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Incidence of potato diseases in cold storage and performance of seed lots under field conditions

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Abstract

In a study conducted at Punjab Agricultural University, Ludhiana during 2015-16 and aimed at exploring the variation in quality of seed-lots having different storage conditions, 50 seed potato lots of variety *Kufri Pukhraj* were collected at random from seed growers of Punjab. There was a large significant ($P < 0.001$) variation among seed-lots in terms of quality (thumb nail injury, scab, *Fusarium* dry rot and wet rot). The variation in seed-lots varied from 0.0-6.7%, 0.0-23.0%, 0.0-90.0% and 0.0-30.0% in respect of scab, scurf, *Fusarium* dry rot and wet rot, respectively. Positive correlation was found between thumb nail injury, wet rot and *Fusarium* dry rot. The field experiment was conducted by taking all the 50 seed-lots as treatments and replicated thrice in randomized block design layout. The variation in seed-lots varied from 2.8-36.4%, 0.0-31.8%, 0.0-9.2% and 0.0-16.5% with respect to *Rhizoctonia* stem canker, scurf, scab and russet scab, respectively. Morphological characteristics of heavily dry rot isolates were also studied with respect to size of microconidia, macroconidia and chlamydospore.

Keywords: Potato, fusarium dry rot, variation, scab, scurf, isolates

Introduction

The potato (*Solanum tuberosum* L.) is an important source of calories, proteins and fats for humans. It is grown in 155 countries and more than a billion people around the world consume potatoes [1]. Total world production of potatoes was estimated at 388,191,000 tonnes in 2017 [2]. India ranked second in terms of production and third in terms of area with a production of 52,588.98 tonnes [3]. In Punjab, it occupied an area of 90000 ha with a production of 2.26 million tonnes during 2014-15 [4]. The major potato growing districts in Punjab are Jalandhar, Hoshiarpur, Kapurthala, Ludhiana, Amritsar and Bathinda. About 60% of the total area under potato cultivation in Punjab is under seed potato as there is a great demand of seed potatoes from Punjab by states of West Bengal, Bihar, Maharashtra, Karnataka and Gujarat. Eighty five per cent seed requirement of the country is met from the Punjab state [5]. Punjab has established itself as a seed producing state of potato and seed potato growers in the state have been doing their seed business under different organizations such as POSCON (Confederation of Potato Seed Farmers) and JPGA (Jalandhar Potato Growers Association). Among many diseases, dry rot of potatoes is an emerging disease of tubers both in the field and cold storage [6, 7]. It is incited by *Fusarium* species [8-13]. Worldwide, more than 13 *Fusarium* species are causing dry rot disease in potato [9]. Hence, the study was planned to (i) examine various potato diseases from seed-lots, (ii) evaluated performance of these seed-lots under field conditions, (iii) morphological characteristics of heavily dry rot infected samples incitant of *Fusarium* species.

Materials and Methods

Incidence of diseases on potato seed

Laboratory and field studies were conducted at Punjab Agricultural University, Ludhiana during 2015-16. Fifty seed potato lots, from member farmers of POSCON of variety *Kufri Pukhraj* were collected at random for the studies. Data on percentage of thumb nail injury, and incidence of scab, *Fusarium* dry rot, scurf, wet rot and were recorded by taking 30 tubers from each seed-lot at random. Data were subjected to analysis of variance using IBM SPSS 26.0 software. Mean value of each isolate were compared according to Fisher's Least Significant Difference ($p=0.05$).

Performance of seed lot

The field experiment was conducted during 2015-16 by taking all the fifty seed-lots as treatments and replicated thrice in randomized block design layout. Fifty tubers from each seed-lot were planted per plot in five rows and three rows were taken as net plot for data

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collection. The planting of tubers was done on Oct 14, 2015 at a row to row spacing of 60 cm and tuber to tuber spacing of 20 cm. The experimental field was applied with 50 tonnes of farmyard manure on fresh weight basis along with 187.5 kg N, 62.5 kg P₂O₅ and 62.5 kg K₂O ha⁻¹. Whole farmyard manure, phosphorus and potash and half of nitrogenous fertilizers were applied at the time of field preparation and the remaining half dose of nitrogenous fertilizer was applied at the time of earthing-up at 25 days after planting the tubers. Data on incidence of Rhizoctonia stem-canker, scab, scurf and russet scab were recorded in the months of January and March. Data were subjected to analysis of variance using IBM SPSS 26.0 software. Mean value of each isolate were compared according to Fisher's Least Significant Difference ($p=0.05$).

