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Influence of Different Climatic Conditions and Edaphic Factors on Root Knot Nematode *Meloidogyne incognita* Growth in the Mulberry Field

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***Abstract* – Root knot nematode infestation is a serious problem in Agricultural crops all over the world mostly spread in tropical and subtropical areas. The root knot nematode has a wide range of host plants and causes major economic damage to many Agricultural crops under irrigated condition, especially in sandy loam soils. Mulberry is an economically important crop for sericulture industry. Root-knot disease is seriously limits its production caused by root knot nematode *Meloidogyne incognita*. The present study aims to evaluation of the influence of different climatic conditions and edaphic factors like Electrical conductivity (EC), Organic carbon (OC), Nitrogen (N), Phosphorus (P), Potassium (K), *Sulphur* (S), Magnesium (Mg) and micronutrients like Copper (Cu), Iron (Fe), Manganese (Mn), Calcium (Ca), and Zinc (Zn) on root knot nematode growth in the mulberry crop production field. Present data regarding weather conditions during the experimental period mentioned that it was very positive co-relation to development of nematode infestation. Low level of Organic carbon, Nitrogen, Sulphur, Iron and Manganese and moderate level of potassium, Calcium, Magnesium. However, sufficient quantity of Phosphorus, Zinc and Copper was recorded in the experimental field.**

***Keywords* – Climatic Conditions, Edaphic Factors, Mulberry, *Meloidogyne Incognita*, Root Knot Nematode.**

I. Introduction

Mulberry (*Morus alba* L.) is a perennial plant and economically important for sericulture industry used not only for silk weaving but also for healthcare products, medicines and edible products [Qiao L Y., 2012]. Mulberry prone to various microbial diseases. These microorganisms derive their nutrition from host plants resulting into the depletion quality of produce. Root-knot disease is an important disease occurring in mulberry caused by *Meloidogyne incognita*. The nematodes live extensively in moist soil and in water or decaying organic substances and they act as ecto or endo parasitic on plants. Root knot nematode causes galls/knots on a wide variety of plants and spread very widely. Their worldwide distribution and involvement in disease complexes with other pathogens make them a serious threat to the world's food supply (Sasser, 1989).

Loss due to root knot nematode in various crops is estimated to be around 11-25% (Sasser, 1979). Root knot nematode is a severe problem in tropical and subtropical countries especially in sandy soils under irrigated conditions (Narayanan *et al*., 1966). The disease spread by the activity of nematode juveniles. They penetrate root meristematic regions and migrate through the cells and undergo second, third and fourth moults to reach the adult stage. The nematode infestation causes severe changes in the infested parts showing hypertrophy and hyperplasia especially in the root. Nematodes are stress inducing factors and are the living organisms that cause the biotic stress in plants. Abiotic factors like soil texture, soil temperature, soil moisture, rainfall etc. are found to influence the nematode population (Norton, 1979). Soil nematodes are the significant regulators of residue decomposition and nutrient release in natural ecosystems. However, root knot nematodes can produce nutrient deficiencies similar to those resulting from low soil nutrient levels. They interfere with the normal absorption

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and translocation of water macro and micro nutrients in the infested plants. Hence, present studies were conducted with the objective to determine the disease incidence, occurrence of root knot nematodes in mulberry cultivation field in different climatic conditions.

II. METHODOLOGY

This experiment was carried out in Sri Padmavathi Mahila Visvavidyalayam, Tirupati, Andhra Pradesh to find out reliable estimate of mulberry field infested with root knot nematode.

A. *Weather Conditions during the Experimental Period*

Data regarding weather conditions during 2014-2018 was collected from the *Meteorological* Department, RARS, Tirupati. The various weather conditions like maximum and minimum temperature, precipitation, relative humidity, and evaporation and sunshine hours have been recorded.

