International Journal of Plant & Soil Science

Volume 35, Issue 20, Page 443-451, 2023; Article no.IJPSS.106989
ISSN: 2320-7035

Weather Influences on the Gas Exchanges of Neem Trees

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Authors' contributions

This work was carried out in collaboration among all authors. Authors RB and GAD carried out verification of output, and wrote the protocol and the first draft of the manuscript. Authors AS, NKS and PSG generated the outputs. Authors KP and GS defined the methodology of the research and verification part. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2023/v35i203825

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/106989

Original Research Article

Received: 15/07/2023
Accepted: 18/09/2023
Published: 23/09/2023

ABSTRACT

The neem tree is a prospective agroforestry tree with significant demand in the medical and timber industries. It has a specific season of reproductive phase in a year, mostly from February to July in India. A study was organized to identify the influence of various weather parameters on the reproductive phase at Tamil Nadu Agricultural University, Coimbatore during 2023 and this paper is confined to weather on gas exchange parameters. The results inferred that the reproductive statuses of neem trees, including regular flowering, dormant flowering, and alternate flowering trees, exhibited notable differences in gas exchange parameters such as photosynthetic rate, Stomatal conductivity, and transpiration rate due to observed variability in prevailing weather conditions. Alternate-bearing trees were found to have higher gas exchange parameters when

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compared to regular flowering and nonflowering trees. The neem trees recorded significantly higher values of these parameters during the preflowering compared to the flowering stage. During both the preflowering and flowering stages, the rainfall, relative humidity, minimum temperature, and wind speed, exhibited a statistically non-significant negative influence on gas exchange activities. The maximum temperature exhibited a positive impact during the pre-flowering stage and a negative impact throughout the flowering phase whereas diurnal temperature exhibited a positive effect on the gas exchange parameter during both the preflowering and flowering stages of the neem tree.

Keywords: Neem tree; flowering habits; weather; gas exchange parameters.

1. INTRODUCTION

Neem (Indian Lilac) belongs to the family Meliaceae (19) is an evergreen tree originated from the Indian subcontinent and Southeast Asian nations. It is also referred to as Vembu (Tamil), Nimba (Sanskrit, 'reliever of sickness'), Nim (Assamese), Nimb (Hindi), Veppu (Malayalam), Nimbanuv (Telungu), Kadukhajur (Marathi), Margosa (Portuguese). It is also mentioned as "Sarva Roga Nivarini" in Tamil and other Indian literature. In Persian literature, neem trees were mentioned as 'Azad-Darakth-E-Hind', referring 'Free tree of India'.

Neem is a fast-growing tree with thick round canopy and having a life span of 200 years in natural conditions [1]. The tree produces oval fruits, 1.5 - 2.5 cm in length, with a tough white shell, brown seed kernel, and sweet yellowish pulp, typically once a year, occasionally twice. Neem seed yield varies with tree age, approximately 9 kg, 13 kg and 19 kgs from 10, 15 and 20-years older trees [2]. The emergence of the new leaves and the inflorescence primordial occurs concurrently in February and March. The flowering of neem begins in March, fruiting starts by May, matured fruit drops during July and season completes ends in August [3].

In general, neem grows up to a height of 25 m and survive in various types of soils including problem soils. It is found mostly in tropical regions with a temperature range of 21-32^{0}C and annual rainfall between 400 to 800 mm. Neem need a dry season and sensitive to frost [4]. Neem is well-adapted to varied climatic conditions, but its physiology, growth and reproductive capacity would be significantly affected by variations in weather parameters [5]. Optimum weather conditions are crucial for successful establishment and growth of trees. A decrease in stomatal conductance, net photosynthetic rate, transpiration rate and leaf relative water content, whereas an increase in leaf mass per area were observed in neem trees of all four provenances China, due to the extreme weather condition. The increased water stress decreased the stomatal conductance, net photosynthetic rate, transpiration rate, and leaf RWC of Neem [6]. It was reported that the fruiting canopy exhibited elevated net photosynthetic rates and canopy conductance compared to the non-fruiting canopy [7].

With this background, a study was conducted to assess the influences of weather parameters on the variation in gas exchange parameters during reproductive phase of the neem trees. The stud also compared three different characterized neem trees viz., regular flowering, dormant flowering and alternate flowering neem tree at Coimbatore climatic condition. The valuable insights into the gas exchange parameters of neem trees and prevailing weather will help to make a decision to improves its productivity.