Morphological characteristics of *Fusarium* spp. incitant of dry rot

Total twenty five heavily dry rot infected samples were selected for further isolation. The *Fusarium* cultures were obtained from these samples and species were confirmed based on morphological characteristics and species specific ITS primers [9, 14, 15]. Previously, three species namely *Fusarium culmorum*, *F. avenaceum* and *F. sambucinum* were identified (Kumar *et al* 2016). In current study, the size and shape as well as septation of micro and macro conidia were recorded and compared with the *Fusarium* laboratory manual [17].

Results and Discussion

Incidence of potato diseases in seed-lots

There was a significant ($P<0.001$) difference in seed lots with respect to thumb nail injury, *Fusarium* dry rot, scab, scurf and wet rot (Table 1). Different category of storage system was also noted. Thumb nails injury and *Fusarium* dry rot was varied from 0.0 to 90.0%. Highest thumb nail injury (90.0%) and *Fusarium* dry rot (90.0%) was observed in seed lot of kanga village (Jalandhar). Highest *Fusarium* dry rot incidence was observed in seed lots of Jalandhar district as compared to other district of Punjab. Scab incidence was a minimum as compared to other diseases. Scab incidence was ranged from 0.0 to 6.7%. While incidence of scurf was varied from 0.0 to 23.0%, being highest was recorded in seed lot of Shekupur, Quadian, Saprai villages of Patiala, Gurdaspur, Jalandhar, respectively. However wet rot incidence ranged from 0.0 to 30.0%, highest incidence was recorded in seed lot of Gakhhal village of Jalandhar. Pearson correlation was also calculated within the nail injury and different diseases (Figure 1). It was found that dry rot ($r = 0.44$) and wet rot ($r = 0.54$) were significantly ($P<0.001$) positively correlated with thumb nail injury.

Dry rot incidence has been earlier recorded in the state of MP and Haryana [18]. Sagar *et al.* [18] recorded the yield loss in October 2009 that the more than 90 percent of tubers were affected by dry rot when removed after six months of storage. Dry rot disease was observed on potato tubers of Cv. *KufriAshoka* in cold stores at Sehore district of Madhya Pradesh. Also, in October 2010 similar symptoms were observed in about 1-2 percent of potato tubers of cv. *KufriBahar* stored in cold stores at Shahbad in Haryana. Positive correlation was found between the injury and dry rot incidence [16]. Pathogens cause infection if the potato peels is ruptured [19].

Performance of seed lots in field conditions

There was a highly significant ($P<0.001$) difference in seed lots with respect to Rhizoctonia stem canker, scurf, scab and russet scab (Table 2). Data was recorded at two different dates (29-01-2015 and 03-03-2015) and it was found that disease incidence was the maximum at 03-03-2015. Rhizoctonia stem canker incidence was recorded in the range of 2.8 to 36.4%. The highest incidence was the maximum (36.4%) in seed lot of Quadian village of Gurdaspur followed by seed lot of Shalanagar village of Jalandhar (24.4%). However minimum (2.8%) incidence was observed in seed lot of Mehatpur village of Jalandhar followed by seed lot of Puna village (3.4%). Scurf incidence was varied from 0.0 to 30.0% and 4.7 to 31.8% on date 29/01/2015 and 03/03/2015, respectively. The maximum scurf incidence was observed in seed lot of Sitalpur village of Jalandhar (30.7%) followed by seed lot of Saraikham village of Nakodar (29.5%). No incidence was recorded in seed lot of Shahjhanpur village of Ludhiana and Mehatpur village of Jalandhar. While the scab and russet scab incidence was low as compared to Rhizoctonia stem canker and scurf (Table 2). Scab incidence and russet scab incidence was recorded in the range of 0.0 to 5.7% and 0.0 to 10.8%, respectively on date 29/01-2015. While on date 03/03/2015, scab and russet scab incidence was 0.0 to 9.2% and 0.0 to 16.5%, respectively.