B. *Edaphic Factors in the Experimental Field*

a. *Topography*

The topography of experimental site is uniform with sandy loam texture.

b. *Soil Sampling*

Soil sampling was prepared by standard method as suggested by Jackson (1973). For the present study soil sample was collected from mulberry rhizosphere randomly and analysed for physio-chemical properties. The soil was analysed for pH, Electrical conductivity (EC), Organic carbon (OC), Nitrogen (N), Phosphorus (P), Potassium (K), *Sulphur* (S), Magnesium (Mg) and micronutrients like Copper (Cu), Iron (Fe), Manganese (Mn), Calcium (Ca), and Zinc (Zn). The values are given in the Table: B.

C. *Chemical Properties of the Soil*

i. *Determination of the Soil pH*

Soil pH is an indication of the soil reaction in terms of acidity, neutral or alkalinity. The pH of the soils was tested by standard method of Jackson (1973).

ii. *Determination of Electrical Conductivity (EC)*

The electrical conductivity is an indicative of the salt concentration of the soil solution and is an important parameter influencing the absorbability or toxicity levels of salts. The EC value of more than 1.0 m mhos/cm is inhibitory to the plant growth. For determining EC, the solution was prepared as per the standards suggested by Jackson (1973). It was expressed as mSm^{-1}.

iii. *Estimation of Available Nitrogen in Soil*

Nitrogen in soil is mainly present in organic form together with small quantities of ammonium and nitrate forms. The nitrogen supplying ability of the soil was determined by distilling the soil with alkaline potassium permanganate solution. During the distillation easily utilizable and amino-N hydrolyzed nitrogen liberated as ammonia is measured. This serves as an index of nitrogen status of soil. Alkaline potassium permanganate method (Subhaiah and Asija, 1956) was followed to estimate the available N of the soil samples. Available nitr-

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-ogen was calculated as (kg/ha). Available nitrogen was calculated as (kg/ha) by using the formula.

$$\text{Total N in the soil Kg/ha} = \frac{T - B \times N \times 1.4}{S}$$

Where

T - Volume (ml) of standard and solution needed for titration of the soil sample.

B - Volume (ml) of standard acid solution needed for blank titration.

N - Normality of standard acid.

S - Sample weight.

Total nitrogen in soil (ppm) = percentage of nitrogen × 10,000

Total nitrogen in soil (kg/ha) = nitrogen content in ppm × 2.24

iv. *Estimation of Total Phosphorus in Soil Sample*

Available phosphorus in the soil was determined by using 0.5 M sodium carbonate as an extractant as outlined by Olsen's method (Olsen *et al*., 1954) and as described by Jackson (1973). Phosphorus availability was determined (kg/ha) by interpolating the readings into a standard curve.

$$P = \frac{Ppm}{106} \times \frac{V}{2.5} \times \frac{10}{W} \times 100$$

Where

Weight of the sample taken = 'W' g

Volume of the triple acid extracts = 'V' ml

Aliquot taken for the colour development = 5ml

v. *Estimation of Total Potassium:*

Available potassium in the soil was treated with normal ammonium acetate and the K was determined from the extract using Flame Photometer (Jackson, 1973). The percentage of potassium was calculated as (kg/ha). With reference to standard graph.

$$\text{Percentage of potassium} = \frac{ppm}{106} \times \frac{100}{W}$$

vi. *Determination of Organic Carbon (OC)*

Organic matter plays an important role in supplying nutrients and water and provides good physical conditions to the plants. The quantity of organic carbon of the soil was estimated by using the method of Walkey and Black (1934). The carbon content of the soil was obtained by using the formula.

Percentage of carbon = M × (V1-V2/s) × 0.39 × mcf

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Where

M = Molarity of ferrous sulphate solution (from the blank titration).

V1 = Ferrous sulphate solution required for blank ml.

V2 = Ferrous sulphate solution required for sample ml.

s = weight of air dry sample in gram.

