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Energy efficient campus landscaping for mitigation of climate change effects

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ABSTRACT

An experiment was conducted within the Indian Agricultural Research Institute (IARI) campus with 5 selected arboriculture tree species, namely, *Ficus religiosa, Ficus infectoria, Azadirachta indica, Alestonia scholaris* and *Morus alba* to compare their modifying capacity of thermal environment below the canopy with open space during peak summer months (May- June) and winter months (December-January) of 2010-11. Tree species and open space were treated as treatments (6) and 4 replications were taken for each treatment. During summer afternoon of 2010, the open space recorded an average temperature of 41.0°C. Temperature below the canopy was reduced by each species. Maximum reduction (7.31%) was observed below the canopy of *Ficus infectoria (*38.0 °C), followed by *Morus alba* (38.4 °C), minimum reduction to 38.7 °C was observed below the canopy of *Alestonia scholaris.* During winter afternoon of 2010-11, the open space recorded an average temperature of 24.0°C. Maximum reduction to 19.5 °C was observed below the canopy of *Ficus infectoria,* followed by *Ficus religiosa (*19.6 °C), *Azadirachta indica* (19.7 °C), *Alestonia scholaris* (20.1 °C) and *Morus alba* (20.8 °C). An average temperature of 7.7°C was observed in the winter morning throughout the season in the open space and an increase in below canopy temperature was observed under each tree species. However, *Morus alba* recorded the highest increase to 8.5°C, followed by *Ficus religiosa, Azadirachta indica*, *Alestonia scholaris* (8.3°C each). The lowest increase was observed under *Ficus infectoria* (7.9°C). The maximum increase in the morning temperature and minimum reduction in that at afternoon was desired in the winter at Delhi for comfort.

Key words: Climate change, Energy efficient, Landscaping, Tree species

Trees form a major part of a landscape design of any urban park or institutional campus. Intelligent landscape management can reduce water and air pollution. That leads to reduction of health risks for people and wildlife, threats to the environment and species diversity. Planning is the key to success and therefore, a proper scientific planning of arboriculture of a campus can create comfortable microclimate, so as to provide cooling effect in summer and warming effect in winter. Indirectly, it helps to conserve energy and save money by reducing electricity bills of residential and office buildings both in summer and winter. Vegetative city spaces could reduce the temperature by 2-8°C than their surroundings (Taha *et al.* 1997). Shashua-Bar *et al*. (2010) also noticed a daytime temperature depression up to 2.5°C on a courtyard with tree shades and grasses at Israel. Similar effects were obtained by several landscape scientists (Aboff *et al.* 2010, Uy and Nagaghosi 2008 and Hill *et al.* 2010). Urban greening had been proposed as one approach to mitigate the human health consequences of increased temperature resulting from climate change (Bowler *et al.* 2010). Earlier reports indicate that trees reduce costs of heating and cooling of the buildings and improve ambiance (Saud and Paswan 2004).

The modern concept of arboriculture is energy-efficient landscaping designed for the purpose of creating, soothing microclimate and energy conservation. Energy-efficient landscaping techniques include use of local materials, on-site composting and chipping to reduce green waste hauling, hand tools instead of fuel powered, and also may involve using drought-resistant plantings in arid areas. Energy conservation is the practice for decreasing the quantity of energy used which comes from fossil fuels mainly. It may be achieved through efficient energy use or by reduced consumption of energy services. Microclimate plays an important role here. Energy conservation leads to reducing emissions, which play an important part of lessening global warming and climate change.

MATERIALS AND METHODS

An experiment was conducted within the Indian Agricultural Research Institute (IARI) campus with 5 selected arboriculture tree species, namely, *Ficus religiosa, Ficus infectoria, Azadirachta indica, Morus alba* and *Alestonia scholaris* to compare their modifying capacity of thermal environment below the canopy with open space during peak summer months (May- June) and winter months

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(December-January) of 2010-11. Five tree species and open space were treated as treatments (6) and 4 replications were taken for each treatment.

Temperature data below the canopies and in the open space were recorded in the afternoon hour (between 13:00 and 14:30 IST, i.e. approximate time period of occurrence of daily maximum temperature) of summer (9 dates), winter (9 dates) and early morning (between 6:00 and 7:00 IST, i.e. approximate time period of occurrence of daily minimum temperature) in the winter (9 dates) with the help of a digital pocket weather tracker. Data of 9 dates (3, 10, 17, 24, 31 December 2010, 7, 14, 21, 28 January 2011) for winters and data of 9 dates (7, 14, 21, 28 May, 4, 11, 18, 25 June and 2 July, 2010) for summer were averaged for each season and compared to see the efficiency of tree species to moderate temperature under present situation with randomized block design. Data of the hottest summer afternoon, the coldest winter morning and afternoon among the observed dates were compared. This study was done to select the efficient tree species to modify temperature during the harsh weather.