2. MATERIALS AND METHODS

2.1 Study Area

Study was conducted in neem tree clusters during the flowering season (February – June 2023) of neem trees at Tamil Nadu Agricultural University (TNAU), Coimbatore, India, which is geographically located near 11^{o} N and 77^{o} E (Fig.1). Coimbatore is comes under Western Agro Climate Zone of Tamil Nadu which is characterised with clay loamy soil having low nitrogen and medium phosphorous and potassium which is having long period average annual rainfall of 690 mm, maximum temperature of 32^{o}C, minimum temperature of 22^{o}C, morning RH of 75% and afternoon RH of 55%. The study was grouped in to Pre-flowering (5 – 14 SMW), flowering (15 - 24 SMW) phases.

Daily observed weather parameters *viz.,* maximum and minimum temperature, rainfall, windspeed, and Relative Humidity were collected from the TNAU observatory and converted to weekly for the study period from February 2023 (5th SMW) to June 2023 (24th SMW) and is depicted graphically in Fig. 2.

The weather was being near normal during both the flowering phases. Pre-flowering phase temperatures ranged from 21.2 to 37.1 degrees Celsius, morning relative humidity ranged from 73 to 97%, and wind speed ranged from 1.7 to 5.9 km/hr. A total of 17 mm had been received during this time. While the flowering phase temperatures ranged from 24.4 to 38.7 degrees Celsius, morning relative humidity ranged from 71 to 92%, and wind speed ranged from 3.7 to 6.6 km/hr. A total of 231 mm had been received during this flowering phase.

2.2 Sampling Tree Selection

In this study, nine neem trees with three different patterns of flowering (F1: Regular, F2: Dormant and F3: Alternate) and three different Breast Height Diameter (DBH, D1: <30 cm, D2: 30 -40 cm & D3: >40 cm) were selected. These nine (3F x 3D) combinations were replicated four times. Basic growth parameters were measured including tree height, crown width, and DBH using a Blume-Leiss dendrometer and standard measuring tapes. The mean values of biometric parameters are depicted in Table 1.

2.3 Measurement of Gas Exchange Parameters

Portable Photosynthetic System (PPS)-Model LCi-SD of ADC Bio-scientific Ltd., Great Am-well, Hertfordshire, UK] was used between 9 and 11 AM to measure the gas exchange parameters. Observations were made for photosynthetic rate (μmol CO2 m^{-2} s^{-1}), transpiration rate (mmol H_2O m^{-2} s^{-1}), stomatal conductance (mol H_2O m^{-2} s^{-1}) during pre-flowering and flowering phases. Each four fully grown leaves in the middle of the canopy from all eight directions of the trees that fully exposed to solar radiation were selected, measured, averaged and the mean values are presented in Table 2.