0.39 = 3 x 10 –3 x 100% x 1.3 (3 = equivalent weight of carbon).

mcf = moisture correction factor.

vii. *Available Calcium and Magnesium*

The soluble Calcium in the extract was determined by EDTA titrimetric method using murexide indicator after adjusting the pH to eleven with 1N NaOH. At this pH, magnesium was precipitated as $Mg(OH)_2$ and only calcium reacted with EDTA. Magnesium was determined by using the method of Jackson (1973).

viii. *Available Sulphur*

The availability of quantum of sulphur was determined by using turbidity method (Jackson, 1967).

D. *Estimation of Available Soil Micronutrients*

The availability of micronutrients i.e. Fe, Mn, Zn and Cu was determined by DTPA (Dithylene Triamine Pentacetic Acid) extractant which consists of 0.005 M DTPA, 0.1 M triethanolamine and 0.01 M CaCl2 and measured on atomic absorption spectrophotometer (Lindsay and Norvell, 1978).

Statistical Analysis

All the experimental data collected in three replicates has been subjected to statistical analysis (SPSS-2.0 Version). The analysis of variance has been done to find out the significant differences between the control and infested plants for the T-test and Two way ANOVA test following the procedures laid down in Agricultural statistics (Rangaswamy, 2000).

III. Results and Discussion

A. *Weather Conditions during the Experimental Period*

The data was collected from the *Meteorological* Department, RARS, Tirupati. The weather conditions during the experimental period was recorded in terms of maximum and minimum temperature, rainfall, relative humidity, evaporation and sunshine hours and all the yearly mean values are mentioned during the years 2014-2018 given in the Table: A.(Fig: 1a-g).

Data regarding weather conditions during the experimental period was mentioned as the 4 years' average values. The average value of temperature ranged with minimum of 22.87^0 C and maximum of 34.08^0 C. The average precipitation value of 99.14 mm, relative humidity of 47.57 %, wind velocity of 5.84 mph, evaporation of 5.66 mm and sun shine hours 5.97 hrs were recorded during the experimental period.

The population of *M. incognita* juvenile were found throughout the year in the rhizospere of mulberry garden

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in different levels of occurrence. Plant parasitic nematode biology, physiology, distribution and pathogenic potential are mostly controlled by various climatic factors including temperature, precipitation, humidity ect. In this experiment it was observed that average maximum temperature during summer season, the soil population of root-knot nematode very low level at 34.8°C. The highest soil nematode population observed when the temperature ranged at minimum level with high precipitation value and average in amount of relative humidity during morning and evening times in low sun shine hours.

Temperature is an important factor influencing the distribution and infestation of the nematode dependent on temperature for vital physiological activities. Temperature affects root-knot nematode migration, development, and the nematode's ability to sense host roots (Tyler, 1933). The optimal temperature for root-knot nematode development was reported to be 28°C, above which development was reduced with no development occurring at 36.5°C (Tyler, 1933). Nematodes have basically aquatic nature and require a water film around soil particles to move. The rainfall was detected as most influential factors for determining gall formation, population and reproduction factor towards *M. incognita* invasion and influences the nematode infestation rate. High percentage of relative humidity create warm climate for plants and nematode development.

Norton, (1979) studied on the development and behaviour of the soil-inhabiting of plant-parasitic nematodes. Under increased rainfall condition and greater long term mean annual precipitation, the PPNs derive more benefit due to concomitant boost in the plant biomass (St-Marseille et al., 2019; Guo et al., 2021; Klusmann et al., 2022). Similar observations were reported by Bristol et al., (2023), who found increase in PPN abundance in long-term due to elevated rainfall. Relative humidity (RH) effects on the survival and pathogenicity.

The results of this study are in conformity with Loubser and Meyer (1987) who has got the similar results in population dynamics of root-knot nematode infesting grape vines during the Ph.D. research and also according to Ferris and McKenry (1974) root infestation in spring is primarily the result of newly hatched larvae because over wintering appear to be of low infectivity. Root knot nematode species found in hot tropical or warm climates (Anwar SA.et, al, 2010). The weather conditions in the experimental site positively for nematode population development. The maximum temperature, has a negative correlation while, rainfall and relative humidity (evening and morning), Evaporation and Sunshine hrs have a positive correlation with root-knot nematode population in the mulberry garden.

