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Population dynamics and forewarning models for prediction of population of groundnut Thrips under different sowing window and groundnut varieties

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Abstract
The correlation was carried out between weather parameter and population of tobacco thrips on different groundnut varieties at different sowing windows and forewarning models for prediction of population of thrips, during *kharif season*, 2017 and 2018. The experiment was laid out in split plot design with three replications. The treatment comprised of four varieties *viz.*, V_1: JL-501, V_2: RHRG-6083 (*Phule Unnati*), V_3: TAG-24 and V_4: JL-776 (*Phule Bharati*) as main plot and four sowing windows *viz.*, S_1: 25rd MW (18th to 24th June), S_2: 26th MW (25th June to 01st July), S_3: 27th MW (2nd to 8th July) and S_4: 28th MW (09th to 15th July) as sub plot treatments. The correlation of weather parameters with incidence of thrips, showed that the population of thrips was found to have significant and positive correlation with minimum temperature, afternoon relative humidity, wind speed and bright sunshine hours whereas maximum temperature, morning relative humidity, and rainfall showed negative correlation with seasonal incidence of thrips. Sowing of groundnut during 26th MW (S_2) and 27th (S_3) recorded lower incidence of thrips, whereas, crop sown during 28thMW (S_4) recorded with maximum incidence. Among the groundnut varieties, higher incidence was recorded with TAG-24 and minimum was recorded on JL-776 followed by RHRG-6083. Prediction of thrips populations in different sowing window based on regression equations (R^2) 52 to 88 per cent validation based on different weather parameters for variety JL-501, (R^2) 58 to 86 per cent validation based on different weather parameter for variety RHRG-6083, (R^2) 48 to 85 per cent validation based on different weather parameter for variety TAG-24, (R^2) 73 to 83 per cent validation based on different weather parameter for variety JL-776 for the prediction of thrips population.

Keywords: Correlation, forewarning models, groundnut, regression analysis, sowing window, variety, thrips

Introduction
Groundnut (*Arachis hypogaea* L.), it belongs to the family *leguminacae* and also known as peanut which ranks sixth among the oilseed crops and thirteenth among the food crops of the world. Groundnut occupies first place in India in respect of acreage and production. Insect pests of groundnut causes damage in both field and storage conditions. Due to the insect pests the annual loss estimated to be around Rs. 1500 million. About 115 insect pest species was reported in India, which causes damage to groundnut crop, in which only 9 species tobacco caterpillar, leaf miner, white grub, thrips, aphid, jassids, gram caterpillar, red hairy caterpillar and termites are found to be economically important. The above-ground pests include tobacco caterpillar, *Spodoptera litura* (Fab) and the groundnut leaf miner, *Aproaerema modicella* Deventer in Asia. Aphids and thrips transmit a number of viral diseases and more foliar damage caused by Jassids reported by Wightman and Amin (2008) [1]. Singh (2014) [2] reported that different strategies have to be involved for keeping the pest in check and stabilizing the productivity of the cropping system. The sowing window is one of the crop habitat desertification that is to be looked into, to minimize the incidence of insect pests on groundnut crop so that its yield can be enhanced. The sowing window takes the advantage of the absence of the pest or avoids susceptible stage of the crop. It prevents carryover of pests from early sown crop to late sown crop and prevents buildup of damaging populations. The pest forewarning model was able to predict the percent population of thrips for different groundnut varieties and sowing windows with good r^2 values.

Keeping these facts in view, the correlation between weather parameter and population of thrips/3 leaves on different groundnut varieties at different sowing windows and development of forewarning models for prediction of population of thrips/3 leaves was studied during *kharif season*, 2017 and 2018.

Material and Methods

Location of the experimental site and climatic condition

The experiment was conducted in a Split plot design with three replications and sixteen treatment combinations formed considering different varieties and sowing windows. The gross and net plot size was 4.5 x 4.5 $m^2$and 3.6 x 3.6 m^2, respectively for two consecutive years at Department of Agricultural Meteorology farm, College of Agriculture, Pune during *kharif*, 2017 and 2018. The geographical location of the site (Pune) was 18° 32'N, latitude; 73°51E, longitude and 557.7 m above mean sea level (MSL). The soil is medium black having depth of about 1m. the experimental site is situated in the sub-tropical region (Plain Zone) on the latitude 18^0 22' N and longitude 73^0 51' E and having an altitude of 557.7 m above the mean sea level. The average annual rainfall of Pune is 675 mm, which is distributed from second fortnight of June to second fortnight of October. Out of total rainfall, about 75 per cent is received from June to September from south-west monsoon, while remaining is received from north-east monsoon during October and November. Urea and single superphosphate were used as source of N and P and applied as per recommended dose *i.e.* 25 kg N and 50 kg P_2O_5. Seed of groundnut was inoculated with *Rhizobium* culture @ 250 g 10 kg^{-1} seed.

Number of thrips/3 leaves

Count the number of nymphs and adults present in top three open leaves of one plant in the selected spot.

The effect of weather factors *viz;* maximum and minimum temperatures (^{0}C), relative humidity in per cent (morning and evening), bright sunshine hours, rainfall (mm) and rainy days, wind speed, evaporation rate from meteorological weeks 25th to 44th in *kharif*; 2017 and 2018, on thrips were studied. The influence of weather parameters on thrips population was estimated by using prediction equation as,

$$Y = a + b1x1 + b2x2 + b3x3 + \ldots\ldots + bnxn.$$

Where, Y= Thrips population, 'a' as constant and 'b' as regression coefficients of independent variable 'x'. Correlation analysis of mean weather parameters and mean data of two years on resultant crop growth characters, yield attributes and yield including water utilized for analysis. Snedecor and Cochron (1968) [3] revealed that the influence of weather parameters on crop growth yield and yield attributes; initially simple correlations were carried out. Drapper and Smith (1998) [4] establishing the relationship between weather parameters and *Spodoptera litura* multiple regression analysis was carried out considering those weather parameters that had significant influence on thrips of groundnut. The forewarning models for different sowing windows and varieties of groundnut were worked out by statistical analysis using SPSS8.0 software with multiple linear regression method. The correlation coefficient values were further used for results and discussion.

