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Management of *Uromyces viciae–fabae* (Pers.) J. Schrot. in *Pisum sativum* L. through alteration in sowing time

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Abstract
Present study was conducted for crop seasons 2013-2014 and 2014-2015 to know the effect of alteration in date of sowing on rust severity and grain yield in field pea. The results of investigation indicate that, early sown crop in 31st October, 7th November and 14th November face lower disease severity (8.67-17.50 percent) with low area under disease progress value (81-198.67) and produce good yield (690.90-775.39 kg/ha) and test weight (162.34-175.34 g) whereas crop sown in 21st November, 28th November, 5th December and 12th December succumb to high disease severity (40-54.17 percent) showing high area under disease progress value (383.50-549.17) with low yield (429.06-581.95 kg/ha) and test weight (146.67-153.73 g). When disease severity at most susceptible stage (110DAS) in different sowing dates were correlated with weather factors, it was found that maximum and minimum temperature were significantly positively correlated whereas relative humidity, rainfall and wind velocity showed negative correlation.

Keywords: Apparent rate of infection, Area Under Disease Progress Curve (AUDPC), Correlation coefficient, disease severity, test weight

Introduction

India accounts for over one third of the total world area and over 20 per cent of total world pulse production. India is the largest producer, consumer and importer of pulses in the world. In India pulses are grown about 24-26 million hectares of area producing 17-19 million tonnes of pulses annually. Consequently per capita production and availability of pulses in the country has witnessed sharp decline. Per capita net pulse availability has declined from around 60 grams per day in the 1950s to 40 grams in the 1980s and further to around 35 grams per day in 2000s. However, in the past four years, there has been significant
increase in consumption averaging around 50 grams due to higher production, under owing to National Food Security Mission (NFSM), with major emphasis on pulses and their imports, mostly of dry peas from Canada and Australia (IIPR, 2014) [8].

Major pulses grown in India include chickpea or bengal gram (*Cicerarietinum*), pigeonpea or red gram (*Cajanuscajan*), lentil (*Lens culinaris*), urdbean or black gram (*Vignamungo*), mungbean or green gram (*Vignaradiata*), lablab bean (*Lablab purpureus*), moth bean (*Vignaaconitifolia*), horse gram (*Dolichosuniflorus*), pea (*Pisumsativum* L.), grass pea or khesari (*Lathyrussativus*), cowpea (*Vignaunguiculata*), and broad bean or faba bean (*Viciafaba*).

During 2012-13, field pea (*Pisumsativum* L.) occupies an area of 0.76 million hectares with a production 0.84 million tonnes and productivity of 1100 kg/ha in our country. In Uttarakhand, area, production and productivity of pea during 2012-13 was 61.0 thousand hectares, 51.3 thousand tones and 841 kg/ha, respectively (NCAER, 2014) [16]. Pea is affected by a number of fungal (rust, powdery mildew, downy mildew, root rot, alternaria blight, aschochyta blight, wilt, anthracnose, cercospora leaf spot, damping off, seedling rot etc.), bacterial (bacterial blight and brown spot), nematode (cyst nematode, lesion nematode and root-knot nematode) and viral diseases (cucumber mosaic virus, pea early browning virus, pea enation mosaic, pea mosaic, pea seed borne mosaic, pea streak and pea stunt). These diseases, under the right conditions, can significantly decrease both yield and quality.Among these, the rust of pea caused by *Uromycesviciae–fabae* (Pers.) J. Schrot (syn. *Uromyces fabae* (Pers.) de Bary) is considered the most important under warm and humid conditions (Chand *et al*. 2004) [3].

It has been reported from different parts of the country including eastern India (Gupta, 1990; Chand *et al*. 1997) [7, 4], central India (Narsinghani *et al*. 1980) [15], southern parts of India (Sokhi *et al*. 1974; Kumar *et al*. 1994) [22, 10] and from Himalayan region of Uttarakhand and Himachal Pradesh (Chauhan *et al*. 1991; Sharma, 1998) [5, 18]. In the last few years, disease has been observed in almost epiphytotic form and could cause up to 20-100% losses in yield (Stavely, 1991; Sharma, 1998) [23, 18].