Table A. Weather conditions during the experimental period 2014-2017.

Year	**Temperature(^{0}C)**				**Precipitation (mm)**		**Relative Humidity (%)**		**Wind velocity (mph)**		**Evaporation (mm)**		**Sunshine (hrs)**	
	Max		**Min**											
	Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D**	**Mean**	**S.D.**
2014	34.71	3.17	22.63	3.28	76.54	71.80	46.85	17.91	7.11	3.42	6.44	1.27	5.30	1.83
2015	33.40	3.13	22.73	3.98	150.16	208.18	49.53	13.00	5.93	1.99	5.29	1.13	5.96	1.36
2016	34.31	2.86	23.02	3.37	68.75	85.62	45.95	7.50	5.11	1.26	5.58	1.34	6.63	2.12
2017	33.88	3.71	23.08	3.72	101.10	105.29	47.94	12.26	5.20	2.16	5.32	1.54	6.00	1.78
Average value (4 years)	34.08	3.17	22.87	3.49	99.14	129.20	47.57	12.84	5.84	2.40	5.66	1.37	5.97	1.80

(Source: *Meteorological* Department, RARS, Tirupati) S.D. = Standard Deviation.

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B. *Edaphic Factors of the Experimental Field*

i. *Topography*

The topography of experimental site was uniform with sandy loam soil. Soil type and texture is recognized as an important factor that affects both crop productivity and plant parasitic nematode infestation and is found to be more serious in sandy loam soils. Crops grown on sandy soils are most susceptible to nematode damage ((Ibrahim et al., 2010). Soil texture largely determines soil moisture holding capacity, aeration and has impact on the nematodes ability to hatch, move through soil and penetrate to host and reproduce (Koenning and Barker, (1995), Zhanar Tileubayeva *et., all* (2021).

Soil is a major source of nutrients needed to plants for growth. The important nutrients are nitrogen, phosphorus, potassium, calcium, magnesium, iron, manganese, copper and sulphur. Soil is important for plants because it holds roots that provide support for plants and sources nutrients.

Before the inoculation of nematode into the soil in field experiment the physiological and chemicals parameters were analysed. The important soil parameters analysed are soil pH, Electrical Conductivity, Organic Carbon content, macro or major nutrients like Nitrogen (N), Phosphorus (P_2O_5), Potassium (K_2O), secondary nutrients such as Calcium (Ca), Magnesium (Mg), Sulphur (S) and Iron (Fe), Manganese (Mn), Copper (Cu) and Zink (Zn) which are micronutrients. The composite soil sample was analysed for chemical properties and results are mentioned in the Table: B.

Table: B. Results of soil analysis.

S. No.	Parameters	Observed Value	Rating
1.	Physico-chemical properties		
	pH	8.72	Highly Alkaline
	Electrical Conductivity (EC)	0.362 mSm^{-1}	Neutral
	Organic Carbon (OC)	0.38 %	Low
2.	Macro nutrients		
	Avail. Nitrogen (N)	88 Kg/ha	Low
	Avail. Phosphorus (P_2O_5)	87 Kg/ha	High
	Avail. Potassium(K_2O)	329 Kg/ha	Medium
	Avail. Calcium(Ca)	27 Cmol (P^+)/Kg	-
	Avail. Magnesium (Mg)	71 Cmol (P^+)/Kg	-
	Avail. Sulphur (S)	5.25 ppm	Deficient
3.	Micro nutrients		
	Zinc (Zn)	1.52 ppm	Sufficient
	Iron (Fe)	0.56 ppm	Deficient
	Copper (Cu)	0.35 ppm	Sufficient
	Manganese (Mn)	0.94 ppm	Deficient

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A balanced amount of macro and micronutrients in the soil is the best way of ensuring that, the crop can be able to with stand the damage caused by nematodes. The effect of nutrient deficiency results in reduced photosynthesis and finally results reduced growth rate, malformation and discoloration causing discomfort and even death. Further it is inferred that if the plant become week due to nutrition deficiency, it could become easily susceptible to pathogens.