Result and Discussion

Population dynamics of thrips on groundnut

During the course of study the incidence of thrips was recorded on different groundnut were sown at different sowing windows. The incidence of thrips was recorded all varieties during the year 2017 and 2018 in Table 1 to 4, across all the windows of sowing.

The nymphs and adults tear the surface of the leaflets and suck the oozing sap resulting in white patches appearing on the lower surface of the leaves and distortion of young leaflets. The injury results in development of dull yellowish-green patches of the upper leaf surface and brown colored (necrotic) areas on the lower surface. Severe infestations cause bronzed appearance of leaf with curling and stunting of plants.

Population dynamics of thrips/3 leaves on different groundnut varieties under different sowing window

Population dynamics of thrips/3 leaves on different groundnut varieties under sowing window (S_1) 25th MW

During the year 2017, first sowing window 25th MW (S_1) with the varieties JL-501 (V_1), RHRG-6083 (V_2) and TAG-24 (V_3) and JL-776 (V_4) the mean incidence of thrips/3 leaves was 1.86, 1.36, 2.09 and 1.61 thrips/3 leaves and which were at peak with a 5.14, 3.54, 5.42 and 3.87 thrips/3 leaves. During the year 2018, the first sowing window 25th MW (S_1) with the varieties JL-501 (V_1), RHRG-6083 (V_2) and TAG-24 (V_3) and JL-776 (V_4) recorded the mean incidence of thrips/3 leaves was 1.99, 1.56, 2.22 and 1.82, which was peak with a 5.31, 3.78, 5.59 and 4.11 thrips/3 leaves, resulting the peak population of thrips/3 leaves was noticed at 36th MW with sowing window 25th MW, during both the year 2017 and 2018.

Population dynamics of thrips/3 leaves on different groundnut varieties under sowing window (S_2) 26th MW

During the second sowing window 26th MW (S_2) of 2017 with the varieties JL-501 (V_1), RHRG-6083 (V_2) and TAG-24 (V_3) and JL-776 (V_4) recorded the mean incidence of thrips/3 leaves was 1.57, 1.12, 1.77 and 1.33 and which were at peak with 3.71, 2.57, 3.99 and 2.90 thrips/3 leaves. During the year 2018, the second sowing window 26th MW (S_2) with the varieties JL-501 (V_1), RHRG-6083 (V_2) and TAG-24 (V_3) and JL-776 (V_4) recorded the mean incidence of thrips/3 leaves was 1.69, 1.27, 1.88 and 1.52, which was peak with a 3.88, 2.81, 4.16 and 3.14 thrips/3 leaves, resulting the peak incidence of thrips/3 leaves was noticed at the 37th MW for the sowing window 26th MW, during both the year 2017 and 2018.

Population dynamics of thrips/3 leaves on different groundnut varieties under sowing window (S_3) 27th MW

During the third sowing window 27th MW (S_3) of the year 2017 with the varieties JL-501 (V_1), RHRG-6083 (V_2) and TAG-24 (V_3) and JL-776 (V_4) the mean incidence of thrips/3 leaves were 1.75, 1.42, 1.96 and 1.67 and which was peak with 5.38, 2.94, 5.66 and 3.08 thrips/3 leaves, respectively. During 2018, the third sowing window 27th MW (S_3) with the varieties JL-501 (V_1), RHRG-6083 (V_2) and TAG-24 (V_3) and JL-776 (V_4) recorded the mean incidence of thrips/3 leaves was 1.88, 1.62, 2.09 and 1.83, which was peak with a 5.55, 3.18, 5.83 and 3.52 thrips/3 leaves, respectively. The peak

incidence of thrips/3 leaves were noticed at the 37th MW for the sowing window 26th MW, during both the year 2017 and 2018,

Population dynamics of thrips/3 leaves on different groundnut varieties under sowing window (S_4) 28th MW

During the fourth sowing window 28th MW (S_4) of 2017 with the varieties JL-501 (V_1), RHRG-6083 (V_2) and TAG-24 (V_3) and JL-776 (V_4) the mean incidence of thrips/3 leaves was 2.15, 2.36, 2.37 and 2.52 and which were at peak with a 5.67, 4.10, 5.95 and 4.43 thrips/3 leaves. During the year 2018, the fourth sowing window 28th MW (S_4) with the varieties JL-501 (V_1), RHRG-6083 (V_2) and TAG-24 (V_3) and JL-776 (V_4), recorded the mean incidence of thrips/3 leaves were 2.23, 2.56, 242 and 2.56, which were at peak with a 5.84, 4.34, 6.12, and 4.67 thrips/3 leaves, respectively. The peak incidence of thrips/3 leaves were noticed during the 37th MW for the sowing window 28th MW, during both the year 2017 and 2018. Similar results were reported by Reddy *et al.* (1983) [5], Upadhyay (1984), Jayanthi *et al.* (1993) [6], Vijayalaxmi (2010) [8] and Ahir *et al.* (2012) [9].