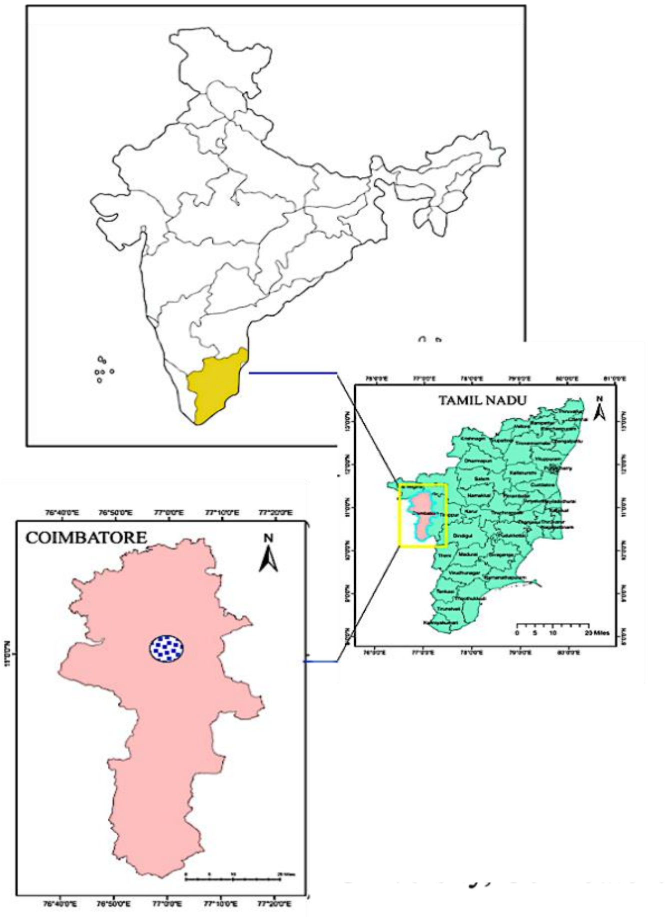

Fig. 1. Study location Tamil Nadu Agricultural University, Coimbatore

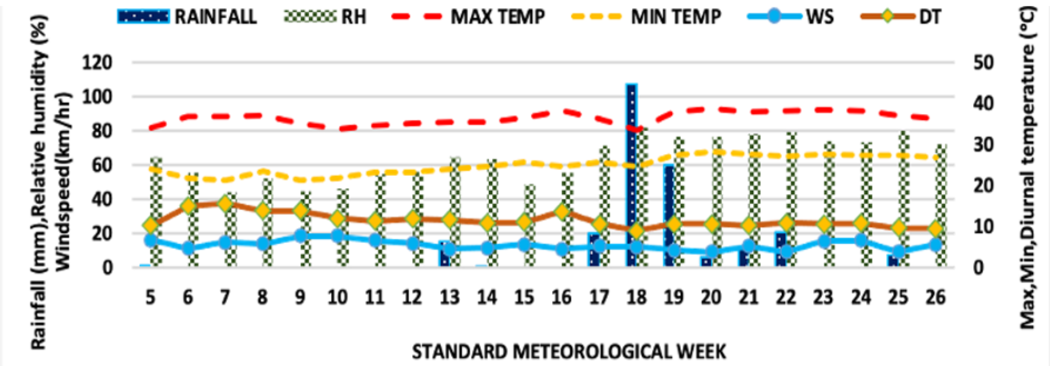

Fig. 2. Weather prevailed during Feb. to Jun. 2023 in the study location

Table 1. Biometric observations of selected trees

Factors	D1	D2	D3	Mean	D1	D2	D3	Mean
	Diameter at Breast Height (DBH, cm)				Trunk height (m)			
F1	41.8	34.2	26.4	**34.1**	3.5	3.5	2.5	**3.2**
F2	42.6	32.4	25.2	**33.4**	3.5	3.5	2.5	**3.2**
F3	43.1	32.4	26.1	**33.9**	3.5	3.5	2.5	**3.2**
Mean	**42.5**	**33.0**	**25.9**	**33.8**	**3.5**	**3.5**	**2.5**	**3.2**
	Crown height (m)				Tree height (m)			
F1	11.5	10.0	9.0	**10.2**	15.0	13.5	11.5	**13.3**
F2	11.0	9.0	8.5	**9.5**	`14.5	12.5	11.0	**11.8**
F3	12.0	10.5	9.5	**10.7**	15.5	14.0	12.0	**13.8**
Mean	**11.5**	**9.8**	**9.0**	**10.1**	**15.3**	**13.3**	**11.5**	**13.4**

F1 - Regular flowering *F2 - Dormant flowering* *F3 - Alternate flowering*
D1 - DBH <30 cm *D2 - DBH 30 -40 cm* *D3 - DBH >40cm*

2.4 Statistical Analysis

Factorial Randomized Block Design was used to analyze the experimental results using "R" programme and the correlation analysis was done between weather parameters and gas exchange parameters.

3. RESULTS AND DISCUSSION

3.1 Physiological Parameters

3.1.1 Photosynthetic rate

Photosynthetic Rate (PR) of neem trees (mol CO_2 m^{-2} s^{-1}) recorded at pre-flowering and flowering phases for the nine-flowering habited and DBH combinations are presented in Table 2. The photosynthetic rate had ranged from 2.090 to 7.848 during pre-flowering phase and 1.818 to 6.840 during flowering stage. The pre-flowering phase had higher PR than the flowering phase. Both flowering types (F) and DBH (D) factors had significant variation in PR as individual and in combination. Among the three flowering types, the PR was higher in alternate flowering followed by regular flowering. Trees with lesser DBH had higher PR than bigger trees. Significantly highest PR was observed in alternate flowering with smallest DBH (D1F3) combination.

Plants engaged in higher food production with increased leaf area during the pre-flowering phase, whereas higher metabolic activity of plants during the reproduction phase increased the water and energy requirements, which could explain why photosynthetic rate was higher during the pre-flowering phase than the flowering phase. This was in line with results of [8-11]. Alternate flowering trees exhibited a higher photosynthetic rate than other trees, which was consistent with the findings of [12] in the Apple tree. In general, DBH increased with tree age, and younger trees with lower DBH (30cm) may have higher PR than older trees with higher DBH.