Similar results were reports by different scientists in different crops. Gnanapragasam and Sivapalan (1991) observed that, the population of root lesion nematodes in tea plants was higher in soils of 3% organic matter content than in soils with 10% of organic matter. Suppression of *Tylenchs* population by higher amount of organic carbon was also observed by Gupta and Sharma (1988). Nitrogen is important component in proteins. Deficiency plants shows slow growth and uniform yellowing of older leaves and produce smaller than normal fruit, leaves, and shoots (https://crops.extension.iastate.edu/files/article/nutrientdeficiency). Xu *et al.,* (2010) studied the effects of root knot nematode on nitrogen and phosphorus contents of cucumber leaves and found that the increase in nematode inoculation rate decreases the nitrogen and phosphorus content in cucumber. Foliage of tomato plants infested with *M. incognita* had shown lower concentration of nitrogen, phosphorus and potassium than the healthy plants (Maung and Jenkins, 1959).

Phosphorus is essential to plant growth and can also show effect on root knot disease caused by nematodes. Plants with high levels of phosphorus, release fewer root exudates and are therefore less attractive to nematodes decreasing the incidence of the disease (Marschner, 1997). Adequate quantity of plant nutrition with potassium helps to reduce the incidence of disease due to increased resistance to the penetration and development of pathogens (Huber and Arny, 1985; Perrenoud, 1990).

Like other nutrients, calcium must be present in sufficient quantity in the soil, because calcium deficient plants are more susceptible to nematode attack (Hurchanik *et al*., 2003). Many phytopathogenic agents reach the plant tissue by producing extra cellularpectolytic enzymes that degrade the middle lamella (McGuire and Kelm--an, 1986) and the enzyme activity will be dramatically inhibited by the presence of calcium (Marschner,1997).

Plants deficient in zinc contain low levels of superoxide dismutase and therefore high levels of superoxide radicals promote membrane lipid peroxidation and a loss of membrane integrity, increasing permeability (Barker and Pilbeam, 2007). Furthermore, the accumulation of free amino acids and amides occurs as a result of protein synthatase inhibition due to the zinc deficiency, boosting the quantity of these amino acids in root exudates (Cakmak and Marschner, 1988).

Since nematodes are attracted by exudates, the higher root exudation in plants deficient in zinc can attract these parasites and speed up the infection process (Streeter *et al.*, 2001). Shaukat and Siddiqui (2003) reported that when zinc alone was applied, it caused a decrease in the number of *Meloidogyne javanica* and boosted increased growth in tomato plants.

The lower lignin content in plants due to deficiency in manganese is an indication of the need for this element at a number of stages in lignin biosynthesis and the reduction in the amount of root material contributes to lower plant resistance to pathogen attack (Marschner, 1997).

The authors suggested that applying manganese may have neutralized a deficiency in the absorption of the nutrient, caused by nematode infestation. Hurchanik *et al*. (2004) observed that coffee plantation infestation by *Meloidogyne konaensis* significantly reduced the absorption of manganese and copper by the root system.

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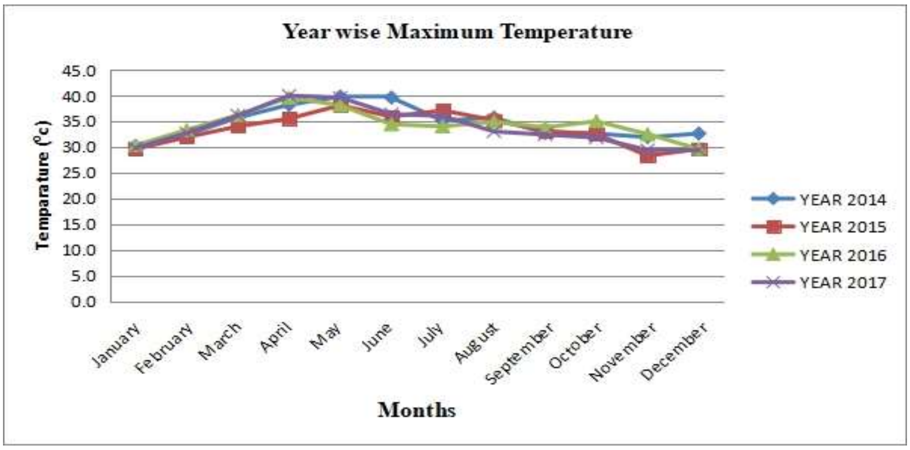
Reductions in calcium and manganese were also observed and attributed to root system damage caused by nematodes.

