International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(2): 3085-3090

Received: 19-01-2018
Accepted: 20-02-2018

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Evaluation of potential fungicides for the management of pea rust under field condition

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Abstract
Diseases are major constraints to pea production in the developing countries. Among various diseases, the rust caused by *Uromyces viciae–fabae* (Pers.) J. Schrot is considered as one of the most important diseases of field pea. It is responsible for substantial losses in terms of both quality and quantity parameters of grain. This reinforces the need to exploit several management strategies including chemical control. Therefore, present investigation was carried out to examine the efficacy of total of sixteen chemicals fungicides alone and/or in combination against rust disease of pea during 2012-2013 and 2013-2014. The results of the study revealed that all the sixteen fungicides were found effective for the management of disease as compare to control (water spray). However tebuconazole, carbendazim + tebuconazole, Mancozeb + tebuconazole, carbendazim + flusilazole, penflufen + trifloxystrobin were found equally and very effective among all. These fungicides showed considerable reduction in rust severity (12.50-16.67%) and area under disease progress curve (AUDPC) value (195.83-291.67) with high total yield (86.72-76.30 kg/ha) and test weight (160.94-180.93 g) as compare to control which showed highest rust severity (54.17%) and AUDPC value (1058.33) with lowest total yield (405.30 kg/ha) and test weight (144.0g). Correlation of AUDPC values with test weight and total yield were found significantly negatively correlated whereas no correlation was found with apparent rate of infection.

Keywords: AUDPC, disease severity, fungicides, rust, test weight

Introduction
A large share of Indian population is vegetarian and pulses are the main source of protein for them. The protein content in pulses is about 18-25 Percent which makes pulses as one of the cheapest source of protein for human consumption (Rana and Sharma, 1993) [21]. India is the major 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. India accounts for over one third of the total world area and over 20 Percent of total world pulse production. Subsequently per capita production and availability of pulses in the country has witnessed sharp decline. Per capita net pulse availability has turned down 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 considerable increase in consumption averaging around 50 grams due to higher production, under owing to National Food Security Mission (NFSM), with major importance on pulses and their imports, mostly of dry peas from Canada and Australia (IIPR, 2014) [12].

Major pulses grown in India includes chickpea or bengal gram (*Cicer arietinum*), pigeonpea or red gram (*Cajanus cajan*), urdbean or black gram (*Vigna mungo*), mungbean or green gram (*Vigna radiata*), lablab bean (*Lablab purpureus*), moth bean (*Vigna aconitifolia*), horse gram (*Dolichos uniflorus*), pea (*Pisum sativum* L.), lentil (*Lens culinaris*), grass pea or khesari (*Lathyrus sativus*), cowpea (*Vigna unguiculata*), and broad bean or faba bean (*Vicia faba*).

During 2012-13, field pea (*Pisum sativum* 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) [20].

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), viral (cucumber mosaic virus, pea early browning virus, pea enation mosaic, pea mosaic, pea seed borne mosaic, pea streak and pea stunt) and nematode diseases (cyst nematode, lesion nematode and root-knot nematode). These diseases, under the right conditions, can considerably decrease both yield and quality. Among these, the rust of pea caused by *Uromyces viciae–fabae* (Pers.) J. Schrot (syn. *Uromyces fabae* (Pers.) de Bary) is considered the most significant under warm and humid conditions (Chand, *et al.*, 2004) [2]. It has been reported from different parts of the country including eastern India (Gupta, 1990; Chand *et al.*, 1997) [10, 4], central India (Narsinghani *et al*., 1980) [19], Southern parts of India (Sokhi *et al.*, 1974; Kumar *et al*., 1994) [26, 14] and from Himalayan region of Uttarakhand and Himachal Pradesh (Chauhan *et al*., 1991; Sharma, 1998) [5, 23]. In the last few years, disease has been observed in more or less epiphytotic form and could cause up to 20-100% losses in yield (Stavely, 1991; Sharma, 1998) [27, 23].

