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Interpolation of Microclimatic Parameters Over Capsicum Under Open Ventilated Greenhouse

K. K. Chauhan* and M. M. Lunagaria

Dept. of Agricultural Meteorology, B.A.C.A. College of Agriculture, Anand Agricultural University, Anand, Gujarat (388 001), India

Corresponding Author

K. K. Chauhan
e-mail: kalyansinhc@gmail.com

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Abstract

A network of 12 grid points was recorded over capsicum crop to interpolate different weather parameters in the open ventilated greenhouse, an environment that differs markedly from open sites. The microclimatic condition was observed at 4.75-meter interval ground area in 4×3 regular grids. The series analyzed consisted of weekly observations recorded for a season. Most part under greenhouse had PAR distribution in range of 200−250 µ mol m^{-2} s^{-1}. Regressions model were used to describe relations between photosynthetically active radiation, Relative Humidity, Air Temperature and Soil Temperature under open ventilated greenhouse to predict inside microclimatic condition. As the air temperature prevailed under greenhouse and open field condition was close during most observations, there was strong association (r =0.96**). Relative humidity also showed significant association (r=0.8**) and functional relationship with coefficient of determination R^2=0.63. PAR and soil temperature also showed highly significant association with correlation coefficient r=0.79** and r=0.9**, respectively.

Keywords: Air Temperature, interpolation, PAR, RH, regression

1. Introduction

The microclimate of a greenhouse is a combination of physical processes involving heat and mass transfer which are governed by environmental conditions, type of structure, state of crop grown and effect of control actuators (Bot, 1983). The assembly of climatic parameters forming around a living plant is termed as microclimate (Bailey, 1985). It is the greenhouse microclimate that directly affects plant metabolic activities and therefore the crop yield (Singh et al., 2018c). The internal climate of a protected structure is strongly dependent on outside climatic conditions, especially under unheated conditions. Light (Wilson et al., 1992), temperature and relative humidity are the key parameters which significantly affect the crop development, yield and fruit quality. According to Sauser et al. (1998), the temperature distribution inside a protected structure influences the uniformity of crop growth. According to De Koning (1996), limiting temperature in desired range is essential for optimal crop growth. The root-zone temperature in relation to air temperature in plant community also significantly affects the plant development and flowering (Khah and Passam, 1992). Thus, the microclimate within the plant community under a protected structure should be according to the requirement of the crop grown (Singh et al., 2018a, 2018b). A better understanding of the relationship between greenhouse microclimate and plants is thus highly desirable to offer optimal plant growth conditions. Microclimate control in greenhouses is one of the first priority problems since even despite good genetic properties of crops, the quality of fertilizers and soil, incorrect maintenance of temperature, humidity mode of the greenhouse and poor dosing by the carbon dioxide may result in a considerable drop in productivity up to the loss of crops.

Interpolation is a commonly used technique for quantification of greenhouse microclimate. Interpolation is a process of obtaining new data within the given range of other known data or in other words we can say that it is a process of getting an unknown value by using other related known values that are present in the sequence with the unknown values. In many instances we may wish to model a feature as a continuous filed (i.e., surface), yet we only have data values for a finite number of points. It therefore becomes necessary to interpolate (i.e., estimate) the values for the intervening points. The interpolation technique is employed for interpolating the microclimatic parameter data. The accuracy of the different recorded data measurement is dependent upon the number of grid points selected in a study area. Spatial interpolation technique can be used to map the data for a study area such as Open ventilated greenhouse. Many spatial interpolation methods can be used to estimate the photosynthetically active radiation, Relative Humidity, Air Temperature and Soil Temperature, such as Fourier series, Thiessen, Spline, Kriging, weighting method.

Interpolation is no straightforward operation and one of the main difficulties is to select the method that provides the best estimates. Two families of methods have come to stand out for the quality of their results: the methods of kriging. Given the statistical constraints associated with them, these methods are not interchangeable and do not yield optimal results in all cases. Kriging is better suited when variables are strongly spatially autocorrelated, where, for different weather parameters, say, a gentle topography engenders regular thermal gradients. To construct spatial variation using observations of grid point's kriging method was employed in GIS environment (QGIS).