RESULTS AND DISCUSSION

Temperature in the summer afternoon (2010)

Temperature in the open spaces and below the canopy of all the trees was measured on 9 dates during summer 2010. Mean values (4 replications) for each tree species and open spaces were worked out. Temperature in the open space was in the range of 37.0°-46.0°C, whereas that below the tree canopies was in the range of 33.1°-41.8°C throughout the season. All the tree species selected for this study reduced the temperature below their canopies. Among the tree species, *Ficus infectoria* was showing the lowest temperature below the canopy in 8 out of 9 dates of observation. The *Ficus infectoria* has the highest ability among the selected species to reduce the temperature below its canopy and to provide cooler microclimate on roads and buildings during summer afternoon was followed by *Azadirachta indica*, *Ficus religiosa* and *Alestonia scholaris*. The species, *F. infectoria* has glossy leaves which reflect the incoming solar radiation more than the other species and subsequently net radiation and sensible heat component below the canopy get reduced. Reduction in sensible heat leads to temperature drop.

Mean value of temperature (mean of 9 dates of observation) below the canopies of 5 selected tree species and in the open space at afternoon during summer 2010 was presented in the Table 1. The open space recorded 41.0°C, whereas the below canopy temperature was reduced in the range of 38.0°-38.7°C by different trees species. The maximum reduction of temperature (3°C) was observed below the canopy of *Ficus infectoria* followed by *Azadirachta indica* (2.7°C) , *Morus alba* (2.6°C) and *Ficus religiosa* (2.4°C). The minimum reduction (2.3°C) was observed below the canopy of *Alestonia scholaris*. Reduction of temperature below the canopy indicates the cooling ability of a canopy. Maximum cooling ability by *Ficus infectoria* in summer afternoon means better micro environment below its canopy than that of other species.

Table 1 Mean temperature at afternoon below the canopy of selected trees and in the open space during summer 2010

Treatment	Mean temperature summer afternoon (entire season) (°C)	Temperature summer afternoon on 18 June 2011 (°C)
T_1	38.6	40.6
T_2	38.4	40.6
T_3	38.7	40.8
T_4	38.0	40.4
T_5	38.4	40.5
T_6	41.0	46.0
CD (P=0.05)	0.245	0.454
SEm ±	0.08	0.145

T_1 = *Ficus religiosa*, T_2 = *Azadirachta indica*, T_3 = *Alestonia scholaris*, T_4 = *Ficus infectoria*, T_5 = *Morus alba*, T_6 = open space.

Table 1 presented the temperature recorded below each tree species and in the open space on 18 June 2010, the extreme day. On this date, below the selected species, the maximum reduction of temperature (5.6°C) was observed below *Ficus infectoria* followed by *Morus alba* and *Ficus religiosa* (5.5°C), *Azadirachta indica* (5.4°C) and *Alestonia scholaris* (5.3°C). Another reason of cooling below the canopies is evapotranspiration in which liquid water is changed into vapour. In this process, a huge amount of heat is absorbed from the surroundings as latent heat of vaporization which brings down the temperature. The results are in accordance with Saxena (2009) who developed model to quantify cooling of air due to trees at the scale of a house or a residential neighborhood. He inferred that the cooling effect on ambient air is associated with the phenomenon of evapotranspiration, and dispersion of moisture into the atmosphere. However, the cooling efficiency of individual tree species depends on evapotranspiration potential of them.

It is evident that the mean temperature of entire season, below each tree canopy was significantly different from that of open space (Table 1). Among the tree species, *Ficus infectoria* differed significantly from each other selected species in terms of temperature reduction. *Azadirachta indica*, *Morus alba* and *Ficus religiosa* were not significantly different from each other; but *Azadirachta indica* and *Morus alba* differed significantly from *Alestonia scholaris*. *Ficus religiosa* was not significantly different from *Alestonia scholaris* in terms of temperature reduction. It can also be found that the temperature reduction below each tree canopy on 18 June 2010 (extreme day) was significantly different from the temperature of open space at 5% level of significance. But there was no difference among the species. But if we see it in terms of mitigation of global warming and climate change, change of temperature by any fraction of a degree centigrade is important.

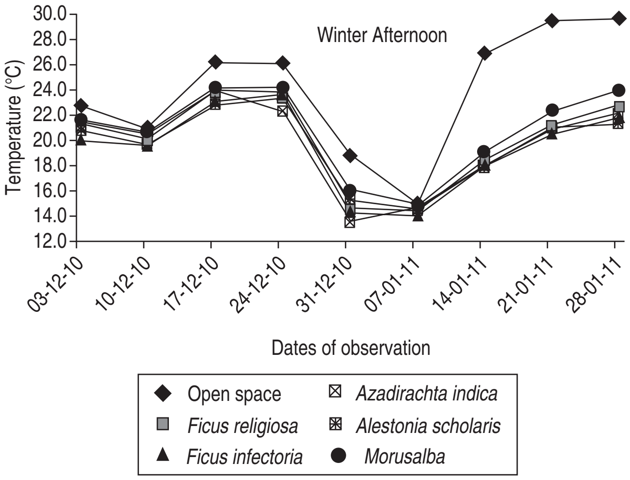

Fig 1 Air temperature below the different tree canopies and in the open space at IARI campus in the afternoon of different dates of during winter 2010-11.

