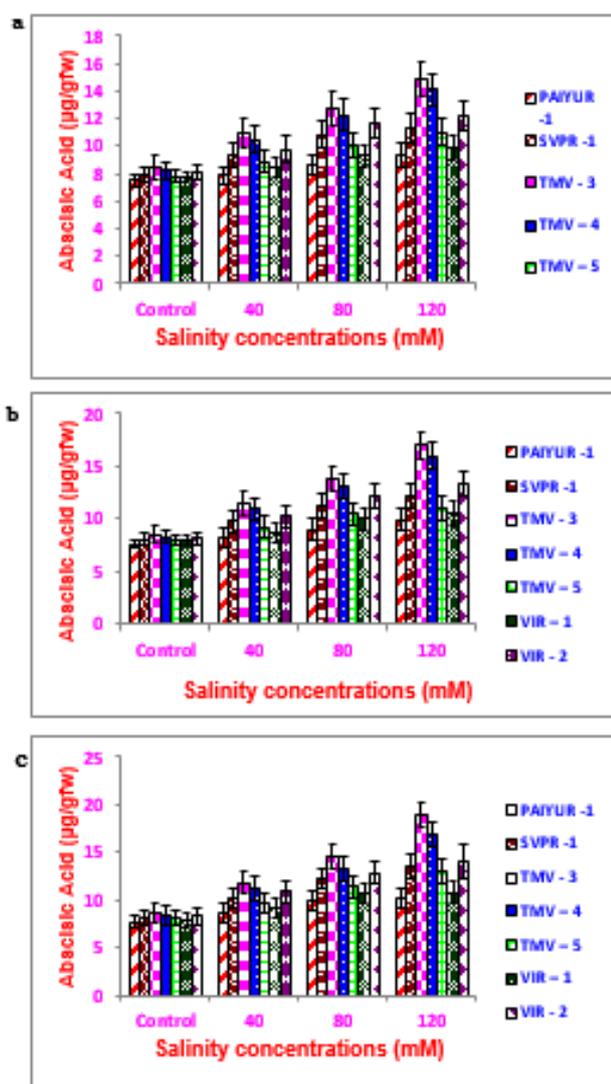


Fig. 6. Variation of abscisic acid content in leaves of sesame varieties on 15th DAT (a), 30th DAT (b) and 45th DAT (c) under varying salinity concentration.

Each value represents mean \pm SE of five independent determinations ($p < 0.05$).

Abscisic Content

Abscisic content (ABA) content was increased with increasing salinity levels on all the sampling days in leaves of sesame varieties as shown in (Fig. 6). ABA content was significantly increased in the variety TMV-3 by 55% (18.93 $\mu\text{g/gfw}$) followed by TMV-4 by 51% (16.87 $\mu\text{g/gfw}$) relative to control plants (8.59 $\mu\text{g/gfw}$ and 8.37 $\mu\text{g/gfw}$, respectively) on 45th DAT under 120mM salinity level, while ABA content was increased in the variety PAIYUR-1 by 25% (10.22 $\mu\text{g/gfw}$) followed by VIR-1 by 27% (10.81 $\mu\text{g/gfw}$) compared to control plants

(7.72 $\mu\text{g/gfw}$ and 7.92 $\mu\text{g/gfw}$, respectively). ABA content was moderately increased by 42% (14.14 $\mu\text{g/gfw}$), 40% (13.50 $\mu\text{g/gfw}$) and 38% (12.98 $\mu\text{g/gfw}$) in the varieties VIR-2, SVPR-1 and TMV-5, respectively under 120mM salinity on 45th DAT compared to control plants (8.26 $\mu\text{g/gfw}$, 8.14 $\mu\text{g/gfw}$ and 8.06 $\mu\text{g/gfw}$, respectively).

Discussion

Maximum photosynthetic rate was noticed in the variety TMV-3 followed by TMV-4 on all the sampling days under salinity stress, while moderate photosynthetic rate was observed in the varieties VIR-2, SVPR-1 and TMV-5 with varying salinity levels. PAIYUR-1 and VIR-1 recorded lowest photosynthetic rate on all the sampling days under salinity stress. Higher photosynthetic rate of TMV-3 was positively correlated with RuBP carboxylase activity.

In the present investigation, the calvin cycle enzyme RuBP carboxylase was measured in control and salinity treated plants of all sesame varieties (Fig. 2). Our results showed the highest activities of RuBP carboxylase in the leaves of variety TMV-3 followed by TMV-4 even under high salinity stress on all the sampling days (15th DAT, 30th DAT and 45th DAT), while lowest activity was observed in the variety PAIYUR-1 followed by VIR-1 under salinity stress. Moderate level of RuBP carboxylase activity was noticed in VIR-2 followed by SVPR-1 and TMV-5 at varying salinity concentration on all the sampling days.