2. Materials and Methods

2.1. Study area

In order to study the microclimatic condition and to evaluate different weather parameters inside and ambient condition, a study was carried out in open ventilated green house. The experiment was conducted under open ventilated greenhouse at Horticulture farm of Department of Horticulture, BACA, Anand Agricultural University, Anand, Gujarat during October 2017 to March 2018. Some of the salient features of the open ventilated greenhouse were outlined (Figure 1).

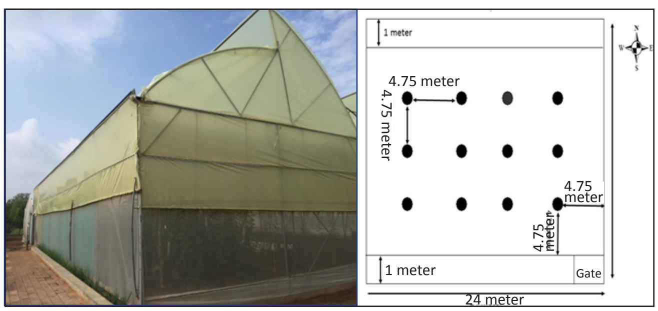

Figure 1: Over view and layout of open ventilated greenhouse

2.1.1. Greenhouse

The open ventilated greenhouse was made of galvanized iron's tubular structure in arch shape. Naturally ventilated greenhouse with 504 m^2 floor area at Horticulture research farm, AAU, Anand shown in Figure 1 was chosen for the study.

2.1.2. Orientation

The length and width of greenhouse was 21 meter (N-S) and 24 meters (E-W). The front view of open ventilated greenhouse was in East direction. East and South side of greenhouse was surrounded by other greenhouse structures with distance of 5 and 4.2 m, respectively. West side of the greenhouse was open having trees with distance of 15.2 m.

2.1.3. Characteristics of the covering materials

Low-density ultra violet stabilized polythene of 200 micro thicknesses with UVA clear properties was used as glazing material in greenhouse. Shade net with collapsible mechanism has been provided at the upper part inside the greenhouse. It allows only certain percent of the solar radiation to pass through it. The open ventilated greenhouse was facilitated with drip irrigation system and misting system.

2.2 Data acquisition and preparation

2.2.1 Data acquisition

The data acquisition process involved collecting the data from open ventilated green house and ambient weather condition period from October 2017 to March 2018. Acquisition process involved collecting the data of PAR, RH, Air Temperature and Soil Temperature.

2.2.2. Data preparation

The data collected was organized into various layers using QGIS software. The following thematic layers were prepared:

• Shapefile

• Network of 12 Grid Points

• Microclimatic parameters data

2.2.3. Interpolation method

Kriging is perhaps the most distinctive interpolation method. The term is derived from the name of D.G. Krige who introduced the use of moving averages to avoid systematic overestimation of reserves. Kriging is based on the regionalized variable theory which assumes the statistical surface to be interpolated has a certain degree of continuity. It is an advanced and complex geostatistical procedure that generates an estimated surface from a scattered set of points. Kriging interpolation offers several types of surface estimators; examples are ordinary Kriging (OK) and universal Kriging (UK). OK assumes that the variation in z values is free of any structural component and can be represented by the Spherical, Circular, Exponential, Gaussian, and Linear methods. UK assumes that the spatial variation in z values is the sum of three components: a structural component, a random but spatially correlated component, and random noise representing the residual error. Generally, OK has more restrictive assumptions but fewer computational problems, whereas the assumptions of UK are more general but difficulties of calculation are greater. For this study, to construct spatial variation using observations of grid point's kriging method was employed in GIS environment (QGIS).