Using principle of avoidance through alteration in date of sowing can be an effective way for the management of rust disease in field pea but the yield parameters should be taken into consideration. Therefore, studies on effect of alteration in sowing dates on severity of rust should be carried out in order to find out the appropriate sowing time of pea when crop suffers from least rust severity.

Materials and Methods

The field trials were conducted during *Rabi* 2013-2014 and 2014-2015 crop seasons, in Randomized Block Design (RBD) with three replications. The size of each plot was 3.0 x 2.0 m^2. Row to row distance was maintained at 30cm. Cultivar 'HFP-4' highly susceptible to rust was sown at seven different dates from October 31 to December 12 at weekly interval. One quintal diammonium phosphate (DAP) per hectare was applied before sowing. One litre of dimethoate 30 EC in 750 L of water per hectare was sprayed twice on the crop at 15 days interval to prevent the crop damage from leaf miner and pod borer and other foliage and stem feeding insects.

Observation on severity of rust was recorded at ten days interval starting from first appearance of the disease till the maturity of crop using 0-9 rating scale (Mayee and Datar, 1986) [13] for each sowing dates. Grain yield (kg/ha) and test weight of seeds (1000 seeds) from each plot was estimated. Thereafter, the rust severity on different treatment at 110 DAS was correlated with the weather parameters using Karl Pearson's correlation coefficient.

The following parameters were calculated in the studies:

(i) AUDPC (A) value: Rust severity was quantified using the formula given by Wilcoxson *et al.*1975.

$$A = \sum_{i=1}^{k} \tfrac{1}{2} (S_i + S_{i-1})\, d$$

Where S_i = Disease incidence at the end of the week i, k = Number of successive evaluations of disease, and d = Interval between two evaluations.

(ii) Apparent rate of infection ('r'): The apparent rate of infection was calculated using Vanderplank (1968) formula:

$$r = \frac{2.303 \log}{t_2 - t_1} \quad \frac{x_2 (1-x_1)}{x_1(1-x_2)}$$

where, r is the apparent infection rate in non-logarithmic phase, x_1 is the disease index at initial week time (t_1), x_2 is the disease index at subsequent week time (t_2)

(iii) Observation on yield components:

(a) 1000-grain weight (g): One thousand grains were counted from each plot and weight (g) was recorded with the help of monophan digital electronic balance.

(b) Grain yield (kg/ha): Naturally dried plants from the individual plot were harvested, air dried, threshed and cleaned. The cleaned grains were dried upto 10 per cent moisture by weight. The grain yield per plot was recorded in gram, and converted into Kg/ha.

Correlation coefficients of AUDPC with test weight and yield was also estimated using Karl Pearson's correlation coefficient (r).

The weather parameters *viz.*, temperature (Maximum and minimum), relative humidity (Morning and afternoon) and total rainfall were correlated with per cent disease severity by calculating the

(iv) Karl Pearson's correlation coefficient (r)

$$r = \frac{1}{n-1} \sum \frac{(x_i - \overline{X})(y_i - \overline{Y})}{s_x s_y}$$

Where, r = coefficient of correlation, X= $x_i - \bar{X}$, Y= yi $-\bar{Y}$,,S_x= standard deviation of x series, S_y= standard deviation of y series, n= number of series.

Partial regression equations were calculated for the meteorological factors as independent variable with the prediction equation.

(v) Prediction equation: $Y = b_0 + b_1X_1 + b_2X_2 \ldots\ldots\ldots b_7X_7$.

Where, Y= Percent disease severity, b_0 = constant; b1, b2…..b_7 = regression coefficients and X_1, X2….X_7 = Independent weather variables.

Results and Discussion

The disease progress was studied at ten days interval. The data recorded on effect of sowing dates on rust severity, 'A' value, 'R' value, test weight and total yield are presented here under (Table 1.).