Correlation between weather parameter and population of thrips/3 leaves on different groundnut varieties at different sowing windows and forewarning models for prediction of population of thrips/3 leaves

The influence of different weather parameters *viz.*, maximum and minimum temperature, morning and evening relative humidity, wind speed evaporation and rainfall on the seasonal population of thrips/3 leaves was observed by working out correlation coefficient (r) (Table 5 and 6) and forewarning model were developed are given in Table 7.

Results of the cumulative correlation showed that the population of thrips was found to have significant and positive correlation with minimum temperature, evening relative humidity, wind speed and bright sunshine hours whereas maximum temperature, morning relative humidity, and rainfall showed negative correlation. On the basis of different sowing windows and varieties, the incidence of thrips with weather factors was studies.

Correlation between weather parameter and population of thrips/3 leaves on groundnut var. JL-501 at different sowing windows and forewarning models for prediction of population of thrips/3 leaves

During first sowing window 25th MW (S_1) with variety JL-501 the population of thrips/3 leaves for one week prior (W-1) was correlated significantly positive with minimum temperature (0.149 and 0.319), afternoon relative humidity (0.389 and 0.0715), wind speed (0.481 and 0.625) whereas it was negatively significant with maximum temperature (-0.652 and -0.734) and bright sunshine hours (-0.328 and -0.477) during *kharif* season 2017 and 2018, respectively. The multiple regression equation is given below:

Y=3.622+0.096(Tmax)-1.702(Tmin)+0.201(RH-I)+0.239(RH-II)-0.055(RF)

An increase of one unit of maximum temperature increased the population of thrips/3 leaves by 0.09 units, one unit of morning humidity increased the population of thrips/3 leaves by 0.20 units and one unit increase in evening relative humidity increase population of thrips/3 leaves intensity by 0.23 units. These weather parameter collectively increased the population of thrips/3 leaves to an effect of 81% (R^2=0.81)

During second sowing window 26th MW (S_2) with variety JL-501 the population of thrips/3 leaves for one week prior (W-1) was correlated significantly positive with minimum temperature (0.157 and 0.010), afternoon relative humidity (0.186 and 0.491), wind speed (0.162 and 0.371) whereas it was negatively significant with maximum temperature (-0.347 and -0.498), rainfall (-0.214 and -0.187) and bright sunshine hours (-0.066 and -0.136) during *kharif* season 2017 and 2018, respectively. The multiple regression equation is given below:

Y=38.268+0.079(Tmax)-2.373(Tmin)+0.024(RH-I)+0.171(RH-II)-0.046(RF)

An increase of one unit of maximum temperature increased the population of thrips/3 leaves by 0.07 units, one unit of morning humidity increased the population of thrips/3 leaves by 0.02 units and one unit increase in evening relative humidity increase population of thrips/3 leaves intensity by 0.17 units. These weather parameter collectively increased the population of thrips/3 leaves to an effect of 88% (R^2=0.88)

During third sowing window 27th MW (S_3) with variety JL-501 the population of thrips/3 leaves for one week prior (W-1) was correlated significantly positive with afternoon relative humidity (0.125 and 0.436), wind speed (0.113 and 0.331) whereas it was negatively significant with maximum temperature (-0.281 and -0.464), rainfall (-0.218 and -0.206) and bright sunshine hours (-0.007 and -0.082) and bright sunshine hours (-0.066 and -0.136) during *kharif* season 2017 and 2018, respectively. The multiple regression equation is given below:

Y=82.398-0.718(Tmax)-2.372(Tmin)-0.053(RH-I)-0.039(RH-II)-0.031(RF)

An increase of one unit of maximum temperature increased the population of thrips/3 leaves by 0.71 units, these weather parameter collectively increased the population of thrips/3 leaves to an effect of 83% (R^2=0.83)

During fourth sowing window 27th MW (S_4) with variety JL-501 the population of thrips/3 leaves for one week prior (W-1) was correlated significantly positive with afternoon relative humidity (0.051 and 0.153), evaporation (0.051 and 0.151) and bright sunshine hours (0.051 and 0.153) whereas it was negatively significant with maximum temperature (-0.085 and -0.211), rainfall (-0.077 and -0.250) and bright sunshine hours (-0.066 and -0.136) during *kharif* season 2017 and 2018, respectively. The multiple regression equation is given below:

Y=43.969+0.712(Tmax)-2.996(Tmin)-0.180(RH-I)+0.276(RH-II)-0.015(RF)

An increase of one unit of maximum temperature increased the population of thrips/3 leaves by 0.71 units and one unit increase in evening relative humidity increase population of thrips/3 leaves intensity by 0.27 units. These weather parameter collectively increased the population of thrips/3 leaves to an effect of 52% (R^2=0.52)

Correlation between weather parameter and population of thrips/3 leaves on groundnut var. RHRG-6083 at different sowing windows and forewarning models for prediction of population of thrips/3 leaves

During first sowing window 25th MW (S_1) with variety RHRG-6083 the population of thrips/3 leaves for one week prior (W-1) was correlated significantly positive with minimum temperature (0.140 and 0.202), afternoon relative humidity (0.340 and 0.666), wind speed (0.338 and 0.488) whereas it was negatively significant with maximum temperature (-0.542 and -0.671), evaporation (-0.078 and -0.402) and bright sunshine hours (-0.259 and -0.368) during *kharif* season 2017 and 2018, respectively. The multiple regression equation is given below:

Y=17.545+0.041(Tmax)-1.584(Tmin)+0.090(RH-I)+0.146(RH-II)-0.030(RF)

