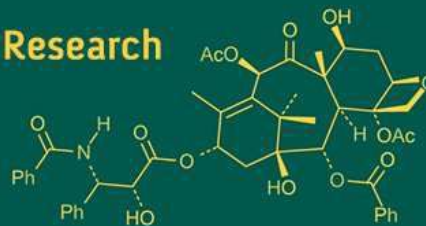


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Effect of soil temperature at different depths of soil on incidence of wilt in selected lentil genotypes

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Abstract

Lentil (*Lens culinaris* Medik) is one of the oldest domesticated legumes and plays a crucial role in global food systems, particularly in countries like India, which is a major producer. Lentil is grown as a Rabi crop in India, thriving in semi-arid environments and contributing to soil fertility through nitrogen fixation. However, lentil production is significantly threatened by various diseases, with Fusarium wilt caused by *Fusarium oxysporum* f. sp. lentis being the most prominent and destructive soil-borne disease. This study investigates the effect of soil temperature at different depths (5 cm, 10 cm, and 20 cm) on the incidence of Fusarium wilt in three susceptible lentil genotypes: L 9-12, Sehore 74-3, and DPL-62. The results show a significant positive correlation between soil temperature and wilt incidence at 10 cm and 20 cm depths for all genotypes, with stronger correlations observed in deeper soil layers. The regression analysis reveals that an increase in soil temperature by 1 °C at 10 cm and 20 cm depths leads to a consistent rise in wilt incidence, particularly in the Sehore 74-3 and DPL-62 genotypes. This study underscores the critical role of soil temperature in the development of Fusarium wilt in lentil crops and provides valuable insights for managing the disease in lentil production systems.

Keywords: Lentil, fusarium wilt, genotype, soil temperature, wilt incidence and disease

Introduction

Lens culinaris Medik is the botanical name of lentil, which is the oldest crops among legumes and belongs to the leguminosae family. It is originated from the Near East and Egypt at the Center and Southern Europe, the Mediterranean basin, Ethiopia, Afghanistan, India, Pakistan, China and later spread to Latin America (Cubero 1981) [5]. India is one of the prime pulse producing countries in the world. In India the total area under lentil was 13.00 lakh ha with a total production of 11.00 lakh tonnes and its average productivity was 847 kg/ha. The major lentil producing states in the country are Madhya Pradesh, Uttar Pradesh, Bihar, Uttarakhand and Bengal. In Madhya Pradesh lentil is grown in 3.79 lakh ha with a total production of 2.94 lakh tonnes with 777 kg/ha productivity (Anon., 2020) [1].

Lentil is grown as a *Rabi* crop or winter crop in India and sown in between months of October and November. Lentil is adapted in semi-arid environments, where it is usually grown in rotations. It is usually cultivated in all continents except Antarctica. Lentil is known by various names in different regions and languages like adas (Arabic), mercimek (Turkey), messer (Ethiopia), masoor (India), and heramme (Japanese) (Muehlbauer and McPhee., 2005) [8]. It can be cultivated on a wide range of soil from light loam to black cotton soils and it can also stand in less fertile moderately alkaline soils and even in rainfed conditions. The crop matures in arounds 90 to 120 days.

Lentil is among the first crops domesticated globally and it has become a prime food legume crop in the farming and food systems in many countries. It is a rich source of protein, minerals, and vitamins and plays an important role in human nutrition. The straw of lentils are pretty much valued animal feed and its ability in nitrogen fixation and carbon sequestration improves the nutrient status of soil, which in turn gives sustainability in production system (Sarker and Erskine, 2006) [9].

Lentil crop is at risk to a various diseases caused by fungi, viruses, nematodes, insect pests, parasitic plants and abiotic stress. The most significant and serious soil-borne disease among them is Fusarium wilt. In many countries like in India, Algeria, Syria and Iran the pathogen of lentils showed high levels of phenotypic and genotypic diversity.

The disease develops at the temperature of 22-25 °C and affects lentil either at seedling and vegetative or at the reproductive stages (Tiwari *et al.*, 2018) ^[11].

In India lentil wilt caused by *Fusarium oxysporum* f. sp. *lentis* is the major disease in lentil growing regions. The disease was first reported in Hungary but in India, it was first observed in 1941 in Delhi and Karnal. The annual yield losses are 10-15 per cent due to this disease alone which valued approximately Rs. 2000-2500 crores (Chaudhary and Amarjit, 2002) ^[4].

If infection takes place in early stage of the plant then it does not produces seeds and if infection occurs at later stage than only few number of seeds are formed. Wilt causes more damage during flowering and pod formation stage of the crop. The *Fusarium* wilt pathogen that primarily infects lentils, *F. oxysporum* f. sp. *lentis* (Vasudeva and Srinivasan 1952) ^[12] is present in many countries in Asia, Europe, Africa and America. Frequently the fungus spreads through the plant debris and soil contamination and it infects the plant through the root system. There is also an evidence of dissemination of fungus through seeds (Bayaa *et al.*, 1990) ^[2]. Temperature and soil moisture are the most important factors in determining symptoms expression and fungal growth rates (Saxena and Khare, 1988) ^[10].

Materials and Methods

Experimental site

The field experiment was conducted in wilt sick plot of the Department of Plant Pathology of R.A.K. College of Agriculture, Sehore, during *Rabi* season of 2021-2022. The experimental site is geographically situated in sub-tropical zone of Vindhyan Plateau of Madhya Pradesh at an elevation of 498.77 meters from mean sea level and lies between altitude and longitude 23° 18', North and 23° 18', East, respectively.

