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Analysis of net leaf photosynthesis in *Aegiceras corniculatum* (L.) Blanco under various saline conditions

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ABSTRACT

In the present investigation, a comparative study was made on the effect of exogenous addition of sodium chloride on net leaf photosynthesis (CO_2 uptake) in *Aegiceras corniculatum* (L.) Blanco, a dicotyledonous mangrove species. The net leaf photosynthesis of *A. corniculatum* was modified in the presence of sodium chloride, it may be called a preferential halophyte. Salinity is one of the most significant environmental challenges also abiotic constraints limiting plant productivity. *A. corniculatum* could tolerate up to 800 mM sodium chloride concentrations. The net leaf photosynthesis rate was increased with increasing NaCl salinity up to 400 mM. This concentration was found to be the optimum salinity level for this species. In conclusion, it may be inferred that sodium chloride promoted the photosynthesis concentrations upto optimum level of 400 mM in *Aegiceras corniculatum* (L.) Blanco. beyond 400 mM NaCl decreased the CO_2 uptake. The maximum photosynthetic obtained at 400 mM NaCl on the l20th day.

***Keywords*:** sodium chloride, *Aegiceras corniculatum,* Photosynthesis, salinity

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1. INTRODUCTION

Salinity is one of the most significant environmental challenges limiting plant productivity. The natural environment for mangrove plants is composed of a complex set of abiotic and biotic stress factors that include salinity. Salinity stress exerts adverse effects on plants by disrupting the ionic and osmotic equilibrium of the cells leading to decrease in plant growth and development (Das *et al*., 2016). Salinity levels and drought status of coastal wetlands may be strongly affected by climate change, and changes in the nitrogen cycle of mangrove wetlands may also be affected (Miao *et al*., 2017).

The ecosystem of Mangroves play a significant role in impact on global environmental change (Pandey *et al*., 2019). Mangroves are trees and shrubs that grow at the interface between land and sea in tropical subtropical latitudes where the plants exist in conditions of salinity, tidal water flow and muddy soil (Saravanavel *et al*., 2011). They are salt tolerant plants of tropical and subtropical intertidal regions of the world (Bidve *et al.*, 2017). Over the past few decades, the global mangrove forests have undergone significant changes on distributive pattern and area, caused by a variety of factors including rising temperatures, changes in precipitation patterns, increased frequency and intensity of storms and sea level rise (Asbridge *et al*., 2015).

There is increasing evidence that NaCl salinity is one factor leading to oxidative stress in plants cells (Hernandez *et al.,* 2000). High NaCl concentration seems to impair electron in chloroplast and mitochondria, and lead to formation of Reactive Oxygen Species (ROS) (Asada, 1999; Foyer and Noctor 2002).

A. corniculatum (L.) Blanco is one of the most salt tolerant mangrove species (Fang *et al*., 2016). It belongs to the Myrsinaceae family distributed in coastal and estuarine areas of India (Geegi and Manoharan, 2018). The present investigation, the effect of various concentrations of sodium chloride on the net leaf photosynthesis (CO_2 uptake) was studied.

The optimal level of salinity for favorable for maximum photosynthetic uptake have been assessed.

2. MATERIALS AND METHODS

2. 1. Plant Material

The plant material used for the present study was the seedlings of *Aegiceras corniculatum* (L.) Blanco, a dicotyledonous mangrove (large shrub with obovate emarginate coriaceous leaves) belonging to the family *Myrsinaceae*. This species was naturally growing in abundance in the mangrove belt of Pichavaram, on the east coast of Tamil Nadu, India, (11°24′N and 79°44′E) about 10 km east of Annamalai University campus. The present study was carried out in the Botanic garden of Annamalai University, Annamalainagar. Mature seeds of *A. corniculatum* are elongate curved about 5 cm in long.

The seeds were collected from Pichavaram mangrove area during monsoon period (November-December) from a single shrub in order to avoid genetic variability and germinated in 7″ × 5″ polythene bags filled with garden soil mixed with farm yard manure and the seedlings were irrigated with tap water at regular intervals for a period of one month. Healthy seedlings were selected and they were transferred to experimental site, which was roofed with transparent polythene sheet to protect the seedlings from rainwater. The plants had an approximate 12 h photoperiod and mean day temperature of 36 °C and night temperature of 27 °C.