3. Results and Discussion

3.1. Spatial variation of different weather parameters in open ventilated greenhouse

3.1.1. PAR (μ mol m^{-2} s^{-1})

Unlike other micrometeorological variables, PAR distribution at different parts of greenhouse is directly governed by transmissivity of the covering materials and solar position. PAR variation inside greenhouse is also dependent on presence of reflective materials and water vapour in air. At the time of transplanting (30th October), the PAR distribution was relatively south western corner (264 μ mol m^{-2} s^{-1}) and there wasn't gradient pattern (Figure 2). Most part under greenhouse had PAR distribution in range of 200-250 μ mol m^{-2} s^{-1}. PAR gradually decreases during the month of December and recorded low at northern and central parts of the greenhouse. It may be due to small micron size of

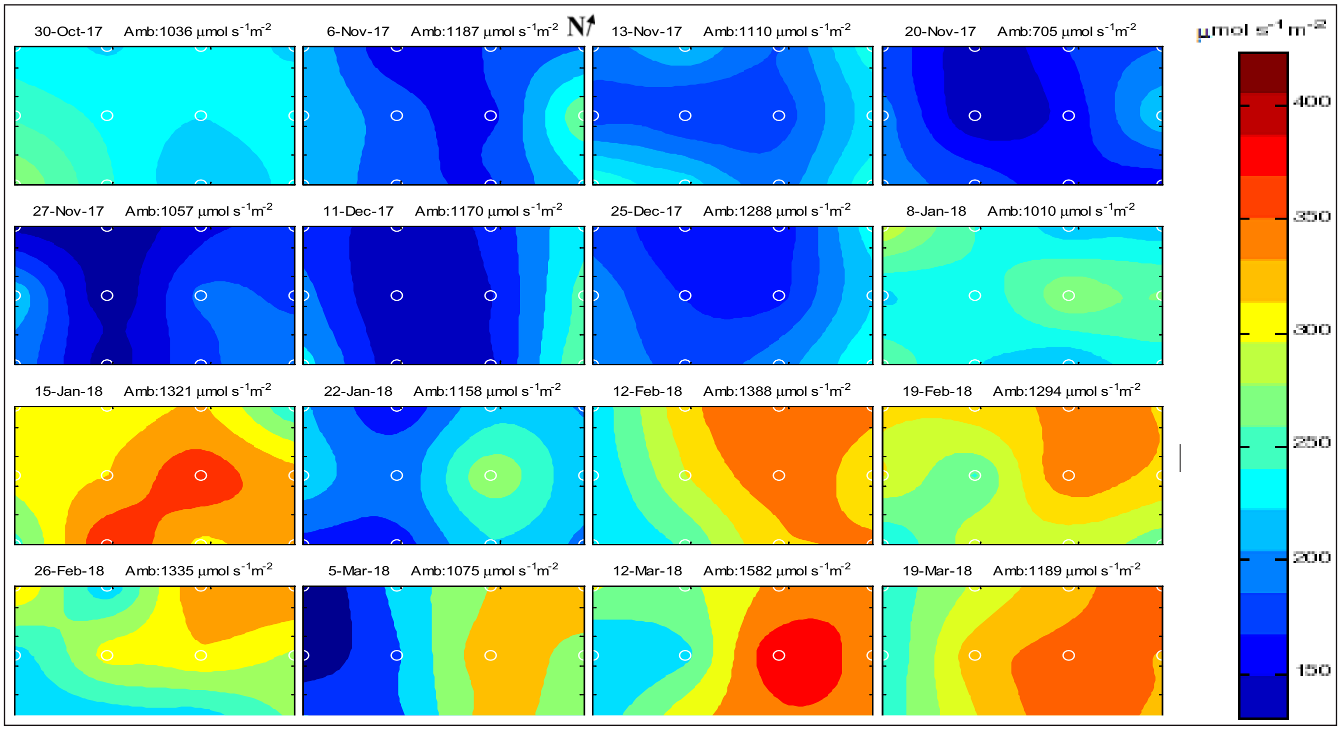

Figure 2: Spatial variation in PAR under open ventilated greenhouse

covering material on greenhouse which allows less amount of PAR inside the greenhouse. In the second week of January, it increased toward the southern (266 µ mol m^{-2} s^{-1}) side of greenhouse and recorded lower penetration of PAR toward the northern side. Seasonal PAR variation pattern observed during the month of March having variation of PAR higher toward the eastern side and lower toward the western side. During study, east side showed relatively more PAR distribution because of solar position.