Collection of lentil Seed: Seeds of lentil varieties/germplasm were collected from the Department of Plant Pathology R.A.K. College of Agriculture, Sehore.

Effect of soil temperature at different depths of soil on incidence of wilt at weekly intervals

Influence of soil temperature at different soil depths (5 cm, 10 cm and 20 cm) on wilt incidence was examined in selected susceptible lentil genotypes L 9-12, Sehore 74-3, DPL-62 grown in factorial RBD design.

Percent wilting was calculated by the following formula:

$$\text{Wilt incidence (\%)} = \frac{\text{Total number of wilted plants}}{\text{Total number of plants observed}} \times 100$$

The absolute disease intensity was calculated as the difference between two successive observations of wilt incidence and correlation coefficient ('r') was computed between the absolute disease intensity and meteorological factors like soil temperature at different depths (5 cm, 10 cm and 20 cm). The significance of correlation coefficient was judged by 't' test as per standard statistical methods.

The data on wilt intensity were plotted against soil temperature at different depths to predict the correlation between wilt and soil temperature. Regressions equations were also computed and scatter diagrams were drawn.

Data on soil temperature at different depths during the period were obtained from Agro-meteorological section, at R.A.K. College of Agriculture, Sehore. (Table-1).

Table 1: Soil temperature at different depths during November to March, 2021 at Sehore

Month	Standard Week	Week	Soil temperature (°C)		
			5 cm	10 cm	20 cm
November	45	5-11	19.157	20.429	23.043
	46	12-18	17.600	20.286	22.643
	47	19-25	21.700	22.414	23.886
	48	26-2 Dec.	16.429	20.171	22.443
December	49	3-9	17.429	19.086	22.000
	50	10-16	16.800	19.257	21.586
	51	17-23	12.714	15.571	18.886
	52	24-31	13.913	17.088	19.388
January	1	1-7	15.243	16.914	19.357
	2	8-14	13.714	15.771	18.486
	3	15-21	12.586	15.114	17.543
	4	22-28	12.200	15.243	17.929
	5	29-4 Feb	13.129	15.600	18.600
February	6	5-11	14.357	16.886	19.414
	7	12-18	15.029	17.729	20.086
	8	19-25	14.829	18.686	21.529
	9	26-4 March	16.457	20.029	22.786
March	10	5-11	17.943	21.229	23.886
	11	12-18	19.886	22.343	25.100
	12	19-25	22.929	25.529	27.214

Statistical Analysis

The data obtained in all the experiments was subjected to the statistical analysis (Panse and Sukhatme, 1978) ^[7]. The percentage values were transformed into arcsine values. The standard error (SE) and critical difference (C.D.) at level P = 0.01 were worked out and results obtained were compared statistically. All the statistical analysis was done using (OP STAT) and R-studio statistical programmer at Computer Laboratory, R.A.K. College of Agriculture, Sehore.

Standard error for treatment means

$$S.E.m. \pm = \frac{\sqrt{Ems}}{r}$$

(2) Critical difference

$$C.D. = S.E.m. \sqrt{2} \times t$$

Where,

Ems (±) = Error means sum of square

R = Number of replications

T = 't' value at 5% probability levels

3) Correlation coefficient

Correlation per cent disease index and per cent seed infection were worked out as per method suggested by Chandel (1991) ^[3].

$$r(x y) = \frac{COV. (x y)}{\sqrt{Var. (x) Var. (y)}}$$

Where,

r (x y) = correlation coefficient between character x and y.

COV (x y) = covariance between character x and y.

$V(x)$ = variance of x character.

$V(y)$ = variance of y character.

Results and Discussion

Effect of soil temperature at different depths of soil on incidence of wilt in selected susceptible lentil genotypes.

Soil temperature and incidence of wilt in L 9-12 lentil cultivar

Wilt incidence in L 9-12 lentil genotype was studied in relation to soil temperature at different depths. The wilt incidence and temperatures were recorded every week and correlated. Correlation coefficient (r) and t statistic was computed at each depth level i.e. 5 cm, 10 cm and 20 cm for is given in (Table 2.) To quantify the effect of soil temperature depth levels the linear regression equation was also worked out (Table 3).

Table 2: Correlation coefficient (r) values between incidence of wilt in L 9-12 and soil temperature at different depth levels

Week Interval	Standard week	Wilt incidence (%) L 9-12	Soil temperature (°C)		
			5 cm	10 cm	20 cm
17 Dec -23 Dec	51	4.392	12.714	15.571	18.886
24 Dec -31 Dec	52	5.166	13.913	17.088	19.388
1 Jan.-7 Jan.	1	7.987	15.243	16.914	19.357
8 Jan.-14 Jan.	2	11.327	13.714	15.771	18.486
15 Jan.-21 Jan.	3	13.892	12.586	15.114	17.543
22 Jan.-28 Jan.	4	23.734	12.200	15.243	17.929
29 Jan.-4 Feb.	5	28.491	13.129	15.600	18.600
5 Feb -11 Feb.	6	35.373	14.357	16.886	19.414
12 Feb -18 Feb	7	47.496	15.029	17.729	20.086
19 Feb -25 Feb	8	49.169	14.829	18.686	21.529
26 Feb-4 March	9	50.025	16.457	20.029	22.786
Coefficient of correlation (r)			0.568	0.700*	0.702*
Test of significance (t)			2.070	2.941	2.957

* Significant at 5% level of significance, respectively

Table 3: Regression equation of soil temperature at different depth levels with incidence of wilt in L 9-12 lentil genotype

Soil temperature depth levels	Regression equation
5 cm	$y = 0.0412x + 12.977$
10 cm	$y = 0.0603x + 15.265$
20 cm	$y = 0.06x + 17.943$

Wilt susceptible L 9-12 lentil genotype did not show significant correlation at 5 cm soil depth the observed correlation coefficient (r) was 0.568 the regression equation of L 9-12 lentil genotype showed that wilt incidence of lentil

increased by 0.0412% with the increase of 1 °C of the soil temperature at 5 cm depth. (Fig.1).