Development of rust resistant variety is considered the most adequate control strategy, but, no complete levels of resistance are available in commercial cultivars which emphasize to integrate several control strategies including chemical control (Sillero *et al*., 2000, 2006) [24-25]. Earliest chemical employed for the management pea rust control was Bordeaux mixture (El-Helaly, 1950) [6]. Since then, a number of generations of fungicides are available and their efficiency against pea rust has not been properly tested yet. Thus, scrutinization for the best fungicides in management of pea rust under field condition should be carried out.

Materials and Methods

Present investigation was carried out during *Rabi* 2013-14 and 2014-2015 crop seasons in plot size of 3.0 x 2.0 m^2 in Randomized Block Design (RBD) at N.E. Borlogue Crop Research Centre (NEBCRC) of G.B. Pant University of Agriculture and Technology, Pantnagar. The sowing of highly susceptible cultivar 'HFP-4' was done with wider spacing of 30 x 10 cm in three replications. Total of sixteen different fungicides alone or in combination (Table 1.) were evaluated under field conditions. Crop was sprayed twice with each fungicide, at recommended doses. First spray was done at the appearance of symptoms (70 days after sowing) and second sprays after 15 days interval, respectively. Control plot were sprayed with same volume of water. Disease severity was recorded using using 0-9 rating scale (Mayee and Datar, 1986) [15] before the beginning of first spray and subsequent observations were recorded and final disease severity was recorded 15 days after second spray. The periodical data were also recorded on rust severity with the initiation of the disease at ten days interval. It was used to determine 'A' value and 'r' value for each treatment. At the end of the season, test weight of seeds (1000 seeds) and grain yield (kg/ha) from each plot was estimated and then converted into kg/ha. Correlation coefficients of AUDPC with test weight and yield was also estimated using Karl Pearson's correlation coefficient (r).

(i) AUDPC (A) value

Rust severity was quantified using the formula given by Wilcoxson *et al.* (1975) [30].

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

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) [29] 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) 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

(iv) 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 Percent moisture by weight. The grain yield per plot was recorded in gram, and converted into Kg/ha.

c) Percent increase in yield

$$\text{Percent increase in yield} = \frac{\text{Yield in treated plot (-) Yield in check plot}}{\text{Yield in check plot}} \times 100$$

Statistical analysis

The data was analyzed statistically by Randomized Block Design (RBD) with three replications. Data recorded were first transformed (angularly transformed) to make them homogenous before analysis and the treatment were compared by means of critical differences at 5% level of significance. Means were compared using Duncan's Multiple Range Test (DMRT) at $P \leq .05$, by SPSS 16.0.

Table 1: List of fungicides used alone and in combination for rust disease management in pea.

Treatments	Fungicides name (Trade name)	Recommended doses (Per litre of water)
	Alone	
T1.	Mancozeb (Dithane M-45)	3g
T2.	Carbendazim (Bavistin 50 WP)	2g
T3.	Propiconazole (Tilt 25 EC)	1ml
T4.	Tebuconazole (Folicur EC 250)	0.7ml
T5.	Trifloxystrobin (Flint 500 WG)	0.1g
	Combination	
T6.	Trifloxystrobin + Tebuconazole (Nativo 75 WG)	0.4g
T7.	Dithane M-45 + Trifloxystrobin	1.5g + 0.05g
T8.	Dithane M-45 + Propiconazole	1.5g + 1g
T9.	Dithane M-45 + Carbendazim	1.5g + 0.5ml
T10.	Carbendazim + Trifloxystrobin	1g + 0.05g
T11.	Carbendazim + Tebuconazole	1g + 0.35ml
T12.	Trifloxystrobin + Propiconazole	0.05g + 0.5ml
T13.	Dithane M-45 + Tebuconazole	1.5g + 0.35ml
T14.	Carbendazim + Propiconazole	1g + 0.5ml
T15.	Carbendazim + Flusilazole (Lustre 37.5 SE)	1.6ml
T16.	Penflufen+ Trifloxystrobin (Trilex Component A)	1ml
	Water (Control)	-