An increase of one unit of maximum temperature increased the population of thrips/3 leaves by 0.04 units, one unit of morning humidity increased the population of thrips/3 leaves by 0.09 units and one unit increase in evening relative humidity increase population of thrips/3 leaves intensity by 0.14 units. These weather parameter collectively increased the population of thrips/3 leaves to an effect of 86% (R^2=0.86)

During second sowing window 26th MW (S_2) with variety RHRG-6083 the population of thrips/3 leaves for one week prior (W-1) was correlated significantly positive with afternoon relative humidity (0.208 and 0.348), wind speed (0.040 and 0.156) whereas it was negatively significant with maximum temperature (-0.344 and -0.319), and rainfall (-0.138 and -0.231) during *kharif* season 2017 and 2018, respectively. The multiple regression equation is given below:

Y=10.076+0.507(Tmax)-1.413(Tmin)-0.056(RH-I)+0.181(RH-II)-0.011(RF)

An increase of one unit of maximum temperature increased the population of thrips/3 leaves by 0.50 units, and one unit increase in evening relative humidity increase population of thrips/3 leaves intensity by 0.18 units. These weather parameter collectively increased the population of thrips/3 leaves to an effect of 76% (R^2=0.76)

During third sowing window 27th MW (S_3) with variety RHRG-6083 the population of thrips/3 leaves for one week prior (W-1) was correlated significantly positive with maximum temperature (0.042 and 0.059) and bright sunshine hours (0.145 and 0.355) whereas it was negatively significant with afternoon relative humidity (-0.059 and -0.150), Rainfall (-0.049 and -0.359) during *kharif* season 2017 and 2018, respectively. The multiple regression equation is given below:

Y=-11.518+0.716(Tmax)-1.031(Tmin)+0.019(RH-I)+0.195(RH-II)-0.008(RF)

An increase of one unit of maximum temperature increased the population of thrips/3 leaves by 0.71 units, one unit of morning humidity increased the population of thrips/3 leaves by 0.019 units and one unit increase in evening relative humidity increase population of thrips/3 leaves intensity by 0.19 units. These weather parameter collectively increased the population of thrips/3 leaves to an effect of 58% (R^2=0.58)

During fourth sowing window 28th MW (S_4) with variety RHRG-6083 the population of thrips/3 leaves for one week prior (W-1) was correlated significantly positive with maximum temperature (0.135 and 0.198), and evaporation (0.051 and 0.429) whereas it was negatively significant with minimum temperature (0.091 and 0.078), rainfall (-0.106 and -0.439) and bright sunshine hours (0.250 and 0.459) during *kharif* season 2017 and 2018, respectively. The multiple regression equation is given below:

Y=-10.358+0.716(Tmax)-1.031(Tmin)+0.019(RH-I)+0.195(RH-II)-0.008(RF)

An increase of one unit of maximum temperature increased the population of thrips/3 leaves by 0.71 units and one unit increase in evening relative humidity increase population of thrips/3 leaves intensity by 0.19 units. These weather parameter collectively increased the population of thrips/3 leaves to an effect of 58% (R^2=0.58)

Correlation between weather parameter and population of thrips/3 leaves on groundnut var. TAG-24 at different sowing windows and forewarning models for prediction of population of thrips/3 leaves

During first sowing window 25th MW (S_1) with variety TAG-24 the population of thrips/3 leaves for one week prior (W-1) was correlated significantly positive with minimum temperature (0.184 and 0.341), afternoon relative humidity (0.404 and 0.738) whereas it was negatively significant with maximum temperature (-0.501 and -0.636), wind speed (-0.333 and -0.495) and bright sunshine hours (-0.334 and -0.495) during *kharif* season 2017 and 2018, respectively. The multiple regression equation is given below:

Y=10.015+0.064(Tmax)-1.804(Tmin)+0.164(RH-I)+0.241(RH-II)-0.053(RF)

An increase of one unit of maximum temperature increased the population of thrips/3 leaves by 0.06 units, one unit of morning humidity increased the population of thrips/3 leaves by 0.16 units and one unit increase in evening relative humidity increase population of thrips/3 leaves intensity by 0.24 units. These weather parameter collectively increased the population of thrips/3 leaves to an effect of 85% (R^2=0.85)

During second sowing window 26th MW (S_2) with variety TAG-24 the population of thrips/3 leaves for one week prior (W-1) was correlated significantly positive with minimum temperature (0.175 and 0.023), afternoon relative humidity (0.198 and 0.491), wind speed (0.157 and 0.370) whereas it was negatively significant with maximum temperature (-0.344 and -0.492), rainfall (-0.219 and -0.197) and bright sunshine hours (-0.671 and -0.139) during *kharif* season 2017 and 2018, respectively. The multiple regression equation is given below:

Y=22.336+0.488(Tmax)-2.062(Tmin)-0.065(RH-I)+0.244(RH-II)-0.027(RF)

An increase of one unit of maximum temperature increased the population of thrips/3 leaves by 0.48 units, and one unit increase in evening relative humidity increase population of thrips/3 leaves intensity by 0.14 units. These weather parameter collectively increased the population of thrips/3 leaves to an effect of 76% (R^2=0.76)

During third sowing window 27th MW (S_3) with variety TAG-24 the population of thrips/3 leaves for one week prior (W-1)

was correlated significantly positive with afternoon relative humidity (0.145 and 0.428), wind speed (0.107 and 0.325) whereas it was negatively significant with maximum temperature (-0.282 and -0.451), rainfall (-0.211 and -0.224) and bright sunshine hours (-0.018 and -0.078) and bright sunshine hours (-0.671 and -0.139) during *kharif* season 2017 and 2018, respectively. The multiple regression equation is given below:

Y=44.894+0.342(Tmax)-2.389(Tmin)-0.171(RH-I)+0.217(RH-II)-0.022(RF)

An increase of one unit of maximum temperature increased the population of thrips/3 leaves by 0.34 units and one unit increase in evening relative humidity increase population of thrips/3 leaves intensity by 0.21 units. These weather parameter collectively increased the population of thrips/3 leaves to an effect of 65% (R^2=0.65)

During fourth sowing window 28th MW (S_4) with variety TAG-24 the population of thrips/3 leaves for one week prior (W-1) was correlated significantly positive with afternoon relative humidity (0.088 and 0.196), evaporation (0.214 and 0.076) and bright sunshine hours (0.073 and 0.157) whereas it was negatively significant with maximum temperature (-0.065 and -0.199), rainfall (-0.086 and -0.258) during *kharif* season 2017 and 2018, respectively. The multiple regression equation is given below:

Y=-11.055+0.951(Tmax)-1.813(Tmin)+0.047(RHI)+0.323(RH-II)-0.021(RF)

An increase of one unit of maximum temperature increased the population of thrips/3 leaves by 0.95 units, one unit of morning humidity increased the population of thrips/3 leaves by 0.47 units and one unit increase in evening relative humidity increase population of thrips/3 leaves intensity by 0.32 units. These weather parameter collectively increased the population of thrips/3 leaves to an effect of 48% (R^2=0.48).

Correlation between weather parameter and population of thrips/3 leaves on groundnut var. JL-776 at different sowing windows and forewarning models for prediction of population of thrips/3 leaves

During first sowing window 25th MW (S_1) with variety JL-776 the population of thrips/3 leaves for one week prior (W-1) was correlated significantly positive with minimum temperature (0.178 and 0.199), afternoon relative humidity (0.357 and 0.654) whereas it was negatively significant with Maximum temperature (-0.533 and -0.653), wind speed (-0.345 and -0.465) and bright sunshine hours (-0.277 and -0.354) during *kharif* season 2017 and 2018, respectively. The multiple regression equation is given below:

Y=18.977-0.037(Tmax)-1.428(Tmin)+0.028(RH+0.123(RH-II)-0.027(RF)

An increase of one unit of maximum temperature increased the population of thrips/3 leaves by 0.02 units, one unit of morning humidity increased the population of thrips/3 leaves by 0.02 units and one unit increase in evening relative humidity increase population of thrips/3 leaves intensity by 0.12 units. These weather parameter collectively increased the population of thrips/3 leaves to an effect of 83% (R^2=0.83)

During second sowing window 26th MW (S_2) with variety JL-776 the population of thrips/3 leaves for one week prior (W-1) was correlated significantly positive with minimum temperature (0.172 and 0.034), afternoon relative humidity (0.187 and 0.336), wind speed (0.080 and 0.158) whereas it was negatively significant with maximum temperature (-0.276 and -0.301), rainfall (-0.227 and -0.261) and bright sunshine hours (-0.018 and -0.007) during *kharif* season 2017 and 2018, respectively. The multiple regression equation is given below:

Y=25.863+0.052(Tmax)-1.467(Tmin)+0.015(RH-I)+0.077(RH-II)-0.019(RF)

An increase of one unit of maximum temperature increased the population of thrips/3 leaves by 0.05 units, and one unit increase in evening relative humidity increase population of thrips/3 leaves intensity by 0.07 units. These weather parameter collectively increased the population of thrips/3 leaves to an effect of 92% (R^2=0.92)

During third sowing window 27th MW (S_3) with variety JL-776 the population of thrips/3 leaves for one week prior (W-1) was correlated significantly positive with afternoon relative humidity (0.130 and 0.032) whereas it was negatively significant with rainfall (-0.046 and -0.327) and bright sunshine hours (-0.090 and -0.296) during *kharif* season 2017 and 2018, respectively. The multiple regression equation is given below:

Y=12.501+0.851(Tmax)-1.920(Tmin)-0.104(RH-I)+0.227(RH-II)-0.006(RF)

An increase of one unit of maximum temperature increased the population of thrips/3 leaves by 0.85 units and one unit increase in evening relative humidity increase population of thrips/3 leaves intensity by 0.22 units. These weather parameter collectively increased the population of thrips/3 leaves to an effect of 73% (R^2=0.73)

During fourth sowing window 28th MW (S_4) with variety JL-776 the population of thrips/3 leaves for one week prior (W-1) was correlated significantly positive with maximum temperature (0.065 and 0.058), afternoon relative humidity (0.094 and 0.012), evaporation (0.212 and 0.281) and bright sunshine hours (0.131 and 0.290) whereas it was negatively significant with rainfall (-0.061 and -0.378) during *kharif* season 2017 and 2018, respectively. The multiple regression equation is given below:

Y=15.223+1.069(Tmax)-2.323(Tmin)-0.134(RH)+0.275(RH-II)-0.006(RF)

An increase of one unit of maximum temperature increased the population of thrips/3 leaves by 1.06 units and one unit increase in evening relative humidity increase population of thrips/3 leaves intensity by 0.27 units. These weather parameter collectively increased the population of thrips/3 leaves to an effect of 73% (R^2=0.73)

Similar findings were reported by Reddy *et al.* (1983) [5], Jayanthi *et al.* (1993) [6], Dash and Sonatakke (1994) [7], Vijayalaxmi (2010) [8] and Ahir *et al.* (2012) [9].

Also the present findings are agreement with Pramod (2007) [10], Prasad *et al.* (2008) [11] and Vijayalaxmi *et al.* (2010) [8].