3.1.2. Air temperature

Air temperature seemed to follow the gradient pattern with low air temperature (24.9˚C) towards northern side. It indicates less ventilation due to absence of wind during night and early morning hours. It was significantly higher during the first week of November and follows the gradient pattern with high temperature (28.2˚C) towards the western side (Figure 3). Air temperature inside the greenhouse significantly decreased from the second week of November and last week of December (24˚C). This indicates less spatial variation inside the greenhouse. Decreased air temperature in the month of first week of January to mid week of February (21.5˚C) follow the gradient pattern with low air temperature towards northern and southern side. It was recorded higher inside the green house at last week of March (28.6˚C), with spatially high values towards western sides. As the greenhouse was open ventilated, active air circulation was maintained. So, air temperature remained close to ambient air temperature with negligible spatial variation during crop cycle.

3.1.3. Relative Humidity

The gradient pattern observed toward North side (61.1%) at

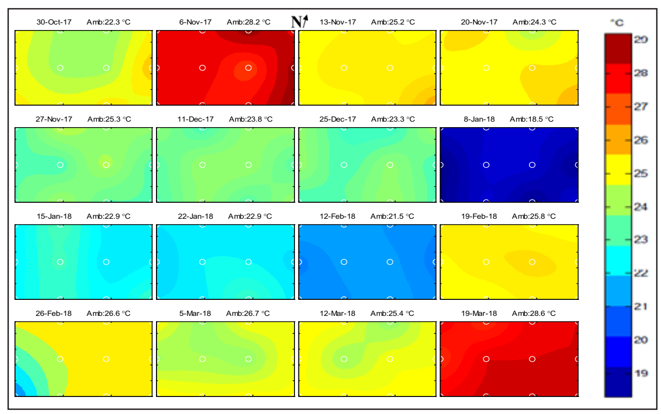

Figure 3: spatial variation in air temperature under open ventilated greenhouse

the time of transplanting (30th October) was due to relatively higher humidity and lower wind speed in the region. The temperature in the upper region was lower and the net total radiation was similar as compared with other two regions. In the month of November, the spatial distribution changes to a different pattern where the highest values were found in the eastern and western part while the lowest values in the North side (Figure 3).

3.1.4. Soil Temperature

Northern side of greenhouse had lower soil temperature (26.5˚C) than other three sides (Figure 4). This might be because of soil temperature gradient generated by solar heating towards south and west side has maintained its residual pattern even after night time cooling. In first week of November, due to initial growth of transplanted capsicum