In our study, significant decrease of SPS activity was observed in leaves of all sesame varieties under salinity stress on all the sampling days (15th DAT, 30th DAT and 45th DAT) (Fig. 3). However, highest SPS activity was measured in the variety TMV-3 followed by TMV-4 under salinity stress, while lowest SPS activity was observed in the varieties PAIYUR-1 followed by VIR-1 under salinity stress. Moderate level of SPS activity was recorded under salinity stress in the varieties VIR-2, SVPR-1 and TMV-5 relative to control plants on all the sampling days. SPS is a key enzyme in the synthesis of sucrose (Baxter et al., 2003).

In the present study, all the sesame varieties show inhibition of Hill reaction activity (with DCPIP as electron acceptor) in isolated chloroplasts under salinity stress on all the sampling days. However, lower inhibition of DCPIP reduction was observed in

the variety TMV-3 followed by TMV-4 even under high salinity on all the sampling days, while higher inhibition of Hill reaction activity was noticed in PAIYUR-1 followed by VIR-1 under varying salinity levels as compared relative controls. The Hill reaction activity was moderately inhibited in the varieties VIR-2 followed by SVPR-1 and TMV-5 under salinity stress (Fig. 4).

In our investigation, foliar nitrogen content decreased under salt stress and the pattern of decrease was varied among the sesame varieties. The foliar nitrogen content showed highly positive correlation with the rates of photosynthesis in all sesame varieties. Higher reduction was observed in the variety PAIYUR-1 followed by VIR-1 with all salinity levels on all the sampling stages (15th DAT, 30th DAT and 45th DAT) compared to control plants, whereas lower reduction of nitrogen content was monitored in TMV-3 followed by TMV-4 under salinity stress and moderate reduction of nitrogen content was noticed in VIR-2 followed by SVPR-1 and TMV-5 on all salinity concentrations on all the sampling days in relative to controls (Fig. 5). It has been reported that leaf nitrogen is involved in major alterations in carbon metabolism, including alterations in starch and sucrose contents in leaves (Hofstra et al., 1985; Dulormne et al., 2010) and the synthesis of organic acids to provide carbon skeletons for amino acid synthesis and to act as counter anions and prevent alkalization (Scheible et al., 1997). Number of laboratory and greenhouse studies have shown that salinity reduces nitrogen accumulation in plants (Al-Rawahy et al., 1992). This is not surprising, since with few exceptions (Feigin, 1985), an increase in Cl⁻ uptake and accumulation is accompanied by a decrease in shoot nitrogen concentration. Example of this effect are also found in barley (Aslam et al., 1984), cotton (Silberbush and Ben-Asher, 1987), cucumber (Martinez et al., 1994), eggplant (Savvas and Lenz, 1996), tomato (Kafkafi et al., 1982), tomato and melon (Feigin et al., 1987) and wheat (Balasubramanian and Sarin, 1975). This study provides evidence that the salt stress reduces the nitrate assimilation capacity in all the sesame varieties, but the percentage of reduction varied. The study on foliar nitrogen content clearly showed that variety TMV-3 has efficient nitrogen assimilation system

compared to other varieties under varying salinity level.

An enhance in ABA is reported in many stress conditions which help plant survival under stressful environments (Ahamad et al., 2009; Thameur et al., 2011). Elevated ABA levels in the leaves are typical response to water deficit induced by drought or salinity (Chapin, 1991). In the current study, ABA content in leaves of all sesame varieties increased under salt stress on all the sampling days (15th DAT, 30th DAT and 45th DAT) (Fig. 6). However, marked increase of ABA content was observed in the variety TMV-3 followed by TMV-4 under salt stress. The lowest increase of ABA content was found in the variety PAIYUR-1 followed by VIR-1, while moderate increase was observed in the varieties VIR-2 followed by SVPR-1 and TMV-5 on all the sampling days. Hassanein et al. (2009) reported that the amount of ABA detected in maize plants was found to increase under NaCl stress and the magnitude of increase was directly proportional to the increase in the concentration of NaCl. In addition, Larosa et al. (1987) found that ABA stimulated osmotic adjustment and involved in adaptation of tobacco callus to NaCl. In our investigation, notable accumulation of ABA in the variety TMV-3 under salinity stress may suggests its role in adaptability and development of salt tolerance trait in these plants. On the other hand, PAIYUR-1 accumulated less ABA and thus less adaptive to salt stress.

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Author contributions

All authors contributed equally in the study and preparation of article. All authors approved the final version of the manuscript for publication.

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