Table 1: Mean number of thrips/3 leaves on groundnut variety JL-501 as influenced bydifferent sowing windows

Sr. No.	MW	Average numbers of thrips/3 leaves							
		2017				2018			
		S_1 (22nd June)	S_2 (29th June)	S_3 (06th July)	S_4 (12th July)	S_1 (22nd June)	S_2 (29th June)	S_3 (06th July)	S_4 (12th July)
1	29	0.33	0.00	0.00	0.00	0.50	0.00	0.00	0.00
2	30	1.07	0.00	0.00	0.00	1.24	0.00	0.00	0.00
3	31	2.58	0.84	0.95	0.00	2.75	1.01	1.12	0.00
4	32	2.87	2.35	2.46	1.37	3.04	2.52	2.63	1.54
5	33	3.14	2.64	2.75	2.88	3.31	2.81	2.92	3.05
6	34	3.48	2.91	3.02	3.17	3.65	3.08	3.19	3.34
7	35	4.37	3.25	3.36	3.44	4.54	3.42	3.53	3.61
8	36	5.14	3.54	3.65	3.78	5.31	3.71	3.82	3.95
9	37	3.36	3.71	5.38	5.67	3.53	3.88	5.55	5.84
10	38	1.49	3.13	3.24	5.47	1.66	3.30	3.41	5.64
11	39	1.14	1.26	1.37	3.66	1.31	1.43	1.54	3.83
12	40	0.84	0.91	1.02	1.79	1.01	1.08	1.19	1.96
13	41	0.00	0.61	0.72	1.44	0.00	0.78	0.89	1.61
14	42	0.00	0.00	0.11	1.14	0.00	0.00	0.28	1.31
15	43	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.00
16	44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean		1.86	1.57	1.75	2.15	1.99	1.69	1.88	2.23

Table 2: Mean number of thrips/3 leaves on groundnut variety RHRG-6083 as influenced by different sowing windows

Sr. No.	MW	Average numbers of thrips/3 leaves							
		2017				2018			
		S_1(22nd June)	S_2 (29th June)	S_3 (06th July)	S_4 (12th July)	S_1 (22nd June)	S_2 (29th June)	S_3 (06th July)	S_4 (12th July)
1	29	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00
2	30	0.84	0.00	0.00	0.00	1.08	0.00	0.00	0.00
3	31	1.42	0.66	0.00	0.00	1.66	0.45	0.00	0.00
4	32	1.71	1.19	1.03	2.19	1.95	1.43	1.27	2.43
5	33	1.98	1.48	1.56	2.72	2.22	1.72	1.80	2.96
6	34	2.32	1.75	1.85	3.01	2.56	1.99	2.09	3.25
7	35	3.20	2.11	2.12	3.28	3.44	2.35	2.36	3.52
8	36	3.54	2.38	2.48	3.64	3.78	2.62	2.72	3.88
9	37	2.87	2.57	2.75	3.91	3.11	2.81	2.99	4.15
10	38	1.54	1.97	2.94	4.10	1.78	2.21	3.18	4.34
11	39	1.14	1.46	2.34	3.50	1.38	1.70	2.58	3.74
12	40	0.89	1.18	1.83	2.99	1.13	1.42	2.07	3.23
13	41	0.34	0.86	1.55	2.71	0.58	1.10	1.79	2.95
14	42	0.00	0.33	1.23	2.39	0.00	0.57	1.47	2.63
15	43	0.00	0.00	0.70	1.86	0.00	0.00	0.94	2.10
16	44	0.00	0.00	0.37	1.53	0.00	0.00	0.61	1.77
Mean		1.36	1.12	1.42	2.36	1.56	1.27	1.62	2.56

Table 3: Mean number of thrips/3 leaves on groundnut variety TAG-24 as influenced by different sowing windows

Sr. No.	MW	Average numbers of thrips/3 leaves							
		2017				2018			
		S_1 (22nd June)	S_2 (29th June)	S_3 (06th July)	S_4 (12th July)	S_1 (22nd June)	S_2 (29th June)	S_3 (06th July)	S_4 (12th July)
1	29	0.61	0.00	0.00	0.00	0.78	0.00	0.00	0.00
2	30	1.35	0.00	0.00	0.00	1.52	0.00	0.00	0.00
3	31	2.86	1.12	1.23	0.00	3.03	1.29	1.40	0.00
4	32	3.15	2.63	2.74	1.65	3.32	2.80	2.91	1.82
5	33	3.42	2.92	3.03	3.16	3.59	3.09	3.20	3.33
6	34	3.76	3.19	3.30	3.45	3.93	3.36	3.47	3.62
7	35	4.65	3.53	3.64	3.72	4.82	3.70	3.81	3.89
8	36	5.42	3.82	3.93	4.06	5.59	3.99	4.10	4.23
9	37	3.64	3.99	5.66	5.95	3.81	4.16	5.83	6.12
10	38	1.77	3.41	3.52	5.75	1.94	3.58	3.69	5.92
11	39	1.42	1.54	1.65	3.94	1.59	1.71	1.82	4.11
12	40	1.12	1.19	1.30	2.07	1.29	1.36	1.47	2.24
13	41	0.28	0.89	1.00	1.72	0.28	1.06	1.17	1.89
14	42	0.00	0.15	0.39	1.42	0.00	0.00	0.56	1.59
15	43	0.00	0.00	0.00	0.81	0.00	0.00	0.00	0.00
16	44	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00
Mean		2.09	1.77	1.96	2.37	2.22	1.88	2.09	2.42

Table 4: Number of thrips/3 leaves on groundnut variety JL-776 as influenced by different sowing windows