3.1.2 Transpiration rate

The transpiration rate (TR) of neem trees (m mol H_2O m^{-2} s^{-1}) recorded at pre-flowering and flowering phases for the nine-flowering habited and DBH combinations are shown in Table 3. The rate of transpiration is important for plant water balance and may affect their ability to grow. The transpiration rate of different neem trees measured at different phases followed the same trend as the photosynthetic rate for all reproductive statuses of neem trees, i.e., flowering, Dormant flowering, and alternate flowering.

The transpiration rate (mmol H_2O m^{-2} s^{-1}) had varied from 0.89 to 2.23 during pre-flowering phase and 0.46 to 2.04 during flowering phase. The pre-flowering phase had higher TR than flowering phase.

The pre-flowering phase had higher TR than flowering phase. Both flowering type (F) and DBH(D) factor had significant variation in TR as individual and in combination. TR was higher in alternate flowering trees followed by regular flowering. Comparatively lesser DBH trees had higher TR than others. Significantly higher TR was observed high in alternate flowering types with DBH of 20 - 40 cm (D2F3) combination. Lower transpiration rate observed in the flowering phase affected the trees photosynthetic activity during that period. Similar observation was found by [13]. In general, the transpiration rate had a positive association with photosynthesis and was an indirect indication of the rate of photosynthesis in leaves [14].

Table 2. Photosynthetic rate (mol CO_2 m^{-2} s^{-1}) of three different reproductive status of neem at two stages

	F1	F2	F3	Mean
Pre-Flowering phase				
D1	4.780	3.138	7.848	**5.255**
D2	5.740	2.090	7.400	**5.077**
D3	4.440	2.890	7.060	**4.797**
Mean	**4.987**	**2.706**	**7.436**	**5.043**
	F	**D**	**F x D**	
	0.112	0.112	0.195	
	0.054	0.054	0.094	
Flowering phase				
D1	3.442	1.975	6.840	**4.086**
D2	4.527	2.140	5.000	**3.889**
D3	2.958	1.818	5.445	**3.407**
Mean	**3.642**	**1.978**	**5.762**	**3.794**
	F	**D**	**F x D**	
SED	0.054	0.054	0.094	
CD	0.112	0.112	0.195	

Table 3. Transpiration rate (mmol H_2O m^{-2} s^{-1}) of three different reproductive status of neem at two stages

	F1	F2	F3	Mean
Pre-Flowering phase				
D1	1.66	0.92	2.10	**1.56**
D2	1.26	0.89	2.23	**1.46**
D3	1.10	1.03	2.11	**1.41**
Mean	**1.34**	**0.95**	**2.15**	**1.48**
	F	**D**	**F x D**	
	0.03	0.03	0.04	
	0.01	0.01	0.02	
Flowering phase				
D1	1.35	0.72	1.76	**1.28**
D2	0.62	0.58	2.04	**1.08**
D3	0.75	0.46	1.77	**0.99**
Mean	**0.91**	**0.59**	**1.86**	**1.12**
	F	**D**	**F x D**	
SED	0.01	0.01	0.02	
CD	0.02	0.02	0.04	

3.1.3 Stomatal conductivity

Stomatal conductivity (SC) of neem trees (mol CO_2 m^{-2} s^{-1}) recorded at pre-flowering and flowering phases for different flowering habited and DBH combinations are exhibited in Table 4.

Stomatal conductivity of neem trees was ranged from 0.030 to 0.147 in pre-flowering phase and 0.020 to 0.060 in flowering phase, respectively. As same as PR and TR, the SC was higher in pre-flowering phase. The same results are reported by [15] Among the different flowering types, the SC was higher in alternate flowering tree followed by regular flowering trees. There was significant difference in the stomatal conductivity between the various reproductive states of the tree during the pre-flowering stage. Stomatal conductance and net photosynthesis are frequently associated [16]. The drop-in photosynthetic rate during the flowering stage that was seen in this study may be caused by a decrease in stomatal conductivity, which was similarly explained by [17] in olive trees. According to [18], phenological phases were advanced, which led to a drop-in photosynthetic rate and stomatal conductivity [19].