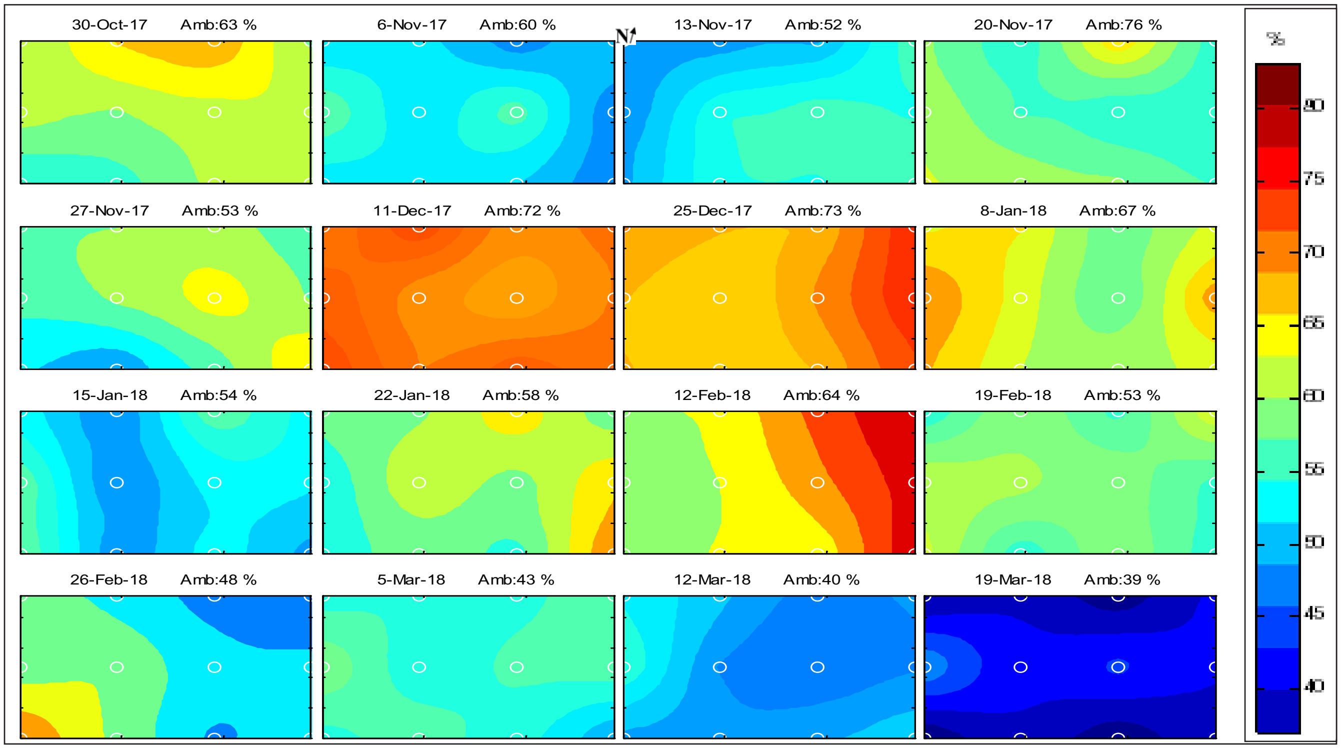

Figure 4: Spatial variation in relative humidity under open ventilated greenhouse

and soil moisture, overall soil temperature reduced (24˚C). Northern side soil temperature was found relatively lower during most observations in November month. After attaining proper canopy growth during December, spatial variation in soil temperature was narrowed (21˚C). Seasonal soil temperature rise pattern was visible since last week of February,with less spatial variation which increases toward east and west side of greenhouse during third week of March.

3.2. Association between micrometeorological parameters of greenhouse and open field parameters

Scattered plots of PAR, Air temperature, Relative humidity and Soil temperature with correlation coefficient are presented in Figure 5 and regression equation is shown in Table 1. As