Soil temperatures at 10 cm and 20 cm depths of soil were found to have significant positive correlation (at 5% level of significance) with lentil wilt, the observed correlation coefficient (r) 0.700 and 0.702 with wilt incidence in L 9-12 lentil genotype, respectively (Table 5). The regression equation showed that wilt incidence of lentil increased by 0.603% and 0.06% with the increase of 1 °C of the soil temperature at 10 cm and 20 cm depth. (Fig. 2 and 3).

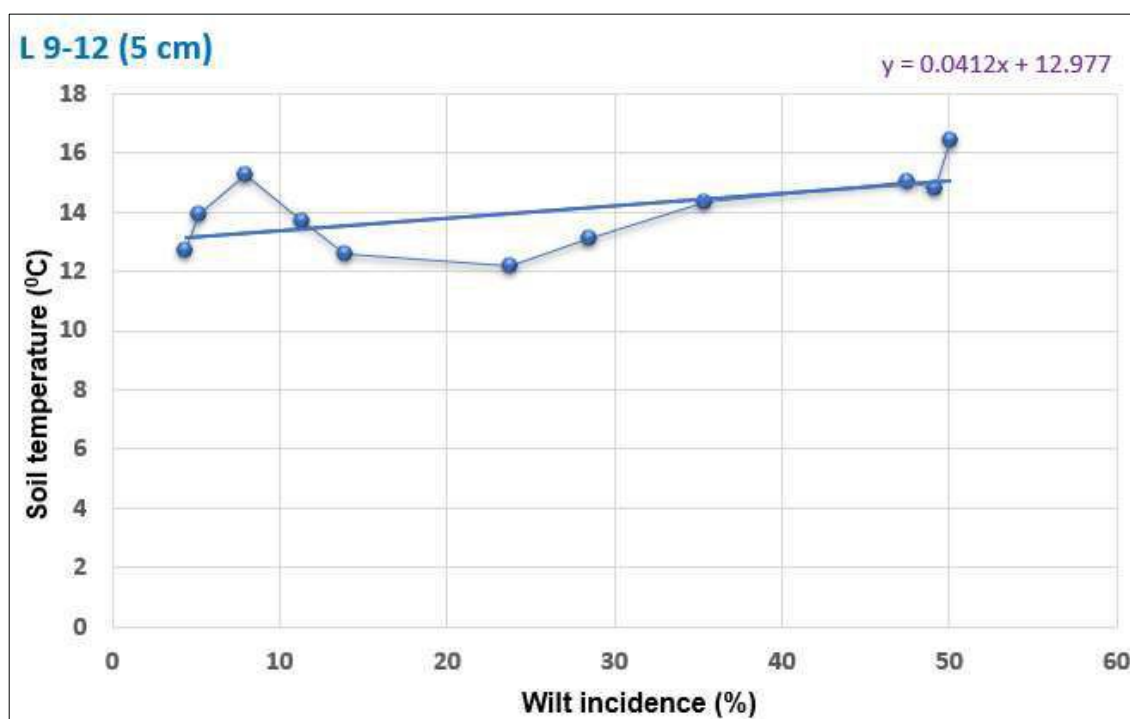


Fig 1: Regression line between wilt incidence in L 9-12 lentil genotype and soil temperature at 5 cm depth