(a)

(b)

Photos 1(a,b). *Aegiceras corniculatum* (L.) Blanco

2. 2. Sodium Chloride Treatment

One month old and fully established seedlings were treated with different concentrations of sodium chloride. The treatment constituted 0 (control), 100, 200, 300, 400, 500, 600, 700, 800, 900 and 1000 mM NaCl. Fifty plants were maintained with each of the above NaCl concentrations. The control of 50 plants was maintained without salt treatment. The salt treatment continued until each plant received the required mM NaCl. Beyond 800 mM NaCl, *A. corniculatum* could not survive a month after salt treatment.

Sodium chloride (Laboratory grade Assay 99.5% - Sarabhai M Chemicals) was used for the experiments. The required amount of this salt was dissolved in distilled water to obtain the desired concentrations.

2. 3. Sampling

First samples for various studies were collected on the 60th day after NaCl treatment. The second and third samples were collected on the 90th and 120th day respectively after salt treatment. Salt treatments were given to plants at different periods, so as to enable to obtain experimental plants whenever required for various investigations on the 60th, 90th and 120th day after salt treatments.

2. 4. Net leaf photosynthesis

The net photosynthesis (CO_2 uptake) was measured using a Li-Cor 6200 portable Infra-Red Gas Analyser (Li-Cor Inc., USA). All the measurements were made during the noon period when the stomata were fully opened. Precautions were taken to avoid any water vapour on the leaf surface during the measurements. Always a 1 litre, leaf chamber was used. Readings were taken at 5 seconds intervals and 10 readings were computed in each measurement. Five to six such measurements were made and only natural light was used during these measurements.

3. RESULTS AND DISCUSSION

The effect of different concentrations of sodium chloride on the net leaf photosynthesis (CO_2 uptake) was monitored by IRGA in the leaves of *A. corniculatum* and the data are presented in Tables 1, 2 and 3. Sodium chloride salinity increased the rate of CO_2 uptake upto 400 mM and concentrations beyond 400 mM NaCl decreased the CO_2 uptake. The maximum photosynthetic rate obtained at 400 mM NaCl on the l20th day was 86.99% higher than that of control. On the optimum level of NaCl the net leaf photosynthesis is promoted, and the stomatal conductance, vascular bundles, salt glands and intercellular CO_2 concentration are modified.

Along with the increase in CO_2 uptake with the increasing concentrations of NaCl, the stomatal conductance, transpiration, leaf chamber temperature and intercellular CO_2 concentration also registered a gradual increase upto 400 mM NaCl (Tables 1, 2 and 3, Fig. 1 & 2). This increasing trend was similar to that of CO_2 uptake. The 'F' values calculated were significant at 1% level. Sodium chloride salinity enhanced the photosynthetic CO_2 uptake upto the optimum level of 400 mM in *A. corniculatum*. The rate of CO_2 uptake was higher in the 120th day samples than 60th and 90th day samples after salt treatment at all concentrations. The control plants showed the lowest values. The increase in the photosynthetic rate was with increase in the age of the seedlings.

There was also linear relationship of CO_2 uptake with stomatal conductance and transpiration. The high water use efficiency of mangrove is achieved through close coupling between photosynthetic mechanism and stomatal conductance (Andrews and Mullar, 1985). The results on the rate of CO_2 uptake in the present investigation in *A. corniculatum* are in agreement with other halophytes and mangroves such as *Kandelia candel* (Yuan-Hsun Hwang and Shuh-Chun Chen, 2001), *Atriplex patula* (Ungar, 1996), *Ceriops roxburghiana* (Rajesh *et al.*, 1998) and *Rhizophora styloza* (Cheeseman *et al.*, 1997).

The salinity stress can decrease the photosynthetic activity of the halophytic plant by inducing partial stomatal closure, decreasing carboxylation efficiency and CO_2 saturated photosynthesis and inhibiting the light reaction mechanism (Mudrik, et al 2003). The increase sodium chloride treatments promoted chlorophyll synthesis in the leaf of *A. officinalis* and net leaf photosynthesis at 0.75%. NaCl concentrations, further increased in NaCl concentration in the (1.00 - 2.00%) decreased the photosynthetic pigments and net leaf photosynthesis (Saravanavel et al., 2011).