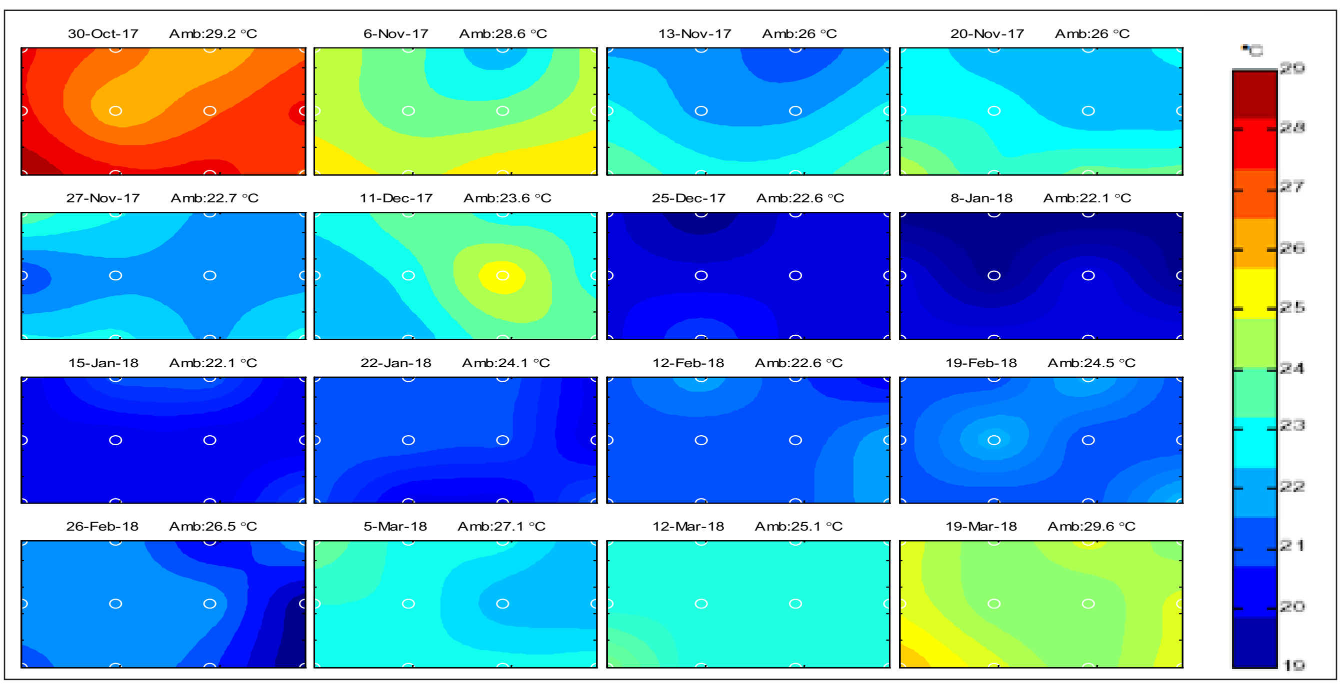

Figure 5: Spatial variation in soil temperature under open ventilated greenhouse

Table 1: Regression model for microclimatic parameters for open ventilated greenhouse with vegetation like capsicum

Parameters	Regression	R^2
PAR	y=2.689x+298.1	0.63**
Air temperature	y=0.881x+2.562	0.93**
Relative Humidity	y=0.525x+29.78	0.65**
Soil temperature	y=0.794x+2.545	0.81**

the air temperature prevailed under greenhouse and open field condition was close during most observations, there was strong association (r=0.96**). Regression analysis result a model to predict inside air temperature using open field air temperature with coefficient of determination 0.93. Relative humidity also showed the significant association (r=0.8**) and functional relationship with coefficient of determination R^2=0.63. The regression model y=1.233x-16.21 can be used to estimate humidity under open ventilated greenhouse for October to March months of a year to judge the suitability of the crops. PAR and soil temperature also showed the highly significant association with correlation coefficient r=0.79** and r=0.9**, respectively. As the PAR prevailed under greenhouse was in narrow range of fraction of open field condition and soil temperature was close during most observations which showed the perfect relationship between the parameters under greenhouse and open field. The regression equation listed in Figure 6 can be used to determine microclimatic condition under open ventilated greenhouse with vegetation like capsicum for the crop growing season during October to March months of a year. Crop suitability during this period may judged by prediction of microclimatic condition inside the greenhouse.