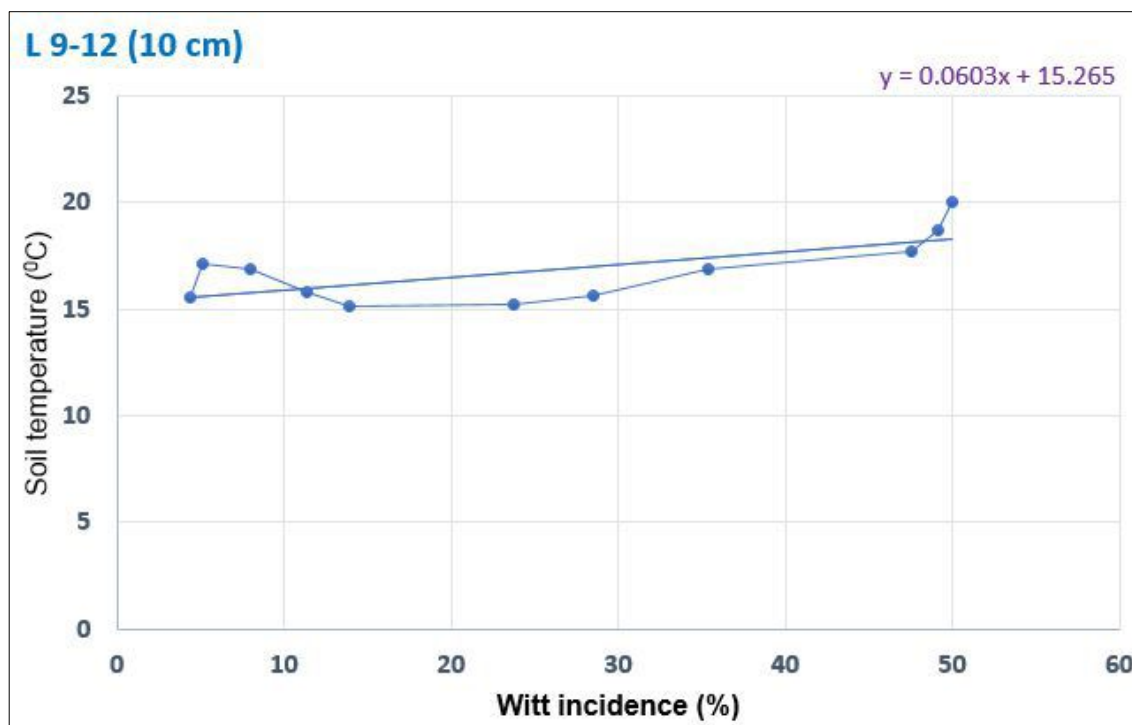


Fig 2: Regression line between wilt incidence in L 9-12 lentil genotype and soil temperature at 10 cm depth

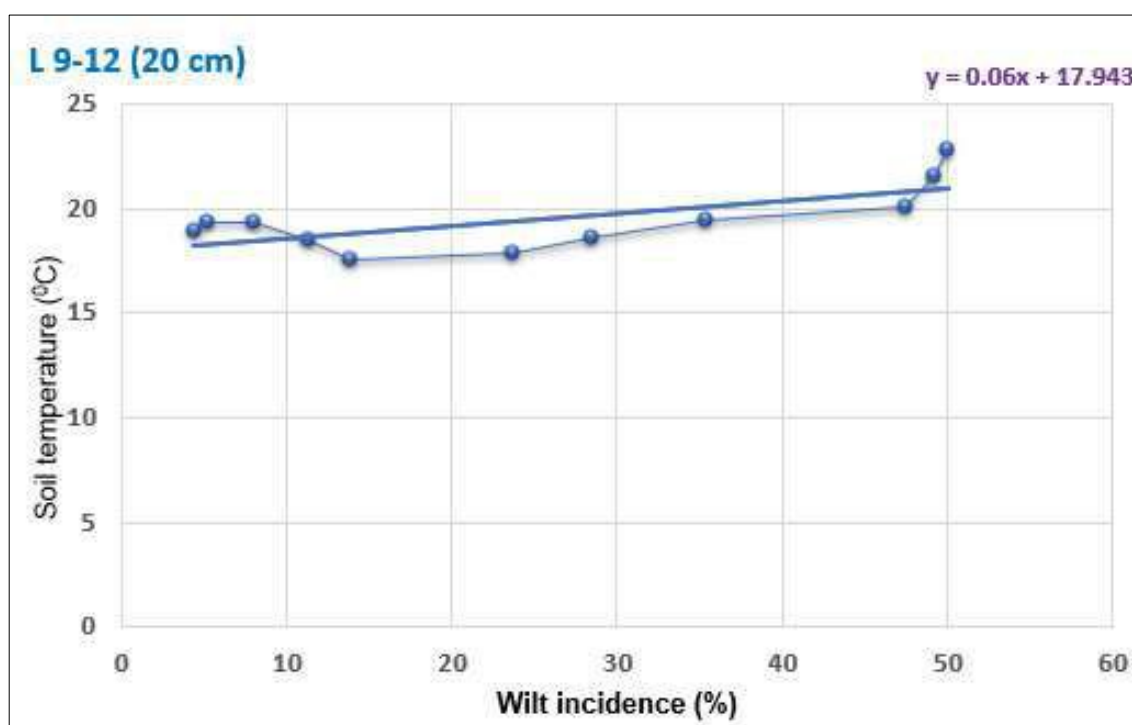


Fig 3: Regression line between wilt incidence in L 9-12 lentil genotype and soil temperature at 20 cm depth

Soil temperature and incidence of wilt in Sehore 74-3 lentil cultivar

Wilt incidence in Sehore 74-3 lentil genotype was studied in relation to soil temperature at different depths. The wilt incidence and temperatures were recorded every week and correlated. Correlation coefficient (r) and statistic was computed at each depth level i.e. 5 cm, 10 cm and 20 cm is given in (Table 4). To quantify the effect of soil temperature depth levels the linear regression equation was also worked out (Table 5).

The Sehore 74-3 lentil genotype did not show significant correlation at 5 cm depth of soil, the observed correlation

coefficient (r) was 0.558. The regression equation of Sehore 74-3 genotype showed that wilt incidence of lentil increased by 0.0517% with the increase of 1°C of the soil temperature at 5 cm depth. (Fig. 4).

Temperatures at 10 cm and 20 cm depth of soil had significant positive correlation (at 5% level of significance) with lentil wilt, the observed correlation coefficient (r) 0.691 and 0.692. The regression equation of Sehore 74-3 lentil genotype showed that wilt incidence of lentil increased by 0.0661% and 0.0755% with the increase of 1°C of the soil temperature at 10 cm and 20 cm depth. (Fig. 5 and 6).