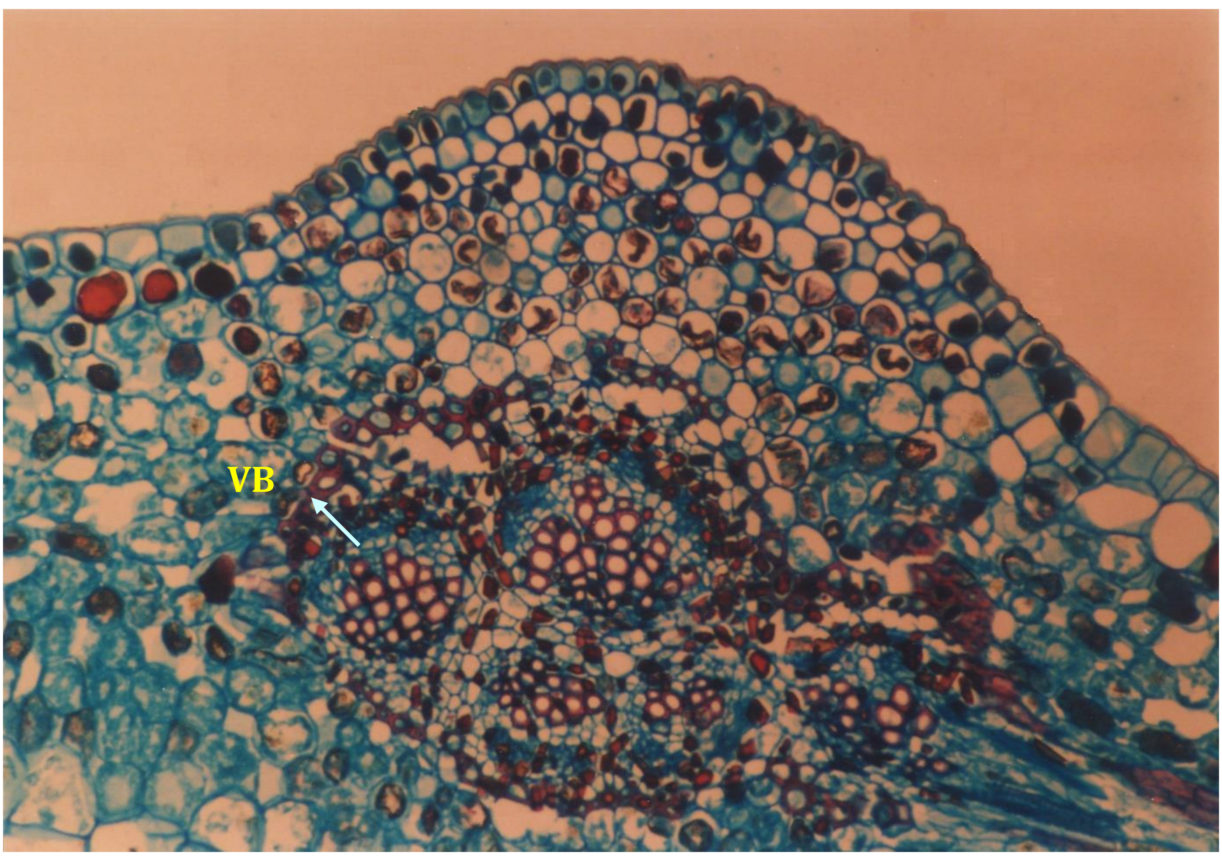

Fig. 1. Transverse section of a leaf of *Aegiceras corniculatum* showing vascular bundles (VB)

On the other hand, the inhibition of net photosynthetic rate at higher salinity has been reported in a few halophytes such as *Arthrocnemum* (Walker *et al.*, 1982), *Ipomoea pes-caprae* (Venkatesan *et al.*, 1995) and *Scaevola sericea* (Goldstein *et al.*, 1996).