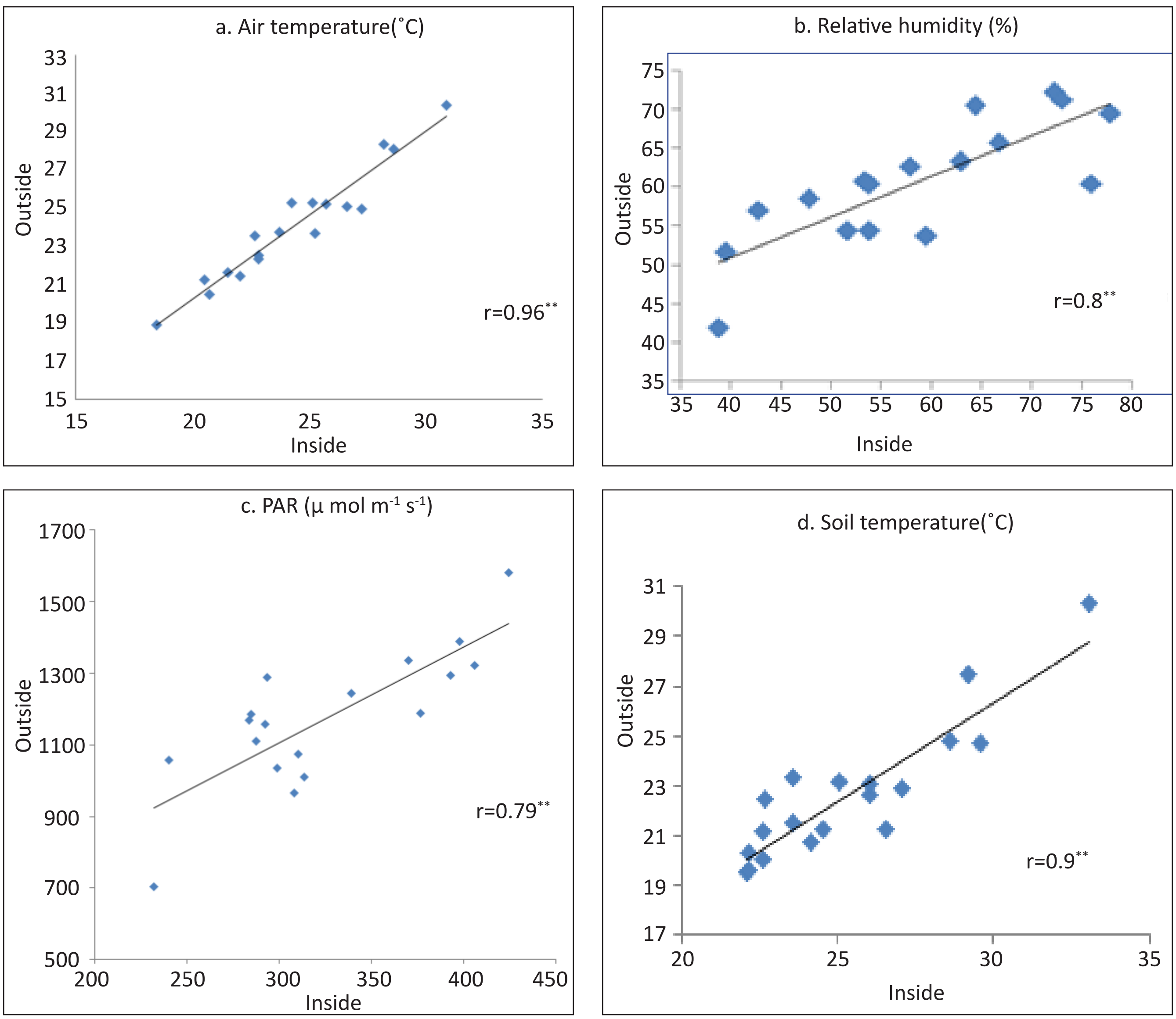

Figure 6: Association between micrometerological parameters of greenhouse and open field parameters

4. Conclusion

The greenhouse maintains crop microclimate more or less congenial with regard to temperature, humidity and PAR so as to encourage crop and plant earliness to improve the yield and make more effective use of water. PAR distribution at different parts of greenhouse was directly governed by transmissivity of the covering materials and solar position. Most part under greenhouse had PAR distribution in range of 200-250 µ mol m^{-2} s^{-1}. The functional relationship established by regression models can be use to predict microclimatic condition of open ventilated greenhouse having vegetation like capsicum during October to March months of the year.

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