Disease severity (%): Average data of two years revealed that maximum per cent disease severity (54.17) was recorded in crop sown on 12th December followed by crop sown on 5th December (53.34), 28th November (53.33), 21st November (40.00), 14th November (17.50), 7th November (11.83). The lowest per cent disease severity (8.67) was recorded in earliest sown crop on 31st October.

AUDPC ('A' value) and apparent rate of infection ('r' value): AUDPC was found utmost on 12th December sown crop (549.17) with rate of infection of 0.087 followed by crop sown on 28th November (499.17) with 0.079 rate of infection, 5th December (457.33) with 0.090 rate of infection, 21st November (383.50) with infection rate of 0.078, 14th November (198.67) with infection rate of 0.044, 7th November (112.50) with rate of infection of 0.052. The lowest AUDPC (81.00) was recorded in earliest sown crop on 31st October with infection rate of 0.077.

Test weight (g): Test weight was found maximum on 7th November sown crop (175.34) followed by crop sown on 31st October (173.50), 14th November (162.34), 28th November (155.67), 21st November (153.73), 5th December (146.67). The lowest test weight (149.67) was recorded in on 12th December.

Total yield (kg/ha): Total yield was highest on 7th November sown crop (776.39) followed by crop sown on 31st October

(741.67), 14th November (690.90), 21st November (581.95), 28 November (484.72), 5th December (480.84). The least total yield (429.06) was recorded in latest sown crop on 12th December.

Correlation studies of AUDPC with test weight and total yield over two years showed that AUDPC value are significantly negatively correlated with test weight (-0.92**) and total yield (-0.98**) (Table 2.).

Progress of disease severity on pea sown at different dates: Studies on progress of disease severity during both the years revealed that appearance of disease was first observed 70 days after sowing (DAS). Highest per cent disease severity was seen on 28th November (4.67) sown crop at 70DAS followed by 12th December and 14th November (3.50), 5th December (3.00), 21st November (2.83), 7th November (1.67). The lowest per cent disease severity (0.43) was recorded in earliest sown crop on 31st October. Disease progressed slowly during both the years in all the treatments till 90 DAS. Rapid increase in per cent disease severity was found at 100DAS and 110DAS on crop sown at 21st November (25.00, 40.00), 28th November (31.67, 53.33), 5th December (27.50, 53.33) and 12th December (30.83, 54.17) whereas crop sown on 31st October (4.83, 8.67), 7th November (76.17, 11.83) and 14th November (12.83, 17.50) showed slow progress of disease throughout the period (Table.3).

Correlation of weather factors with different sowing dates on rust disease of pea

Correlation of weather parameters with different sowing dates at 110 DAS on rust disease of pea during both the year revealed that that the per cent disease severity was having a positive correlation with maximum temperature (0.921) and minimum temperature (0.834). Whereas disease severity show negative correlation with morning (-0.940) and afternoon relative humidity (-0.859), rainfall (-0.807) and wind velocity (-0.368) (Table 4 and Table 5).

The multiple linear regression equation after step down elimination for disease severity was, $Y= -1666.911+21.578X_1 -0.412X_2 +9.679X_3 +6.107X_4 -3.898 X_5$ indicating an unit increase in maximum temperature, relative humidity (morning) and relative humidity (afternoon), enhance the disease severity by 21.578, 9.679 and 6.107 units. Whereas every unit increase in minimum temperature and rainfall will decrease the severity of disease by 0.412 and 3.898 units (Table 5).