Results

A field experiment was conducted during 2013-2014 and 2014-2015 to see the effect of foliar sprays of total sixteen fungicides alone and in combination *viz.* Mancozeb (T1), carbendazim (T2), propiconazole (T3), tebuconazole (T4), trifloxystrobin (T5), Mancozeb + trifloxystrobin (T6), Mancozeb + propiconazole (T7), Mancozeb + carbendazim (T8), carbendazim + trifloxystrobin (T9), carbendazim + tebuconazole (T10), trifloxystrobin + propiconazole (T11), Mancozeb + tebuconazole (T12), carbendazim +propiconazole (T13), trifloxystrobin + tebuconazole (T14), carbendazim + flusilazole (T15), penflufen + trifloxystrobin (T16) on disease severity, AUDPC value, apparent rate of infection, test weight, total yield and percent increase in yield over control (Table 2).

Disease severity (%)

During both the years foliar spray with fungicides alone and/or in combination significantly reduced the rust severity in comparison to control (54.17). The data on efficacy of chemical fungicides revealed that the Percent rust severity was lowest in T10 (12.50) followed by T4 (13.17), T12 (13.33), T15 (15.00), T16 (16.67), T11 (25.00), T14 (30.00), T7 (30.83), T13 (31.67), T8 and T9 (32.50), T1 (34.17), T3 and T6 (35.00), T2 (38.33) and T5 (40.83).

AUDPC (‘A’ value) and apparent rate of infection (‘r’ value)

‘A’ value was found minimum in T10 (195.83) with infection rate of 0.080 followed by T4 (237.50) with 0.060 rate of infection, T16 (274.17) with ‘r’ value of 0.080, T15 (275.00) with infection rate of 0.057, T12 (291.67) with 0.049 rate of infection, T11 (495.00) with ‘r’ value of 0.058, T14 (526.67) with infection rate of 0.064, T13 (540.00) with 0.069 rate of infection, T9 (614.17) with ‘r’ value of 0.065, T1 (630.83) with infection rate of 0.069, T6 (635.00) with 0.067 rate of infection, T3 (638.33) with ‘r’ value of 0.070, T7 (650.00) with infection rate of 0.057, T8 (671.67) with 0.057 rate of infection, T2 (678.33) with 0.074 rate of infection and T5 (739.17) with infection rate of 0.065. The maximum AUDPC (1058.33) was recorded in control with infection rate of 0.068. No relation was found between AUDPC and apparent rate of infection.

Test weight (g)

Maximum test weight was found in T16 (180.93) followed by T12 (170.00), T15 (166.40), T4 (165.93), T11 (165.54), T14 (160.94), T13 and T10 (159.87), T6 (159.80), T9 (159.54), T3 (159.14), T5 (158.14), T9 (156.40), T8 (154.40), T2 (152.17) and T1 (151.90). Minimum test weight was observed in control (144.00).

Total yield (kg/ha)

Highest yield was recorded in T4 (756.28) followed by T10 (748.58), T12 (746.75), T15 (717.06), T16 (714.30), T11 (613.42), T8 (586.06), T7 (584.89), T3 (577.03), T13 (572.45), T5 (567.53), T14 (566.86), T1 (561.64), T9 (557.42), T2 (553.11) and T6 (552.89). Least yield was found in control (405.03).

Correlation of AUDPC with test weight and total yield revealed that AUDPC value are significantly negatively correlated with test weight (-0.79**) and total yield (-0.96**) (Table 3.).

Percent increase in yield over control

Estimation of Percent increase in yield over control due to individual fungicides will provide us the information about the role of individual fungicides in reducing rust severity. It was found in present experiment that T4 (86.72) recorded maximum Percent increase in yield followed by T10 (84.82), T12 (84.37), T15 (77.04), T16 (76.30), T11 (51.45), T8 (44.69), T7 (44.41), T3 (42.47), T13 (41.33), T5 (40.12), T14 (39.96), T1 (38.67), T9 (37.62), T2 (36.56) and T6 (36.51) (Table 2.).

Table 2: Efficacy of fungicides for the management of rust disease in pea during crop season 2013-2014 and 2014-2015.