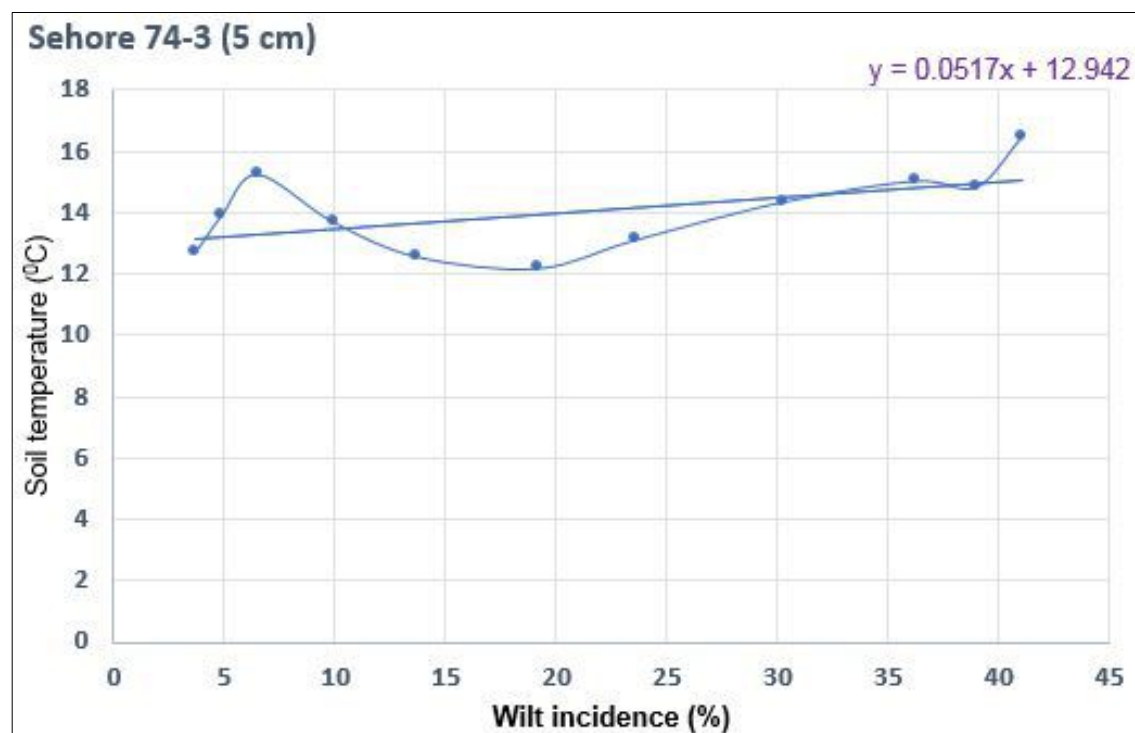
Table 4: Correlation coefficient (r) values between incidence of wilt in Sehore 74-3 lentil genotype and soil temperature at different depth levels

Week Interval	Standard week	Wilt incidence (%) Sehore 74-3	Soil temperature (°C)		
			5 cm	10 cm	20 cm
17 Dec -23 Dec	51	3.72	12.714	15.571	18.886
24 Dec -31 Dec	52	4.91	13.913	17.088	19.388
1 Jan.-7 Jan.	1	6.52	15.243	16.914	19.357
8 Jan.-14 Jan.	2	9.93	13.714	15.771	18.486
15 Jan.-21 Jan.	3	13.72	12.586	15.114	17.543
22 Jan.-28 Jan.	4	19.16	12.200	15.243	17.929
29 Jan.-4 Feb.	5	23.63	13.129	15.600	18.600
5 Feb -11 Feb.	6	30.32	14.357	16.886	19.414
12 Feb -18 Feb	7	36.31	15.029	17.729	20.086
19 Feb -25 Feb	8	38.99	14.829	18.686	21.529
26 Feb-4 March	9	41.08	16.457	20.029	22.786
Coefficient of correlation (r)			0.558	0.691*	0.692*
Test of significance (t)			2.017	2.868	2.876

* Denotes significant at 5% level of significance, respectively

Table 5: Regression equation of soil temperature different depth levels with incidence of wilt in Sehore 74-3 lentil genotype

Soil temperature depth levels	Regression equation
5 cm	$y = 0.0517x + 12.942$
10 cm	$y = 0.0661x + 15.471$
20 cm	$y = 0.0755x + 17.888$