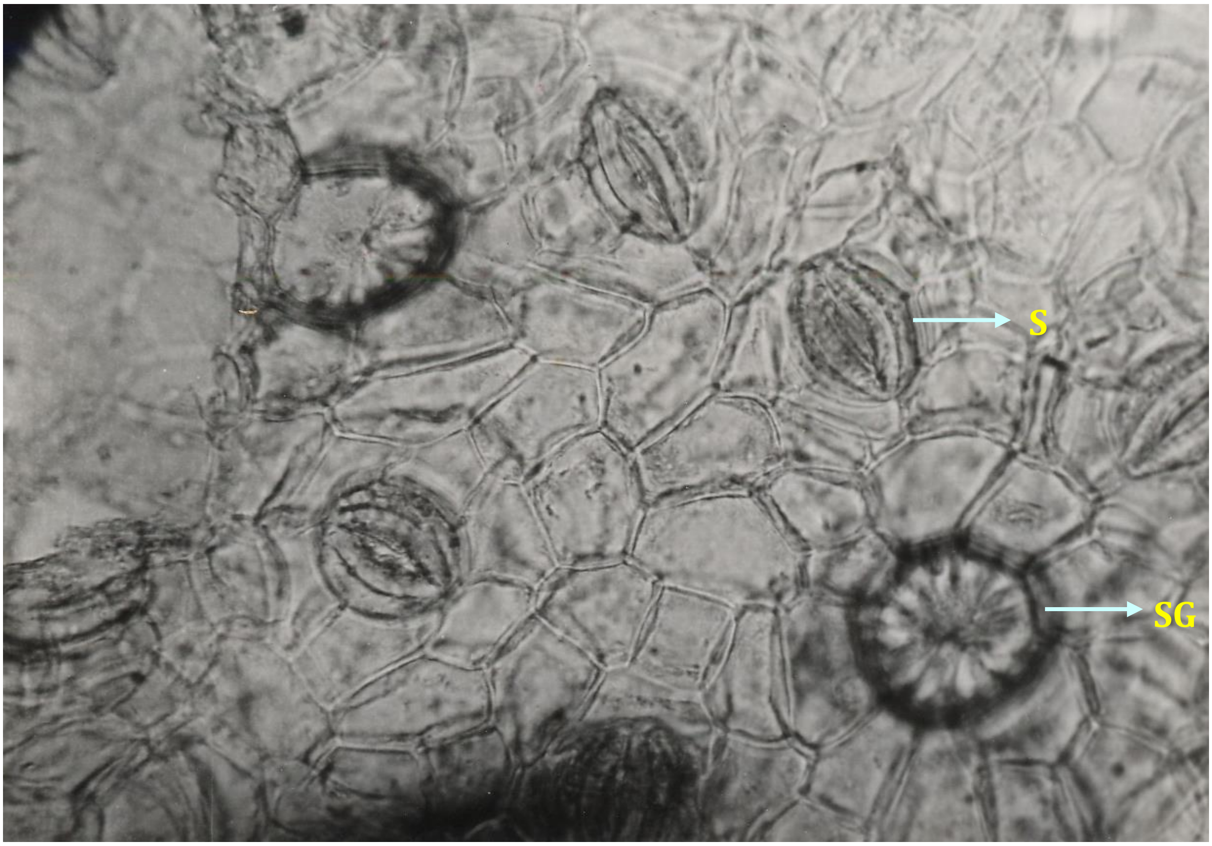

Fig. 2. Epidermal peel of a leaf of *Aegiceras corniculatum* showing stomata (S) and salt glands (SG)

Table 1. Effect of NaCl on the net leaf photosynthesis of *Aegiceras corniculatum* (μ moles/CO_2 m^{-2} s^{-1}) on 60th day

Con of Nacl (mM)	Net photosynthesis	Stomatal conductance	Transpiration	Leaf chamber temperature	Intercellular CO_2 concentration
Control	8.2	0.19	5.3	31.0	0302
100	8.5 (+ 3.65)	0.19 (+ 0.00)	5.5 (+ 3.77)	31.6 (+ 1.93)	0325 (+ 7.61)
200	10.0 (+ 21.95)	0.21 (+ 10.52)	6.0 (+ 13.20)	32.3 (+ 4.19)	0334 (+ 10.59)
300	12.7 (+ 54.87)	0.22 (+ 15.78)	6.4 (+ 20.75)	32.7 (+ 5.48)	0349 (+ 15.56)
400	16.5 (+ 101.21)	0.24 (+ 26.31)	7.0 (+ 32.07)	33.7 (+ 8.70)	0365 (+ 20.86)

500	13.9 (+ 69.51)	0.23 (+ 21.05)	6.3 (+ 18.86)	32.6 (+ 5.16)	0320 (+ 5.96)
600	10.2 (+ 24.39)	0.21 (+ 10.52)	5.6 (+ 5.66)	30.4 (- 1.93)	0300 (- 0.66)
700	6.5 (- 20.73)	0.17 (- 10.52)	5.0 (- 5.66)	28.9 (- 6.77)	0281 (- 6.95)
800	5.0 (- 39.02)	0.15 (- 21.05)	4.7 (- 11.32)	27.0 (- 12.90)	0263 (- 12.91)

F_1 = 90.04 F_1 = 20.29 F_1 = 20.40 F_1 = 35.35 F_1 = 80.16
F_2 = 149.36 F_2 = 142.68 F_2 = 64.10 F_2 = 69.49 F_2 = 245.98