3.1.4 Correlation between weather and gas exchange parameters during the pre-flowering stage

Results of the correlation analysis between weather and gas exchange parameters during the pre-flowering stage of different statuses of neem trees is presented in Table 5.

Table 4. Stomatal conductance (mol H_2O m^{-2} s^{-1}) of three different reproductive status of neem at three stages

	F1	F2	F3	Mean
Pre-flowering phase				
D1	0.060	0.040	0.120	**0.073**
D2	0.070	0.030	0.140	**0.080**
D3	0.080	0.090	0.147	**0.106**
Mean	**0.070**	**0.053**	**0.136**	**0.086**
	F	**D**	**F x D**	
	0.001	0.001	0.002	
	0.001	0.001	0.001	
Flowering phase				
D1	0.030	0.020	0.040	**0.030**
D2	0.020	0.030	0.050	**0.033**
D3	0.022	0.050	0.060	**0.044**
Mean	**0.024**	**0.033**	**0.050**	**0.036**
	F	**D**	**F x D**	
	0.002	0.002	0.003	
	0.001	0.001	0.002	

Table 5. Correlation matrix among the Gas Exchange Parameters and with the weather parameter during the pre-flowering stage

	MAX	MIN	RF	WS	DT	RH
Regular Flowering						
PR	0.299^{NS}	-0.309^{NS}	-0.178^{NS}	-0.077^{NS}	0.399^{NS}	-0.049^{NS}
TR	0.143^{NS}	-0.164^{NS}	-0.155^{NS}	-0.059^{NS}	0.202^{NS}	0.133^{NS}
SC	0.373^{NS}	-0.371^{NS}	-0.188^{NS}	-0.135^{NS}	0.489^{NS}	-0.093^{NS}
Dormant flowering						
PR	0.181^{NS}	-0.194^{NS}	-0.161^{NS}	-0.104^{NS}	0.246^{NS}	0.127^{NS}
TR	0.290^{NS}	-0.299^{NS}	-0.178^{NS}	-0.090^{NS}	0.387^{NS}	-0.024^{NS}
SC	0.296^{NS}	-0.320^{NS}	-0.143^{NS}	0.081^{NS}	0.405^{NS}	-0.257^{NS}
Alternate Flowering						
PR	0.246^{NS}	-0.258^{NS}	-0.172^{NS}	-0.084^{NS}	0.331^{NS}	0.028^{NS}
TR	0.284^{NS}	-0.290^{NS}	-0.178^{NS}	-0.119^{NS}	0.378^{NS}	0.011^{NS}
SC	0.355^{NS}	-0.351^{NS}	-0.186^{NS}	-0.157^{NS}	0.464^{NS}	-0.049^{NS}

In all reproductive statuses of neem trees, the minimum temperature and rainfall show a negative correlation with all the gas exchange parameters, and no significance is observed at the 5% confidence level, as the maximum temperature and diurnal temperature were positively correlated with all gas exchange parameters in all reproductive statuses of a neem tree. However, no significant correlation existed for any of the observed parameters at a 5% confidence interval. In flowering trees, relative humidity correlates positively with a transpiration rate of 0.133 Karl Pearson coefficient, while it is negatively correlated with both photosynthetic rate and stomatal conductance, and wind speed correlates negatively with all gas exchange parameters with no significant level of confidence.

In the dormant flowering tree, relative humidity had a positive association with photosynthetic rate and a negative correlation with transpiration rate and stomatal conductance, but no other parameters were found to be significantly associated. Wind speed was also shown to be positively associated with stomatal conductance with a 0.081 Karl-Pearson coefficient and negatively correlated with photosynthetic rate and transpiration rate.

In the alternate flowering tree, wind speed is also negatively correlated with all gas exchange parameters, whereas relative humidity is positively correlated with photosynthetic rate and transpiration rate, while it is negatively correlated with stomatal conductance and has no significance with all gas exchange parameters.

Overall, the gas exchange parameters correlated positively, among themselves, and the photosynthetic rate was shown to be strongly positively correlated with the transpiration rate in alternate flowering trees, with a correlation coefficient of 0.998 and significance at a 1% confidence interval. With a correlation coefficient of 0.993, transpiration rate has a strong positive association with stomatal conductance.

3.1.5 Correlation between weather and gas exchange parameters during the flowering stage

Correlation analysis between weather parameters during the study period and the gas exchange parameters in the flowering stage was done and results were depicted in Table 6. The correlation matrix of the regular flowering trees revealed negative correlations between rainfall, wind speed, minimum temperature, and maximum temperature with the recorded gas exchange parameters. However, no statistically significant associations were found among the observed data.