**Fig 4:** Regression line between wilt incidence in Sehore74-3 lentil genotype and soil temperature at 5 cm depth

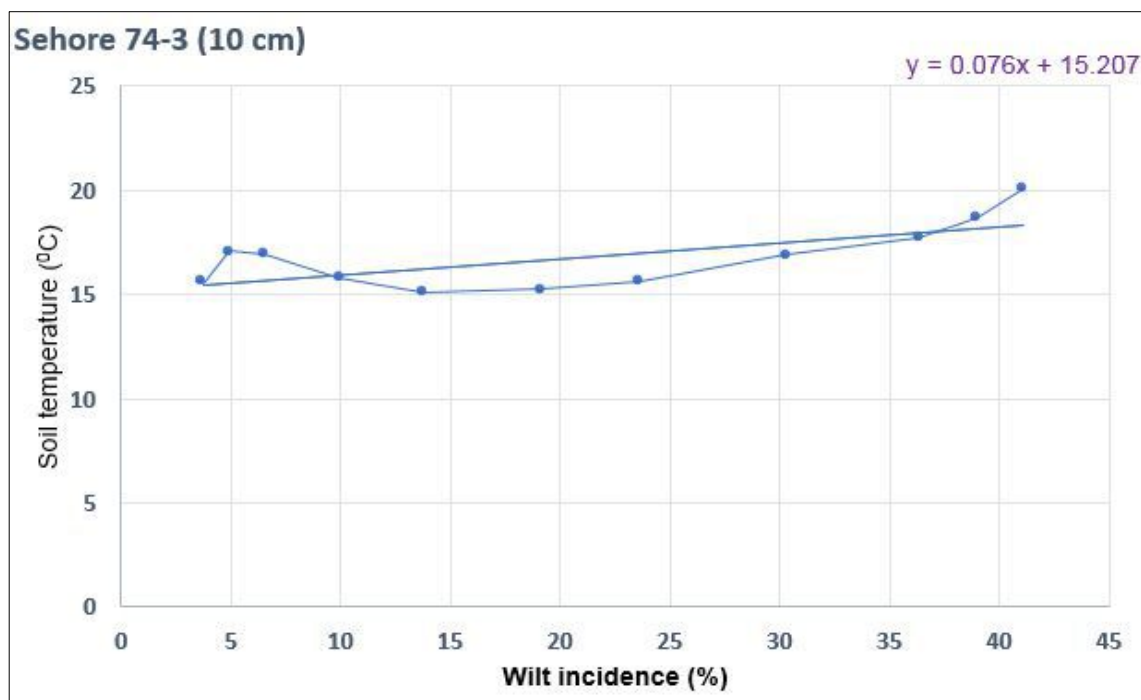


Fig 5: Regression line between wilt incidence in Sehore74-3 lentil genotype and soil temperature at 10 cm depth

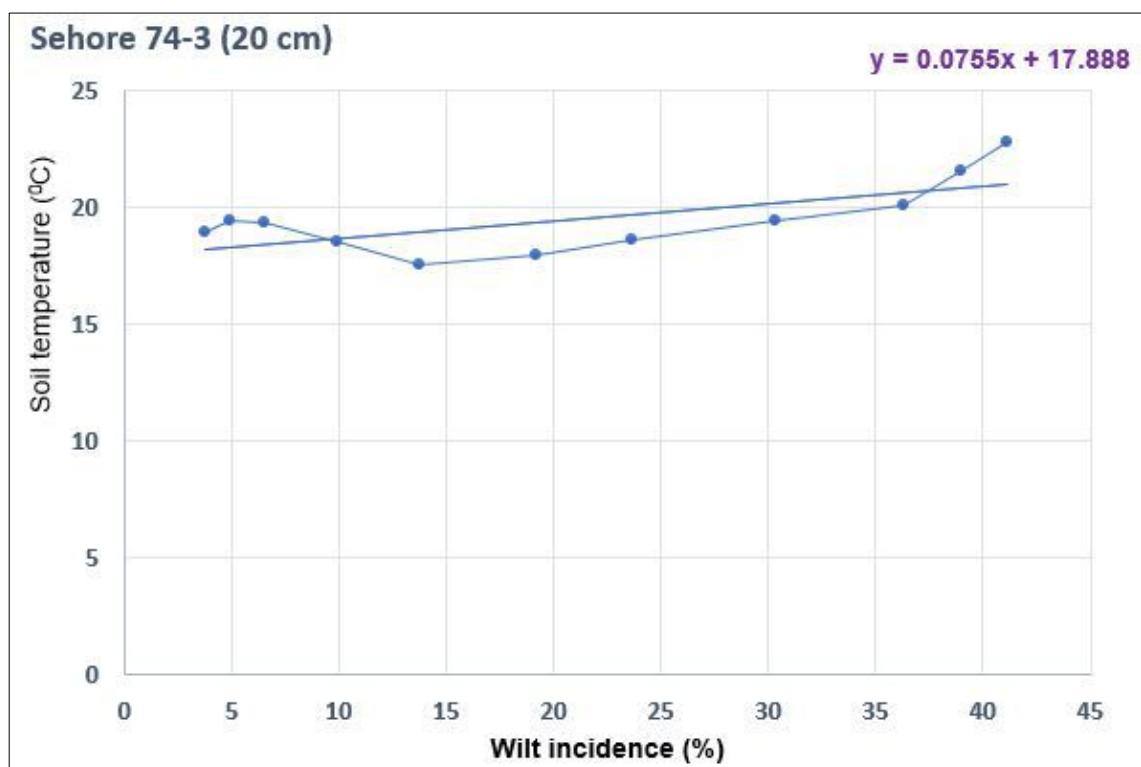


Fig 6: Regression line between wilt incidence in Sehore74-3 lentil genotype and soil temperature at 20 cm depth

Soil temperature and incidence of wilt in DPL-62 lentil cultivar: Wilt incidence on DPL-62 lentil genotype was studied in relation to soil temperature at different depths. The wilt incidence and temperatures were recorded every week and correlated. Correlation coefficient (r) and statistic was computed at each depth level i.e. 5 cm, 10 cm and 20 cm (Table 6). To quantify the effect of soil temperature at different depth levels the linear regression equation was also worked out (Table 10).

The DPL-62 lentil genotype was found to have a significant positive correlation (at 5% level of significance) at 5 cm depth of soil, the observed correlation coefficient (r) was

0.672). The regression equation of DPL-62 genotype showed that wilt incidence of lentil increased by 0.0759% with the increase of 1°C of the soil temperature at 5 cm depth. (Fig. 7). Temperatures at 10 cm and 20 cm depth of soil was found to have significant positive correlation (at 1% level of significance) with lentil wilt, the observed correlation coefficient (r) 0.781 and 0.770. The regression equation of DPL-62 genotype showed that wilt incidence of lentil increased by 0.01047% and 0.1024% with the increase of 1 °C of soil temperature at 10 cm and 20 cm depth. (Fig. 8 and 9).