S. No.	Fungicides	Disease severity (%)			A value			'r' value			Test weight (g)			Total yield (kg/ha)			Percent increase in yield over control		
		2013	2014	pooled	2013	2014	pooled	2013	2014	pooled	2013	2014	pooled	2013	2014	pooled	2013	2014	pooled
Alone																			
1.	Dithane M-45	38.33cde (38.19)	30.00de (33.16)	34.17cde (33.16)	816.70	445.00	630.83	0.065	0.072	0.069	143.60abc	160.20ab	151.90ab	589.42bc	533.86b	561.64b	49.53	28.37	38.67
2.	Carbendazim	43.33de (41.16)	33.33de (35.25)	38.33de (35.25)	891.60	465.00	678.33	0.071	0.076	0.074	142.00ab	162.33abc	152.17ab	578.11bc	528.11ab	553.11b	46.66	26.99	36.56
3.	Propiconazole	38.33cde (38.24)	31.67de (34.23)	35.00cde (34.23)	816.70	460.00	638.33	0.065	0.074	0.070	149.07abc	169.20abc	159.14ab	588.14bc	565.92b	577.03b	49.20	36.08	42.47
4.	Tebuconazole	13.33a (21.33)	13.00a (21.10)	13.17a (21.10)	276.60	198.33	237.50	0.043	0.077	0.060	157.93bcd	173.93abc	165.93bc	724.33f	788.22f	756.28e	83.75	89.54	86.72
5.	Trifloxystrobin	45.00e (42.12)	36.67e (37.25)	40.83e (37.25)	923.35	555.00	739.17	0.062	0.068	0.065	144.80abc	171.47abc	158.14ab	575.86bc	559.19b	567.53b	46.09	34.47	40.12
Combination																			
6.	Dithane M-45 + Trifloxystrobin	38.33cde (38.24)	31.67de (34.23)	35.00cde (34.23)	774.90	495.00	635.00	0.063	0.071	0.071	153.13abc	166.47abc	159.80ab	557.06b	548.72b	552.89b	41.32	31.95	36.51
7.	Dithane M-45 + Propiconazole	35.00bcd (36.23)	26.67cd (31.07)	30.83bc (31.07)	813.35	486.67	650.00	0.055	0.059	0.059	156.20bc	162.87abc	159.54ab	601.56c	568.22b	584.89b	52.61	36.64	44.41
8.	Dithane M-45 + Carbendazim	36.67bcde (37.20)	28.33cd (32.09)	32.50cd (32.09)	846.75	496.67	671.67	0.055	0.058	0.058	146.07abc	162.73abc	154.40ab	552.72e	619.39e	586.06d	40.22	48.94	44.69
9.	Carbendazim + Trifloxystrobin	36.67bcde (37.25)	28.33cd (32.14)	32.50cd (32.14)	783.40	445.00	614.17	0.062	0.067	0.067	149.73abc	163.07abc	156.40ab	526.86e	587.97cde	557.42d	33.66	41.39	37.62
10.	Carbendazim + Tebuconazole	11.67a (19.88)	13.33a (21.33)	12.50a (21.33)	209.95	181.67	195.83	0.064	0.096	0.096	148.87abc	170.87abc	159.87ab	711.08f	786.08f	748.58e	80.39	89.03	84.82
11.	Trifloxystrobin + Propiconazole	28.33b (32.14)	21.67bc (27.71)	25.00b (27.71)	633.40	356.67	495.00	0.054	0.061	0.061	160.20bcd	170.87abc	165.54bc	574.53d	652.31c	613.42c	45.75	56.86	51.45
12.	Dithane M-45 + Tebuconazole	15.00a (22.59)	11.67a (19.88)	13.33a (19.88)	345.05	238.33	291.67	0.041	0.057	0.057	161.67bcd	178.33bc	170.00bc	713.42g	780.08g	746.75f	80.98	87.58	84.37
13.	Carbendazim + Propiconazole	35.00bcd (36.23)	28.33cd (32.14)	31.67cd (32.14)	678.30	401.67	540.00	0.064	0.074	0.074	151.53abc	168.20abc	159.87ab	580.78bc	564.11b	572.45b	47.34	35.65	41.33
14.	Trifloxystrobin + Tebuconazole	33.33bc (35.21)	26.67cd (30.94)	30.00bc (30.94)	675.00	378.33	526.67	0.060	0.068	0.068	157.60bcd	164.27abc	160.94ab	591.86bc	541.86b	566.86b	50.15	30.30	39.96
15.	Carbendazim + flusilazole	15.00a (22.59)	15.00a (22.59)	15.00a (22.59)	320.00	495.00	275.00	0.043	0.071	0.071	164.07cd	168.73abc	166.40bc	724.00e	710.11de	717.06d	83.67	70.76	77.04
16.	Penflufen+ Trifloxystrobin	16.67a (24.04)	16.67ab (24.04)	16.67a (24.04)	346.75	486.67	274.17	0.057	0.102	0.102	177.93cd	183.93c	180.93c	758.75d	669.86cd	714.30c	92.48	61.08	76.36
17.	Water (control)	60f (50.78)	48.33f (44.04)	54.17f (44.04)	1296.5	496.67	1058.3	0.067	0.069	0.069	132.67a	155.33a	144.00a	394.19a	415.86a	405.03a	-	-	-
	CD at 5%	4.99**	4.15**	3.92**							18.66*	18.22	16.34*	36.59**	44.79**	33.06**			
	SEM	1.73	1.44	1.36							6.48	6.32	5.67	12.70	15.54	11.47			
	CV	8.90	8.27	7.37							7.3	6.53	6.12	4.72	5.02	3.97			