Morphological characteristics of *Fusarium* species incitant of dry rot

Previously out of 50 seed lots, 25 seed lots were selected on the basis of high dry rot incidence. Eleven isolates (F5, F6, F7, F12, F15, F18, F19, F22, F23, F24 and F25) were identified as *Fusarium avenaceum* and five isolates (F28, F31, F36, F37 and F40) were identified as *F. sambucinum* While, *F. culmorum* was obtained from nine isolates (F38, F41, F42, F44, F45, F46, F48, F49, F50). In current study, morphological characteristics of twenty dry rot isolates was studied and found that much differences in size of microconidia and macroconidia (Table 3). In *F. avenaceum*, chlamyospore was not formed. The size of microconidia and macroconidia was ranged from 7.5-21.0 x 1.6-2.8 μm (length x breadth) and 49-85 x 3.3-5.1 μm with an average of 11.2-14.8 x 2.1-2.5 μm , respectively while number of septa in microconidia varied from 0-2 and number of septa in macroconidia ranged from 3-5. *F. culmorum* did not form microconidia. The size of macroconidia ranged from 24-50 x 3.1-7.0 μm with an average of 15.7-40.0 x 3.5-5.1 μm . Size of chlamyospore was varied from 7.0-14.8 μm . In *F. sambucinum*, size of microconidia and macroconidia was ranged from 5.0-14.5 x 1.7-3.2 μm (length x breadth) and 19-50 x 2.8-5.9 μm , respectively while number of septa in microconidia varied from 0-1 and number of septa in macroconidia ranged from 3-4.

The current study indicated that large variation in visual general impression, scurf, scab and *Fusarium* dry rot incidence among the seed lots. The well maintained storage facilities are very important for production of better quality of tuber. The frequency of occurrence and aggressiveness of dry rot causing *Fusarium* strains also differ depending upon the prevalent cultivars and environmental conditions in a location-specific manner.

Table 1: Incidence of diseases on potato seed of seed-lots collected from different villages of Punjab state during 2015-16