Relative humidity had a negative correlation with the gas exchange parameter, with a Karl-Pearson correlation coefficient of -0.950, and was found to be significant. The diurnal temperature showed a positive association with the gas exchange parameters, however, none of the correlations were significant.

In Dormant flowering trees, the maximum temperature, rainfall, and wind speed were all negatively correlated with the observed gas exchange parameters, however there was no significant correlation for any of the observed parameters. In contrast, the minimum temperature was negatively correlated with all of the exchange parameters and the correlation

Table 6. Correlation matrix among the gas exchange parameters and with the weather parameter during the Flowering stage

	MAX	MIN	RF	WS	DT	RH
Regular Flowering						
PR	-0.170^{NS}	-0.615^{NS}	-0.950**	-0.334^{NS}	0.515^{NS}	-0.056^{NS}
TR	-0.200^{NS}	-0.541^{NS}	-0.915**	-0.312^{NS}	0.386^{NS}	-0.013^{NS}
SC	-0.214^{NS}	-0.600^{NS}	-0.910**	-0.318^{NS}	0.438^{NS}	-0.043^{NS}
Dormant flowering						
PR	-0.198^{NS}	-0.679*	-0.882**	-0.323^{NS}	0.556^{NS}	-0.100^{NS}
TR	-0.177^{NS}	-0.678*	-0.918**	-0.334^{NS}	0.584^{NS}	-0.098^{NS}
SC	-0.187^{NS}	-0.684*	-0.691*	-0.273^{NS}	0.577^{NS}	-0.153^{NS}
Alternate Flowering						
PR	-0.144^{NS}	-0.721*	-0.824**	-0.316^{NS}	0.680*	-0.156^{NS}
TR	-0.157^{NS}	-0.716*	-0.841**	-0.319^{NS}	0.656*	-0.145^{NS}
SC	-0.159^{NS}	-0.704*	-0.898**	-0.333^{NS}	0.639*	-0.123^{NS}

was significant. Relative humidity was shown to be highly significant at 1%, with a Karl-Pearson correlation coefficient of 0.918. Diurnal temperature correlates positively with all gas exchange measures, but no significance was detected.

The correlation matrix in the alternate flowering tree revealed that maximum temperature, rainfall, and wind speed were all negatively correlated with all gas exchange parameters, with no significant association observed for any of the values recorded. The diurnal temperature revealed a stronger positive correlation with a Karl-Pearson correlation coefficient of 0.680 and was determined to be significant at a 5% confidence level. The photosynthetic rate was found highly correlated with transpiration rate. When the transpiration rate increases, the gas exchange activities tend to increase but based on the other environmental conditions like soil moisture status, temperature, relative humidity the photosynthetic rate may increase or decrease. The present study supported by had already been reported in [14] that weather variables such as rainfall and temperature affect photosynthesis, transpiration, and Stomatal conductance in neem tree.

4. CONCLUSION

The reproductive statuses of neem trees, including regular flowering, dormant flowering, and alternate flowering trees, exhibited notable differences in gas exchange parameters such as photosynthetic rate, stomatal conductivity, and transpiration rate. These variations were attributed to the observed variability in prevailing weather conditions. Alternate-bearing trees were found to have a higher gas exchange parameters when compared to regular and nonflowering trees. The neem trees recorded significantly higher values of these parameters during the pre-flowering compared to the flowering stage. Also, the relationship among the photosynthetic rate, transpiration rate, stomatal conductance and with weather parameters were confirmed in this study.

During both the pre-flowering and flowering stages, several environmental parameters, including rainfall, relative humidity, minimum temperature, and wind speed, exhibited a negative influence on gas exchange activities. However, it is important to note that this influence was found to be statistically non-significant. The maximum temperature exhibited a positive impact during the pre-flowering stage and a negative impact throughout the flowering phase. The diurnal temperature exhibited a positive effect on the gas exchange parameter during both the pre-flowering and flowering stages of the neem tree.

ACKNOWLEDGEMENT

The authors are thankful to the Agro Climate Research Centre and Department of Crop Physiology for providing the fellowship under Coromandel sponsored NEEM scheme to carry out the research work and like to extend our sincere thanks to all staff members, seniors and my batchmates for their valuable comments and constructive suggestions on the manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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