But the climate change is not all about increase of temperature. Climatic extremes are also increasing. Das *et al.* (2009) reported that cold days and nights had increased at IARI campus across 1980-2008 and sub-zero temperature was recorded during the last decade only. Therefore, the tree species, which can increase the daily minimum temperature and comparatively less decrease the daily maximum temperature, are the most desired ones.

Temperature in the winter afternoon (2010-11)

During winter, IARI campus experiences cold and chilling conditions. Sub-zero temperature and frosting were also observed in few winter mornings in recent past. Day hours are also cold particularly on cloudy days. Unlike summer, warmer temperature below the tree canopies and open space are wanted at that time. Study was conducted with an aim to select the tree species which are efficient to provide warm micro-climate below their canopies in winter.

The temperature (mean of the replications) in the open space and below the canopy of 5 selected tree species in the afternoon on 9 dates during winter 2010-11 was depicted in Fig 1. The temperature in the open space itself was reduced in the range of 15.1°-29.8°C due to seasonal effect. It reduced further below the tree canopies in the range of 14.1° -24.2°C. But the extent of reduction was different for different species.

Table 2 Mean temperature at afternoon below the canopy of selected tree species and in the open space during winter 2010-2011

Treatment	Mean temperature winter afternoon (entire season) (°C)	Temperature winter afternoon on 07 Jan 2011 (°C)
T_1	19.6	14.7
T_2	19.7	14.5
T_3	20.1	14.6
T_4	19.5	14.1
T_5	20.8	15.0
T_6	24.0	15.1
CD (P=0.05)	0.422	N.S.
SEm ±	0.139	0.247

T_1 = *Ficus religiosa*, T_2 = *Azadirachta indica*, T_3 = *Alestonia scholaris*, T_4 = *Ficus infectoria*, T_5= *Morus alba*, T_6= open space

The minimum decrease of afternoon temperature (3.2°C) was observed below the canopy of *Morus alba. Alestonia scholaris* stood second in terms of temperature decrease below the canopy (3.9°C), followed by that of *Azadirachta indica* (4.3°C) and *Ficus religiosa* (4.4°C). The maximum reduction of (4.6°C) was observed below the canopy of *Ficus infectoria.* Less decrease of temperature below the canopy indicates the less cooling of a canopy in winter (wanted character). Less cooling by *Morus alba* in winter afternoon means comparatively warmer micro environment below its canopy in comparison with that of other species. *Morus alba* with no leaf during this period allowed most of the incoming solar radiation to reach the ground and the temperature did not fall at the level of other species.

During foggy and cloudy winter afternoon, temperature under the trees canopy was recorded in 9 dates in the season studied. The lowest open space temperature (15.1°C) was found on 07 January 2011 out of the study made at different time within the entire season. This date was considered the extreme winter day in this season. The minimum reduction (wanted character) was recorded below the canopy of *Morus alba* (0.1°C), followed by *Ficus religiosa* (0.4°C), *Alestonia scholaris* (0.5°C), *Azadirachta indica* (0.6°C) and *Ficus infectoria* (1.0°C). On an extreme winter day also, *Morus alba* was found to be desirable among the species as its canopy reduced less temperature.

We can find that the temperature below the canopy of each tree species is significantly different from the temperature of open space during winter afternoon. Among the tree species, *Morus alba* differed significantly from others. *Alestonia scholaris* and *Azadirachta indica* were not significantly different from each other, but *Alestonia scholaris* was significantly different from *Ficus religiosa*. Also *Azadirachta indica* and *Ficus religiosa* were not significantly different from each other. *Ficus religiosa* and *Ficus infectoria were* also not different significantly. But *Alestonia scholaris* and *Azadirachta indica* were significantly different from *Ficus infectoria.* It can also be found that the temperature reduction below all the tree canopies on 07 January 2011 (extreme day) was not significantly different from the temperature of open space. Among the tree species, temperature did not differ significantly below their canopies.