The results of present investigation clearly show that, early sown crop in 31st October, 7th November and 14th November face lower disease pressure and produce good yield and test weight whereas crop sown in 21st November, 28th November, 5th December and 12th December succumb to high disease pressure with low yield and test weight. When disease severity at most susceptible stage (110DAS) in different sowing dates were correlated with weather factors, it was found that maximum and minimum temperature were significantly positively correlated whereas relative humidity (morning and afternoon), rainfall and wind velocity showed negative correlation. Our results are in agreement with findings of Singh *et al*. (1996) [21] where he mentioned that incidence of rust (*Uromyces viciae-fabae*) increase with delay in sowing. Mittal (1997) [14] also stated that pea sown on 19 October is most effective in reducing the rust disease and increasing yield of lentil. Similar finding were reported earlier by Sangar and Singh (1994) [17] and Bhardwaj and Sharma (1996) [2] that delay in sowing after 5th October increased the incidence of *Uromycesviciae-fabae* and decreased grain yield. Marcellos *et al*. (1995) [12] estimated that rust disease accounted for yield loss mainly by reducing the seed size and weight. Singh *et al*. (2012) [20] found least rust severity when pea was planted on October 15. He mentioned that crop when sown lately i.e. sown on November 14, November 29 and December 13 record highest severity of rust. He recorded highest grain yield from November 14 (mid) sown crop whereas lowest grain yield was found in December 13 (late) sown crops. He also observed significant and positive correlation between rust severity and temperature. However, disease severity has a strong negative correlation with relative humidity. Similarly, Singh *et al*. (2014) [19] recorded the highest disease severity and minimum grain yield on 13th December planting. There is significant positive correlation between the disease severity and the maximum and minimum temperatures (Bal and Kumar, 2012) [1]. Stavely (1991) [23] stated that moist weather with a temperature of 15-24^{0}C increased the severity of pea rust. Kushwaha *et al*. (2006) [11] reported the germination of aeciospores of pea rust favoured by a temperature in the range of 10-25^{0}C. Joshi and Tripathi (2012) [9] observed that a temperature of 20^{0}C is optimum for the germination of aeciospores, uredospores and teliospores of rust disease of lentil and thereby augment the rust severity of lentil.

The above knowledge of principle of avoidance through alteration in date of sowing can be an effective way to disturb the interaction of three important factors namely host, pathogen and environment important for disease development and thus can be utilized as important cultural practice that can be fruitfully integrated with other principles of management for the control of rust disease in field pea.

Table 1: Effect of alteration in sowing dates on rust disease of pea during crop season 2013 and 2014 (pooled).

Sowing dates	*Disease severity (%)*			*'A' value*			*'r' value*			*Test weight (1000 seeds)*			*Yield (kg/ha)*		
	2013	**2014**	**pooled**	**2013**	**2014**	**pooled**	**2013**	**2014**	**pooled**	**2013**	**2014**	**pooled**	**2013**	**2014**	**pooled**
31-Oct	12.33a (20.49)	5.00a (12.92)	8.67a (17.09)	108.33	53.67	81.00	0.076	0.116	0.077	170.67c	176.33d	173.50d	734.72d	748.61e	741.67e
07-Nov	15.33ab (23.00)	8.33ab (16.59)	11.83ab (20.04)	141.67	83.33	112.50	0.051	0.055	0.052	172.67c	178.00d	175.34d	773.61e	779.17f	776.39f
14-Nov	21.67b (27.71)	13.33b (21.33)	17.50b (24.69)	232.67	164.67	198.67	0.050	0.037	0.044	158.00b	166.67c	162.34c	715.56d	666.23d	690.90d
21-Nov	36.66c (37.25)	43.33c (39.21)	40.00c (38.24)	385.00	382.00	383.50	0.064	0.101	0.078	143.46a	164.00bc	153.73bc	576.39c	587.51c	581.95c
28-Nov	48.33d (44.04)	58.33c (49.80)	53.33d (48.35)	459.67	538.67	499.17	0.074	0.084	0.079	148.00a	163.33bc	155.67bc	487.50b	481.94b	484.72b
05-Dec	46.67d (43.08)	60.00c (50.78)	53.34d (47.39)	414.00	500.67	457.33	0.086	0.094	0.090	150.00ab	143.33a	146.67a	496.39b	465.28b	480.84b