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

Table 3: Correlation coefficients of AUDPC of rust with test weight and yield of pea treated with fungicides.

Correlation coefficients (r)			
	AUDPC		
	2013	2014	2013 and 2014 (pooled)
Test weight	-0.74**	-0.75**	-0.79**
Yield	-0.93**	-0.89**	-0.96**

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

Discussion

The results of present investigations on efficacy of chemical fungicides against rust disease of pea during both the seasons revealed that all the fungicides are effective for the management of disease as compare to control, however tebuconazole, carbendazim + tebuconazole, Mancozeb + tebuconazole, carbendazim + flusilazole, penflufen + trifloxystrobin are very effective among all. These differences observed in the efficacy among tested fungicides depend on their fungicidal action. These fungicides showed considerable reduction in rust severity and AUDPC with significant increase in total yield and test weight. Similar observation on efficiency of tebuconazole in reducing the rust severity with good increase in yield of pea was earlier demonstrated (Huge and Nahar, 1997; Basandrai *et al*., 2013; Emeran *et al*., 2011; Sugha *et al*., 2008) [11, 1, 7, 28]. We have observed that there were considerable differences among fungicides in their capability to suppress the disease progress and protect the photosynthetic area of the plant which is very essential for obtaining good yield. But the solo application of tebuconazole and its combination with carbendazim and mancozeb were found most efficient in managing the rust disease in pea with a significant reduction in AUDPC value with increased yield. Efficiency of triazoles (difenoconazol, epoxiconazol, tebuconazol) and their combination with benzimidazoles (carbendazim-flutriafol and carbendazim-flusilazole) in pea rust management was also demonstrated (Emeran *et al*., 2011; Scherm *et al*., 2009) [7, 22]. Triazoles are sterol synthesis inhibitors and many of them have good action against rust diseases (Kuck *et al*., 1995) [13]. The role of triazole fungicides in managing soya bean rust (*Phakopsora pachyrhizi* Syd. & P. Syd.) has also been demonstrated (Miles *et al*., 2003; Galloway, 2008) [16, 8]. Among wide range of triazole active ingredients, tebuconazole performing best against soya bean rust (Miles *et al*., 2003, 2007) [16-17]. Triazole fungicides are well known to have a few degree of acropetal systemic movement in plants (Godwin *et al*., 1992; Kuck *et al*., 1995) [9, 13]. However, the intensity of protective and curative activity can differ among fungicides (Mueller *et al.*, 2004; Wong and Wilcox, 2001) [18, 31]. In absence of accessibility of resistant varieties, fungicides application can be a suitable short term strategy for rust disease management in pea. Thus new generation fungicides and/or combination of new and old generation fungicides provide a promising approach for the management of rust disease in pea.

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