The symptoms of nitrogen deficiency are related to its function in the plant, i.e. for chlorophyll formation and protein for cell growth. When nematode interferes with Fe and Mn absorption, it results in reduced chlorophyll formation. Mn deficiency also disturbs carbohydrate and nitrogen metabolism. (http://www.westone.wa.gov.au). Nematodes also cause deficiency of element phosphorus and calcium in the plant tissue (http://www.sesl.com.au).

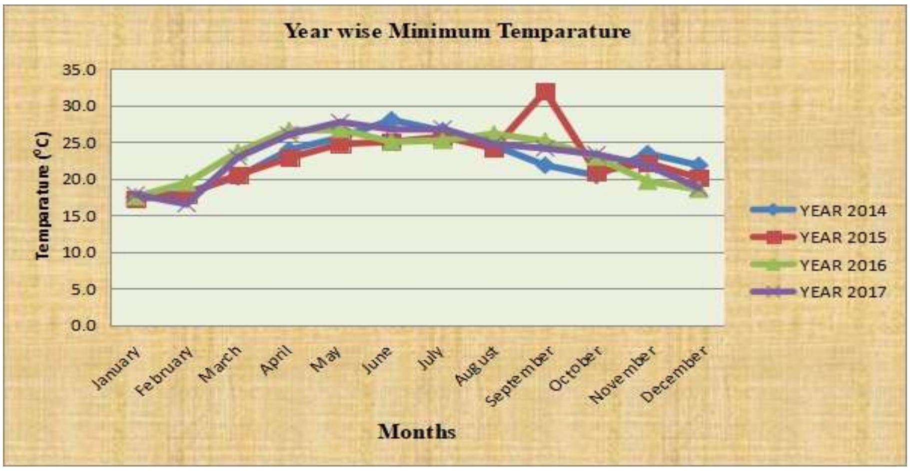
IV. Conclusion

Mulberry is an economically important crop for sericulture industry. Root-knot disease is seriously limits its production caused by root knot nematode *Meloidogyne incognita*. The weather conditions in the experimental site positively for nematode population development. The maximum temperature, has a negative correlation while, rainfall and relative humidity (evening and morning), Evaporation and Sunshine hrs have a positive correlation with root-knot nematode population in the mulberry garden. Adequate quantity of plant nutrition macro and micro nutrients helps to reduce the incidence of disease due to increased resistance to the penetration and development of pathogens crop.

Figures



(a) Year wise Maximum Temperature.



(b) Year wise Minimum Temperature.