Photosynthetic inhibition under high salinity may be attributed to the disruption of chloroplast in senescent leaves (Joshi and Mishra, 1970) and in great degree to the decrease in K content. Potassium is required for the maintenance of CO_2 uptake (Pier and Berkowitz, 1987). Salinity stress can decrease the photosynthetic activity of the halophytic plant by inducing partial stomatal closure decreasing carboxylation efficiency and/or CO_2-saturated photosynthesis and inhibiting the light reaction mechanism (Ungar, 1991). A decrease in the chlorophyll content under NaCl salinity has been reported in a number of mangroves such as *Ceriops roxburghiana* (Natarajan and Chellappan. 2004) and *Aegiceras corniculatum* (Parida *et al*., 2004).

Table 2. Effect of NaCl on the net leaf photosynthesis of *Aegiceras corniculatum* (µ moles/CO_2 m^{-2} s^{-1}) on 60th day

Con of Nacl (mM)	Net photosynthesis	Stomatal conductance	Transpiration	Leaf chamber temperature	Intercellular CO_2 concentration
Control	9.3	0.22	6.0	32.9	0336
100	10.6 (+ 13.97)	0.23 (+ 4.54)	6.4 (+ 6.66)	33.9 (+ 3.03)	0351 (+ 4.46)
200	14.7 (+ 58.06)	0.24 (+ 90.90)	6.7 (+ 11.66)	35.0 (+ 6.38)	0356 (+ 5.95)
300	16.8 (+ 80.64)	0.26 (+ 18.18)	7.0 (+ 16.66)	36.0 (+ 9.42)	0365 (+ 8.63)
400	18.6 (+ 100.00)	0.27 (+ 22.72)	7.7 (+ 28.33)	36.8 (+ 11.85)	0377 (+ 12.20)
500	16.2 (+ 74.19)	0.23 (+ 4.54)	6.9 (+ 15.00)	33.0 (+ 0.30)	0380 (+ 13.09)
600	12.2 (+ 31.80)	0.22 (+ 0.00)	6.5 (+ 8.33)	32.0 (- 2.73)	0330 (- 1.78)
700	7.5 (- 19.35)	0.20 (- 9.09)	5.8 (- 3.33)	30.0 (- 8.81)	0294 (- 12.50)
800	7.0 (- 24.73)	0.18 (- 18.18)	5.0 (- 16.66)	29.0 (- 9.37)	0282 (- 16.07)

Table 3. Effect of NaCl on the net leaf photosynthesis of *Aegiceras corniculatum* (µ moles/CO_2 m^{-2} s^{-1}) on 60th day

Con of Nacl (mM)	Net photosynthesis	Stomatal conductance	Transpiration	Leaf chamber temperature	Intercellular CO_2 concentration
Control	12.3	0.26	6.7	33.8	0366
100	13.7 (+ 11.38)	0.28 (+ 7.69)	7.2 (+ 7.46)	34.5 (+ 2.07)	0382 (+ 4.37)
200	17.9 (+ 45.52)	0.30 (+ 15.38)	7.9 (+ 17.90)	36.0 (+ 6.50)	0395 (+ 7.92)
300	19.2 (+ 56.90)	0.33 (+ 26.92)	9.2 (+ 37.31)	36.7 (+ 8.57)	0408 (+ 11.47)
400	23.0 (+ 86.99)	0.37 (+ 42.30)	9.9 (+ 47.76)	38.0 (+ 12.42)	0420 (+ 14.75)
500	20.2 (+ 64.22)	0.33 (+ 26.92)	8.0 (+ 19.40)	35.8 (+ 5.91)	0.390 (+ 6.55)
600	16.5 (+ 34.14)	0.29 (+ 11.53)	7.3 (+ 8.95)	34.5 (+ 2.07)	0.362 (- 1.09)
700	12.0 (- 2.43)	0.26 (0.00)	6.5 (- 2.98)	33.2 (- 1.77)	0353 (- 3.55)
800	10.3 (- 16.26)	0.24 (- 7.69)	5.9 (- 11.94)	30.7 (- 9.17)	0320 (- 12.56)

4. CONCLUSIONS

In the present investigation, a comparative study was made on the effect of exogenous addition of sodium chloride on net photosynthetic rate in the seedlings of *Aegiceras corniculatum* Blanco, a dicotyledonous mangrove species. In conclusion, the net leaf photosynthesis, stomatal conductance, vascular bundles, salt glands, and intercellular CO_2 concentration were promoted upto the optimum level and declined at higher NaCl salinity.

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