12-Dec	53.33d (46.92)	55.00c (47.87)	54.17d (45.47)	520.67	577.67	549.17	0.081	0.095	0.087	142.67a	156.67b	149.67b	423.61a	434.51a	429.06a
CD at 5%	4.59**	4.49**	1.19**							8.49**	7.78**	6.58**	30.02**	23.98**	19.37**
SEM±	1.49	3.69	3.69							2.75	2.52	2.13	9.74	7.90	6.28
CV	7.45	6.02	6.02							3.07	2.66	2.32	2.80	2.30	1.82

Value in parenthesis are angular transformed, 'A'- Area under disease progress curve (AUDPC), 'r' Apparent rate of infection, **Significant level at 0.01.Data with the same letter, per row, are not significantly different (Duncan, P < 0.05).

Table 2: Correlation coefficients of AUDPC of rust with test weight and yield of pea sown at different dates.

Correlation coefficients (r)			
	AUDPC		
	2013	**2014**	**2013 and 2014 (pooled)**
Test weight	-0.94**	-0.80**	-0.92**
Yield	-0.97**	-0.98**	-0.98**

AUDPC - Area under disease progress curve, ** Correlation is significant at 0.01 level (2-tailed).

Table 3: Progress of rust severity on pea sown at different dates during 2013-2014 and 2014-2015 (pooled data).

	Disease severity (%)				
Sowing dates	**70DAS**	**80DAS**	**90DAS**	**100DAS**	**110DAS**
31-Oct	0.43	1.08	3.33	4.83	8.67
07-Nov	1.67	3.00	4.33	6.17	11.83
14-Nov	3.50	6.17	9.17	12.83	17.50
21-Nov	2.83	7.33	12.17	25.00	40.00
28-Nov	4.67	10.67	18.00	31.67	53.33
05-Dec	3.00	7.67	13.17	27.50	53.33
12-Dec	3.50	9.50	15.67	30.83	54.17
CD at 5%	*a= 1.03***	*b= 1.22***	*a*b= 2.73***		
SEM±	*a= 0.36*	*b= 0.43*	*a*b= 0.97*		
CV	*8.63*				

DAS- Days after sowing, a= Time interval, b= Different sowing dates, ** Significant level at 0.01

Table 4: Correlation of weather factors with different sowing dates on rust disease of pea during 2013 and 2014 (pooled).

Sowing dates	***Disease severity at 110 DAS (%)***	***Temperature (^{0}C)***		***Relative Humidity (RH)***		***Rainfall (mm)***	***Wind speed (km/hr)***
		Maximum	**Minimum**	**Morning**	**Afternoon**		
31-Oct	8.67	21.85	7.97	92.05	54.75	4.66	5.32
07-Nov	11.83	22.34	9.74	91.35	54.09	3.58	5.58
14-Nov	17.50	23.94	12.49	90.35	53.85	7.84	5.36
28-Nov	53.33	26.83	12.70	88.35	47.90	0.72	4.80
05-Dec	53.33	28.60	14.29	86.30	44.70	0.00	4.45
12-Dec	54.17	30.83	15.94	86.00	38.70	1.46	5.81

DAS- Days after sowing

Table 5: Correlation coefficients of rust severity with weather parameters in different sowing dates of pea during 2013 and 2014 (pooled data)

	Maximum Temperature (^{0}C)	**Minimum Temperature (^{0}C)**	**Morning RH (%)**	**Afternoon RH (%)**	**Rainfall**	**Wind velocity (km/hr)**
Percent rust severity	0.921**	0.834*	-0.940**	-0.859*	-0.807*	-0.368

Dependent Parameter	Multiple regression equation
Percent rust severity (Y)	$-1666.911+21.578X_1 -0.412X_2 +9.679X_3 +6.107X_4 -3.898 X_5$

** Correlation is significant at 0.01 level (2-tailed), * Correlation is significant at 0.05 level (2-tailed), X_1= Maximum temperature; X_2= Minimum temperature; X_3= Morning RH; X_4= Afternoon RH, X_5= Rainfall

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