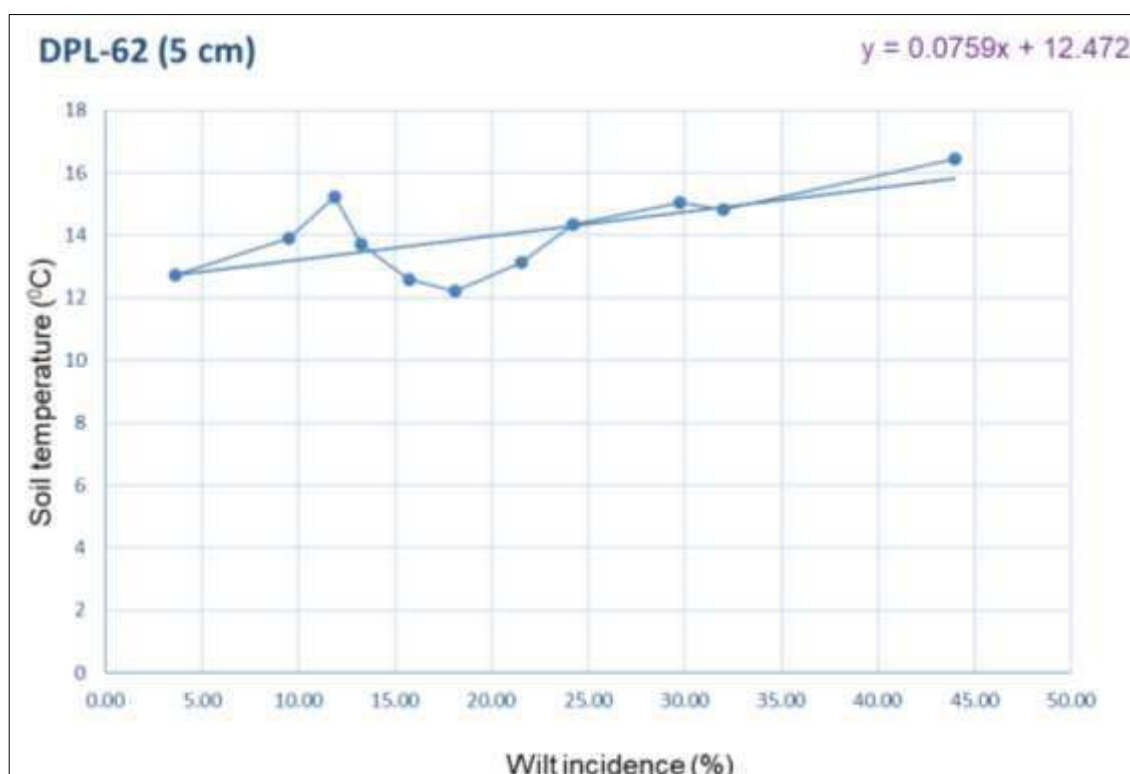
Table 6: Correlation coefficient (r) values between incidence of wilt in DPL-62 lentil genotype and soil temperature at different depth levels

Week Interval	Standard week	Wilt incidence (%) DPL-62	Soil temperature (°C)		
			5 cm	10 cm	20 cm
17 Dec -23 Dec	51	3.60	12.714	15.571	18.886
24 Dec -31 Dec	52	9.49	13.913	17.088	19.388
1 Jan.-7 Jan.	1	11.88	15.243	16.914	19.357
8 Jan.-14 Jan.	2	13.27	13.714	15.771	18.486
15 Jan.-21 Jan.	3	15.73	12.586	15.114	17.543
22 Jan.-28 Jan.	4	18.14	12.200	15.243	17.929
29 Jan.-4 Feb.	5	21.57	13.129	15.600	18.600
5 Feb -11 Feb.	6	24.22	14.357	16.886	19.414
12 Feb -18 Feb	7	29.72	15.029	17.729	20.086
19 Feb -25 Feb	8	32.01	14.829	18.686	21.529
26 Feb-4 March	9	44.01	16.457	20.029	22.786
Coefficient of correlation (r)			0.672*	0.781**	0.770**
Test of significance (t)			2.722	3.752	3.620

** And * significant at 1% level and 5% level of significance, respectively

Table 7: Regression equation of soil temperature different depth levels with incidence of wilt in DPL-62 lentil genotype

Soil temperature depth levels	Regression equation
5cm	$y = 0.0759x + 12.472$
10cm	$y = 0.1047x + 14.657$
20cm	$y = 0.1024x + 17.373$