Temperature in the winter morning (2010-11)

Warm temperature below the tree canopies and open space are wanted during cold winter mornings. Study was conducted with a purpose to select the tree species which are efficient to provide comparatively warmer micro-climate

Table 3 Mean temperature in the morning below the canopies of selected tree species and in the open space during winter 2010-2011

Treatment	Mean temperature winter morning (entire season) (°C)	Temperature winter morning on 07 Jan 2011 (°C)
T_1	8.3	5.7
T_2	8.3	5.6
T_3	8.3	5.7
T_4	7.9	5.5
T_5	8.5	5.7
T_6	7.7	4.9
CD (P=0.0-5)	0.371	0.257
SEm ±	0.122	0.084

T_1 = *Ficus religiosa,* T_2 = *Azadirachta indica,* T_3 = *Alestonia scholaris,* T_4 = *Ficus infectoria,* T_5 = *Morus alba,* T_6 = open space.

below their canopies.

The temperature in the open space itself was in the range of 5.0° -10.4°C due to seasonal and diurnal effect. It was in the range of 5.5° -10.0°C below the tree canopies. Except first three dates, below canopy temperature was more than that of the open space. It means the trees enhanced their below canopy temperature. But the extent of enhancement was different for different species. The maximum enhancement of temperature in the winter morning (wanted character) was observed below the canopy of *Morus alba*, follow by *Azadirachta indica*, *Alestonia scholaris*, *Ficus religiosa and Ficus infectoria*, respectively.

Mean temperature (mean of 9 observations in entire season) below the canopies of 5 selected tree species and open space worked out for the winter morning during 2010-2011 and was given in the Table 3. The maximum increase of 0.7°C was observed below the canopy of *Morus alba* followed by that of *Alestonia scholaris*, *Azadirachta indica* and, *Ficus religiosa* (all 0.5°C). The minimum increase of (0.1°C) was observed below the canopy of *Ficus infectoria.* Increasing of temperature below the canopy indicates the warming ability of a canopy in cold winter morning. The canopies of the trees, probably, did not allow the terrestrial radiation to escape and the net radiation as well as sensible heat below canopy increased which translated into warmer microclimate. The highest temperature increase below *Morus alba* with no leaf during winter morning is difficult to explain. Without leaves, probably, evapotranspiration became negligible and no loss of latent heat occurred.

After studying the mean temperature of winter mornings in the open space and below the canopies of selected tree species for the entire season, a similar study was conducted for an extreme cold winter morning. It could be observed that the lowest open space morning temperature (4.9°C) was recorded on 07 January 2011 within the entire season. Morning of this date was considered the extreme cold winter morning in this season. Table 3 showed that the mean temperature in the open space and below the canopy of selected tree species on 7 January 2011. There was an increase in temperature below the canopy of each tree. The maximum increase (wanted character) was recorded below the canopy of *Morus alba*, *Alestonia scholaris* and *Ficus religiosa* with (all 0.8°C), followed by *Azadirachta indica* (0.7°C) and *Ficus infectoria* (0.6°C). In an extreme winter morning, *Morus alba*, *Alestonia scholaris* and *Ficus religiosa* were found to be desirable among the species as their canopy increase more temperature during this time.

We can find that the temperatures below all the tree canopies except *Ficus infectoria* are significantly different from the temperature of open space (Table 3). *Morus alba*, *Azadirachta indica*, *Ficus religiosa* and *Alestonia scholaris* are not significantly different from each other. *Alestonia scholaris* and *Azadirachta indica* are not significantly different from each other. But *Ficus infectoria* is significantly different from all the species. Therefore, except *Ficus infectoria*, other species are suitable in the respect. It can also be found that the temperature below all the tree canopies in the morning of 07 January 2011 (extreme day) was not significantly different from each other. But these differed significantly from that of open space.

Trees are more efficient than the cultivated field crops in carbon sequestration and modifying the temperature. Selection of the best suitable trees through micrometeorological studies and planting them can lead to cooler climate in summer and warmer climate in winter within park/campus. This, in turn, leads to reduction in cooling requirement in summer and heating requirement in winter both within the residences and vehicles. There would be reduced requirement of energy (electricity/petrol/diesel) originating from fossil fuels. Pandit and Laband (2010) studied the trees casting shade on homes and buildings, lowering the inside temperatures and thus reducing the demand for power to cool these buildings during hot times of the year in Auburn, Alabama, USA.Trees in urban areas showed multiple benefits including air quality improvement, energy savings, greenhouse gas reduction and possible water conservation (Gray 2006). Among the tree species, all are not equally efficient in moderating microclimate. Tree species can be selected as per requirements. Fahmy and Sharples (2009) also opined that new urban development in Cairo shouldn't only consider tree planting at the planning stage, but also specific type of trees should be used for better climate. However, the impact of the individual tree species, selected in this study, on climate has not been found in literature and this kind of study may be very new.

From the present study, another dimension like heating requirement during winter and suitable tree species adjoining the buildings and the suitable tree species to reduce heating is also highlighted. This is also linked to reduction of energy requirement. *Morus alba* was found to be most suitable tree species overall, particularly for the winter in terms of energy efficiency.

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