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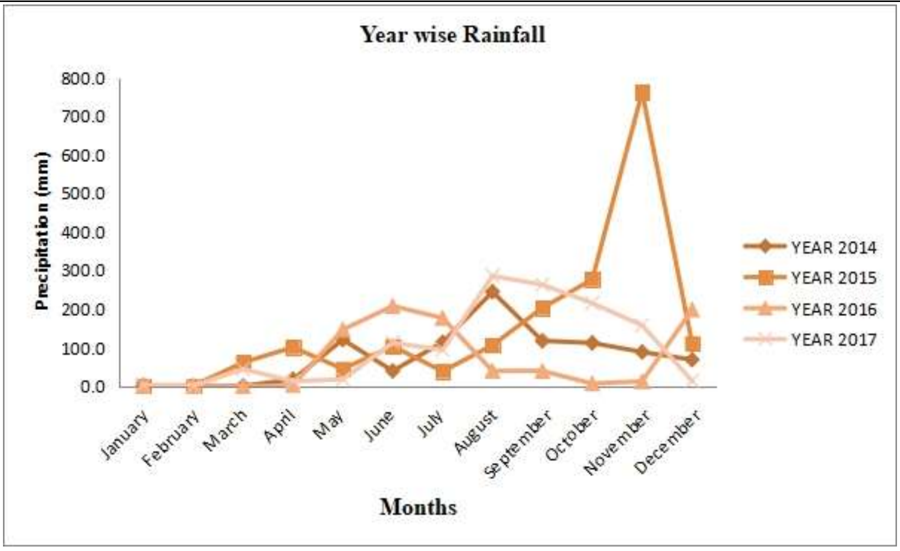
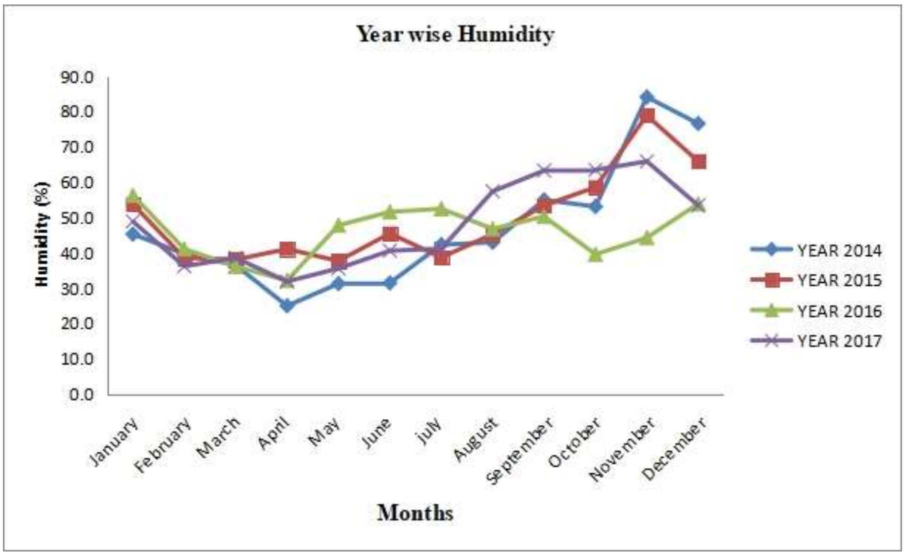
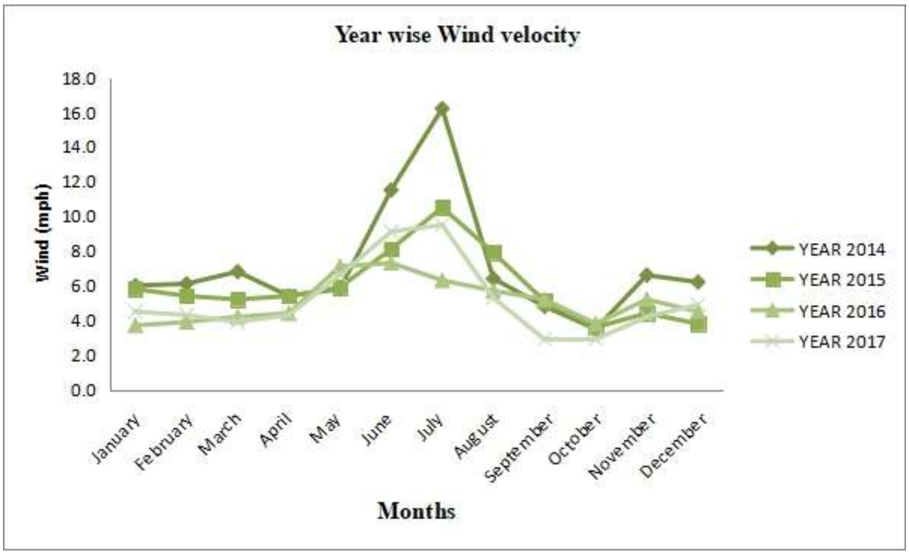


(c) Year wise Rainfall.