**Fig 7:** Regression line between wilt incidence in DPL-62 lentil genotype and soil temperature at 5 cm depth

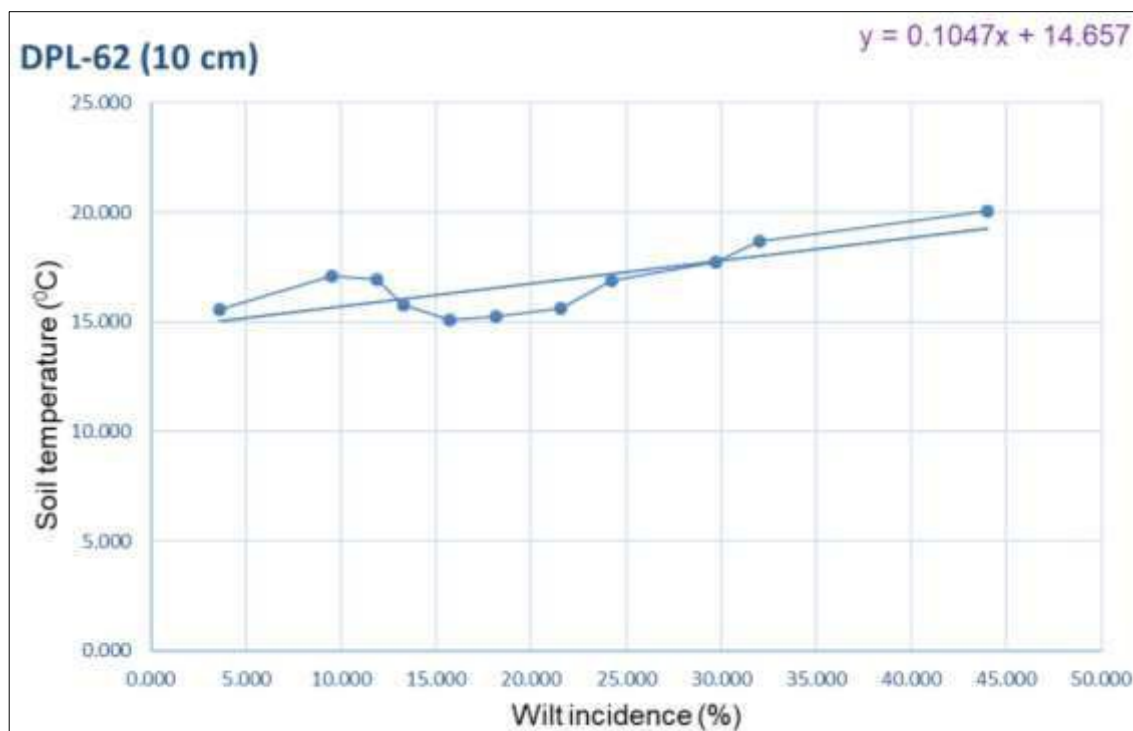


Fig 8: Regression line between wilt incidence in DPL-62 lentil genotype and soil temperature at 10 cm depth

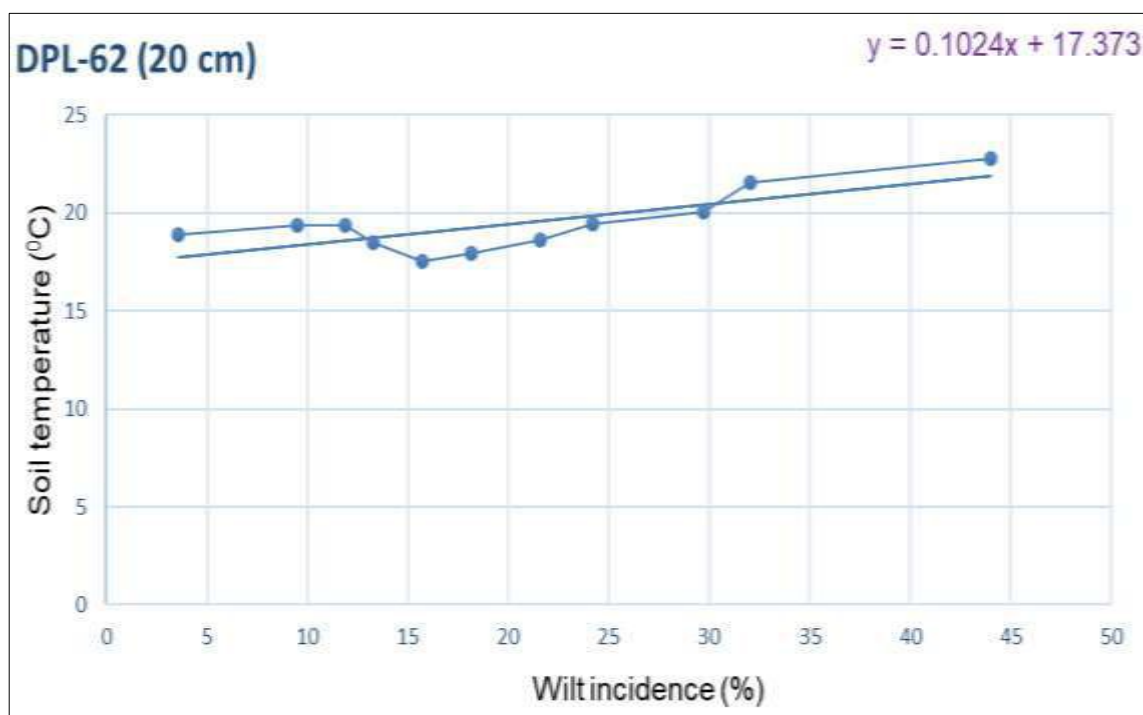


Fig 9: Regression line between wilt incidence in DPL-62 lentil genotype and soil temperature at 20 cm depth

Conclusion

- L 9-12 lentil genotype was studied in relation to soil temperature at different depths. Soil temperature at 5 cm depth did not show significant correlation with wilt incidence while soil temperature at 10 cm and 20 cm depths of soil had significant positive correlation with wilt incidence.
- Sehore 74-3 lentil genotype was studied in relation to soil temperature at different depths. Soil temperature at 5 cm depth did not show significant correlation with wilt incidence while soil temperature at 10 cm and 20

cm depths of soil had significant positive correlation with wilt incidence.

DPL-62 lentil genotype was studied in relation to soil temperature at different depths. Temperature at all the three soil depths viz. 5 cm 10 cm and 20 cm had significant positive correlation with wilt incidence.

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