Sr. No.	MW	Average numbers of thrips/3 leaves							
		2017				2018			
		S_1 (22nd June)	S_2 (29th June)	S_3 (06th July)	S_4 (12th July)	S_1 (22nd June)	S_2 (29th June)	S_3 (06th July)	S_4 (12th July)
1	29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	30	1.17	0.00	0.00	0.00	1.41	0.00	0.00	0.00
3	31	1.75	0.99	0.33	0.00	1.99	0.78	0.00	0.79
4	32	2.04	1.52	1.36	2.52	2.28	1.76	1.60	2.76
5	33	2.31	1.81	1.89	3.05	2.55	2.05	2.13	3.29
6	34	2.65	2.08	2.18	3.34	2.89	2.32	2.42	3.58
7	35	3.53	2.44	2.45	3.61	3.77	2.68	2.69	3.85
8	36	3.87	2.71	2.81	3.97	4.11	2.95	3.05	4.21
9	37	3.20	2.90	3.08	4.24	3.44	3.14	3.32	4.48
10	38	1.87	2.30	3.27	4.43	2.11	2.54	3.51	4.67
11	39	1.47	1.79	2.67	3.83	1.71	2.03	2.91	4.07
12	40	1.22	1.51	2.16	3.32	1.46	1.75	2.40	3.56
13	41	0.67	1.19	1.88	3.04	0.91	1.43	2.12	3.28
14	42	0.00	0.00	1.56	2.72	0.00	0.90	1.80	2.96
15	43	0.00	0.00	1.03	2.19	0.00	0.00	1.27	2.43
16	44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean		1.61	1.33	1.67	2.52	1.79	1.52	1.83	2.7 5

Table 5: Correlation between number of groundnut thrips/3 leaves of groundnut with weather parameters during *kharif* 2017

Treatment		r' values							
Sowing window	Variety	Tmax	Tmin	RH-I	RH-II	WS	RF	Epan	BSS
S_1- 25th MW	V_1- JL-501	-0.652	0.149	-0.317	0.389	0.481	-0.074	-0.111	-0.328
S_2- 26th MW	V_1- JL-501	-0.347	0.157	-0.195	0.186	0.162	-0.214	0.133	-0.066
S_3- 27th MW	V_1- JL-501	-0.281	0.147	-0.171	0.125	0.113	-0.218	0.174	-0.007
S_4- 28th MW	V_1- JL-501	-0.085	0.166	0.070	0.110	-0.163	-0.077	0.213	0.051
S_1- 25th MW	V_2 - RHRG-6083	-0.542	0.140	-0.217	0.340	0.338	-0.058	-0.078	-0.259
S_2- 26th MW	V_2 - RHRG-6083	-0.274	0.167	-0.097	0.208	0.040	-0.138	0.152	-0.027
S_3- 27th MW	V_2 - RHRG-6083	0.042	0.078	0.183	0.070	-0.342	-0.049	0.215	0.145
S_4- 28th MW	V_2 - RHRG-6083	0.135	-0.091	0.272	-0.059	-0.474	-0.106	0.205	0.250
S_1- 25th MW	V_3 - TAG-24	-0.656	0.184	-0.348	0.404	0.501	-0.086	-0.097	-0.334
S_2- 26th MW	V_3 - TAG-24	-0.344	0.175	-0.195	0.198	0.157	-0.219	0.129	-0.071
S_3- 27th MW	V_3 - TAG-24	-0.282	0.167	-0.165	0.145	0.107	-0.211	0.166	-0.018
S_4- 28th MW	V_3 - TAG-24	-0.065	0.136	0.091	0.088	-0.195	-0.086	0.214	0.073
S_1- 25th MW	V_4- JL-776	-0.533	0.178	-0.232	0.357	0.345	-0.082	-0.094	-0.277
S_2- 26th MW	V_4- JL-776	-0.276	0.172	-0.159	0.187	0.080	-0.227	0.162	-0.018
S_3- 27th MW	V_4- JL-776	0.013	0.155	0.152	0.130	-0.309	-0.046	0.202	0.090
S_4- 28th MW	V_4- JL-776	0.065	0.111	0.170	0.094	-0.373	-0.061	0.211	0.131

Table 6: Correlation between number of groundnut thrips/3 leaves of groundnut with weather parameters during *kharif* 2018

Treatment		r' values							
Sowing window	Variety	Tmax	Tmin	RH-I	RH-II	WS	RF	Epan	BSS
S_1- 25th MW	V_1- JL-501	-0.734	0.319	0.115	0.715	0.625	0.036	-0.481	-0.477
S_2- 26th MW	V_1- JL-501	-0.498	0.010	0.110	0.491	0.373	-0.187	-0.162	-0.136
S_3- 27th MW	V_1- JL-501	-0.464	-0.043	0.075	0.436	0.331	-0.206	-0.121	-0.082
S_4- 28th MW	V_1- JL-501	-0.211	-0.249	0.152	0.201	0.007	-0.250	0.063	0.153
S_1- 25th MW	V_2 - RHRG-6083	-0.671	0.202	0.191	0.666	0.488	0.047	-0.402	-0.368
S_2- 26th MW	V_2 - RHRG-6083	-0.319	-0.060	0.181	0.348	0.156	-0.231	-0.027	0.007
S_3- 27th MW	V_2 - RHRG-6083	0.059	-0.345	0.211	-0.019	-0.231	-0.359	0.285	0.355
S_4- 28th MW	V_2 - RHRG-6083	0.198	-0.414	0.189	-0.150	-0.306	-0.439	0.429	0.459
S_1- 25th MW	V_3 - TAG-24	-0.750	0.341	0.116	0.738	0.636	0.052	-0.497	-0.495
S_2- 26th MW	V_3 - TAG-24	-0.492	0.023	0.103	0.491	0.370	-0.197	-0.152	-0.139
S_3- 27th MW	V_3 - TAG-24	-0.451	-0.031	0.068	0.428	0.325	-0.224	-0.105	-0.078
S_4- 28th MW	V_3 - TAG-24	-0.199	-0.237	0.151	0.196	0.005	-0.258	0.076	0.157
S_1- 25th MW	V_4- JL-776	-0.653	0.199	0.173	0.654	0.465	0.059	-0.366	-0.354
S_2- 26th MW	V_4- JL-776	-0.301	-0.034	0.155	0.336	0.158	-0.261	-0.004	0.007
S_3- 27th MW	V_4- JL-776	0.030	-0.234	0.209	0.032	-0.185	-0.327	0.244	0.296
S_4- 28th MW	V_4- JL-776	0.058	-0.180	0.169	0.012	-0.170	-0.378	0.281	0.290