(d) Year wise Humidity.



(e) Year wise Wind velocity.

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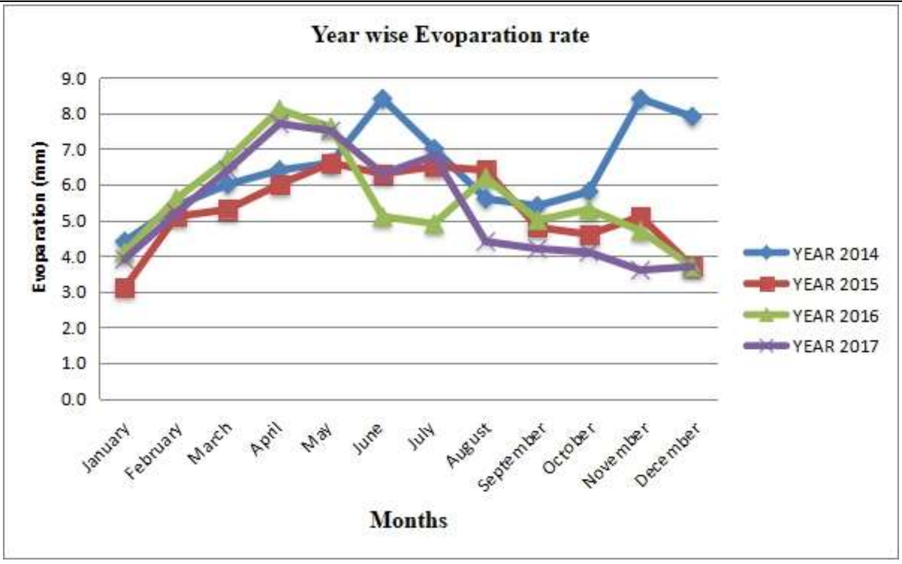
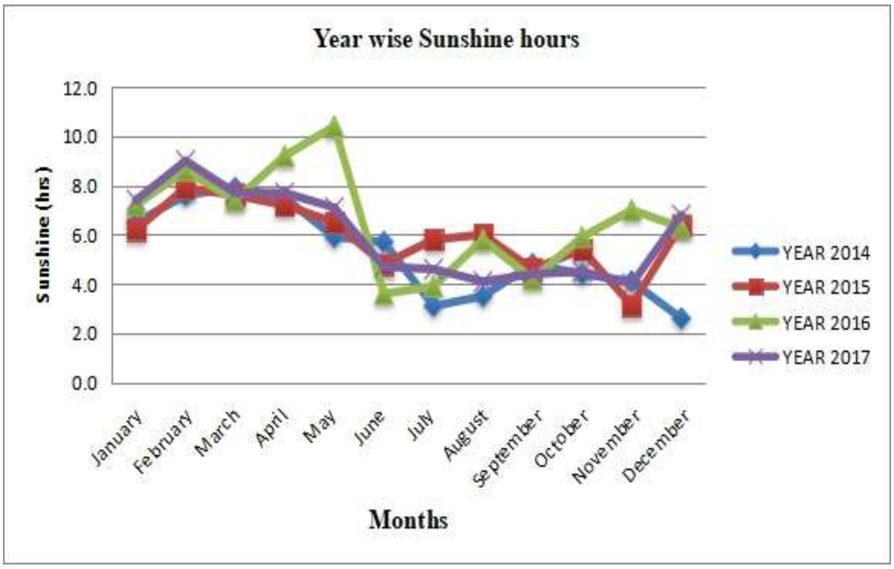


(f) Year wise Evaporation rate.



(g) Year wise Sunshine hours.

Fig. 1. Weather conditions during the experimental period 2014-2017.

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