Tmax- Maximum temperature, Tmin- Minimum temperatur, RH-I- Morning humidity, RH-II- Evening humidity, WS- Wind speed, RF- Rainfall, Epan- Evaporation, BSS- Bright sunshine hours

Table 7: Forewarning model developed for one week prior (W-1) prediction of incidence of thrips/3 leaves on groundnut

Treatment		Forewarning model	r2 Value
Sowing window	Variety		
S_1 - 25th MW	V_1 - JL-501	Y=3.622+0.096(Tmax)-1.702(Tmin)+0.201(RH-I)+0.239(RH-II)-0.055(RF)	0.81
S_2 - 26th MW	V_1 - JL-501	Y=38.268+0.079(Tmax)-2.373(Tmin)+0.024(RH-I)+0.171(RH-II)-0.046(RF)	0.88
S_3 - 27th MW	V_1 - JL-501	Y=82.398-0.718(Tmax)-2.372(Tmin)-0.053(RH-I)-0.039(RH-II)-0.031(RF)	0.83
S_4 - 28th MW	V_1 - JL-501	Y=43.969+0.712(Tmax)-2.996(Tmin)-0.180(RH-I)+0.276(RH-II)-0.015(RF)	0.52
S_1 - 25th MW	V_2 - RHRG-6083	Y=17.545+0.041(Tmax)-1.584(Tmin)+0.090(RH-I)+0.146(RH-II)-0.030(RF)	0.86
S_2 - 26th MW	V_2 - RHRG-6083	Y=10.076+0.507(Tmax)-1.413(Tmin)-0.056(RH-I)+0.181(RH-II)-0.011(RF)	0.76
S_3 - 27th MW	V_2 - RHRG-6083	Y=-11.518+0.716(Tmax)-1.031(Tmin)+0.019(RH-I)+0.195(RH-II)-0.008(RF)	0.58
S_4 - 28th MW	V_2 - RHRG-6083	Y=-10.358+0.716(Tmax)-1.031(Tmin)+0.019(RH-I)+0.195(RH-II)-0.008(RF)	0.58
S_1 - 25th MW	V_3 - TAG-24	Y=10.015+0.064(Tmax)-1.804(Tmin)+0.164(RH-I)+0.241(RH-II)-0.053(RF)	0.85
S_2 - 26th MW	V_3 - TAG-24	Y=22.336+0.488(Tmax)-2.062(Tmin)-0.065(RH-I)+0.244(RH-II)-0.027(RF)	0.76
S_3 - 27th MW	V_3 - TAG-24	Y=44.894+0.342(Tmax)-2.389(Tmin)-0.171(RH-I)+0.217(RH-II)-0.022(RF)	0.65
S_4 - 28th MW	V_3 - TAG-24	Y=-11.055+0.951(Tmax)-1.813(Tmin)+0.047(RH-I)+0.323(RH-II)-0.021(RF)	0.48
S_1 - 25th MW	V_4 - JL-776	Y=18.977-0.037(Tmax)-1.428(Tmin)+0.028(RH-I)+0.123(RH-II)-0.027(RF)	0.83
S_2 - 26th MW	V_4 - JL-776	Y=25.863+0.052(Tmax)-1.467(Tmin)+0.015(RH-I)+0.077(RH-II)-0.019(RF)	0.92
S_3 - 27th MW	V_4 - JL-776	Y=12.501+0.851(Tmax)-1.920(Tmin)-0.104(RH-I)+0.227(RH-II)-0.006(RF)	0.73
S_4 - 28th MW	V_4 - JL-776	Y=15.223+1.069(Tmax)-2.323(Tmin)-0.134(RH-I)+0.275(RH-II)-0.006(RF)	0.73

Tmax- Maximum temperature, Tmin- Minimum temperature, RH-I- Morning humidity, RH-II- Evening humidity, WS- Wind speed, RF- Rainfall, Epan- Evaporation, BSS- Bright sunshine hours

Conclusion

The correlation of weather parameters with incidence of thrips, showed that the population of thrips was found to have significant and positive correlation with minimum temperature, afternoon relative humidity, wind speed and bright sunshine hours whereas maximum temperature, morning relative humidity, and rainfall showed negative correlation with seasonal incidence of thrips. Prediction of thrips populations in different sowing window based on regression equations (R^2) 52 to 88 per cent validation based on different weather parameters for variety JL-501, (R^2) 58 to 86 per cent validation based on different weather parameter for variety RHRG-6083, (R^2) 48 to 85 per cent validation based on different weather parameter for variety TAG-24, (R^2) 73 to 83 per cent validation based on different weather parameter for variety JL-776 for the prediction of thrips population.

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