Samples	Geographical location (village/district)	Nail marks/ Injury (%)	Incidence on potato seed (%)**				Storage system: transitional/ Upgraded/advanced
			Dry rot	Scab	Scurf	Wet rot	
F1	Shalanagar, Jalandhar	20.0 ^{j*}	0.0 ^o	0.0 ^c	3.3 ^f	0.0 ^h	Banker
F2	Shekupur, Patiala	20.0 ^j	0.0 ^o	0.0 ^c	23.3 ^a	0.0 ^h	Cooling coil
F3	Ramgarh	33.3 ^f	6.7 ^m	0.0 ^c	3.3 ^f	13.3 ^d	Banker
F4	Kapurthala	26.7 ^h	10.0 ^l	0.0 ^c	0.0 ^g	6.7 ^f	Banker
F5	Mehraampur	30.0 ^g	13.3 ^k	0.0 ^c	0.0 ^g	6.7 ^f	Banker
F6	Madar, Jalandhar	36.7 ^e	13.3 ^k	0.0 ^c	0.0 ^g	0.0 ^h	Cooling coil
F7	Nurmahal, Jalandhar	33.3 ^f	20.0 ⁱ	0.0 ^c	6.7 ^e	0.0 ^h	Diffuser
F8	Kala bahian, Jalandhar	13.3 ^l	3.3 ⁿ	0.0 ^c	6.7 ^e	0.0 ^h	Banker
F9	Passan, Jalandhar	30.0 ^g	3.3 ⁿ	0.0 ^c	0.0 ^g	6.7 ^f	Banker
F10	Jalandhar, Jalandhar	36.7 ^e	10.0 ^l	0.0 ^c	6.7 ^e	10.0 ^e	Banker
F11	Shalanager, Jalandhar	20.0 ^j	6.7 ^m	3.3 ^b	0.0 ^g	0.0 ^h	Banker
F12	Kassochahal, Jalandhar	16.7 ^k	40.0 ^c	0.0 ^c	0.0 ^g	0.0 ^h	Banker
F13	Gokalpur	20.0 ^j	13.3 ^k	3.3 ^b	10.0 ^d	3.3 ^g	Banker
F14	Nagalpurdil, Jalandhar	23.3 ⁱ	6.7 ^m	6.7 ^a	16.7 ^b	0.0 ^h	Banker
F15	Shahjhanpur, Ludhiana	26.7 ^h	16.7 ^j	0.0 ^c	0.0 ^g	0.0 ^h	Frick unit
F16	Quadian, Gurdaspur	23.3 ⁱ	10.0 ^l	3.3 ^b	3.3 ^f	10.0 ^e	Cooling coil
F17	Sherpur, Sangrur	20.0 ^j	0.0 ^o	3.3 ^b	3.3 ^f	0.0 ^h	Banker
F18	Gonachak, Jalandhar	36.7 ^e	33.3 ^e	0.0 ^c	3.3 ^f	6.7 ^f	Banker
F19	Kohala, Jalandhar	20.0 ^j	23.3 ^h	0.0 ^c	0.0 ^g	0.0 ^h	Banker
F20	Lambra, Jalandhar	13.3 ^l	6.7 ^m	0.0 ^c	6.7 ^e	0.0 ^h	Banker
F21	Nathuchahal,	0.0 ^p	3.3 ⁿ	0.0 ^c	6.7 ^e	0.0 ^h	Banker
F22	Quadian, Gurdaspur	30.0 ^g	13.3 ^k	3.3 ^b	23.3 ^a	3.3 ^g	Baner
F23	Ballan, Rupnagar	20.0 ^j	16.7 ^j	0.0 ^c	0.0 ^g	0.0 ^h	Cooling coil
F24	Gakhal, Jalandhar	16.7 ^k	13.3 ^k	0.0 ^c	3.3 ^f	30.0 ^a	Banker
F25	Hazara, Jalandhar	16.7 ^k	13.3 ^k	0.0 ^c	0.0 ^g	0.0 ^h	Cooling coil
F26	Saraikham, Nakodar	13.3 ^l	13.3 ^k	0.0 ^c	6.7 ^e	0.0 ^h	Banker
F27	Puna	16.7 ^k	6.7 ^m	0.0 ^c	0.0 ^g	0.0 ^h	Cooling unit
F28	Jamsherkhas,	13.3 ^l	33.3 ^e	0.0 ^c	0.0 ^g	0.0 ^h	Banker
F29	Uggi, Jalandhar	10.0 ^m	6.7 ^m	0.0 ^c	3.3 ^f	0.0 ^h	Banker
F30	Madar, Jalandhar	70.0 ^b	6.7 ^m	0.0 ^c	0.0 ^g	13.3 ^d	Cooling coil
F31	Talwandibharo, Jalandhar	53.3 ^c	43.3 ^b	0.0 ^c	0.0 ^g	6.7 ^f	Cooling unit
F32	Dharmkot, SBS Nagar	20.0 ^j	6.7 ^m	0.0 ^c	0.0 ^g	0.0 ^h	Banker
F33	Sitalpur, Jalandhar	53.3 ^c	10.0 ^l	6.7 ^a	6.7 ^e	10.0 ^e	Banker
F34	Kassochahal, Kapurthala	40.0 ^d	6.7 ^m	0.0 ^c	6.7 ^e	3.3 ^g	Banker
F35	Kohala, Jalandhar	20.0 ^j	6.7 ^m	6.7 ^a	13.3 ^c	0.0 ^h	Banker
F36	Mehatpur, Jalandhar	16.7 ^k	20.0 ⁱ	6.7 ^a	0.0 ^g	0.0 ^h	Banker
F37	Kanga, Jalandhar	30.0 ^g	43.3 ^b	0.0 ^c	3.3 ^f	3.3 ^g	Banker
F38	Kanga, Jalandhar	90.0 ^a	90.0 ^a	0.0 ^c	0.0 ^g	20.0 ^b	Cooling coil
F39	Dhogri, Jalandhar	0.0 ^p	10.0 ^l	0.0 ^c	0.0 ^g	0.0 ^h	Banker
F40	Shalanagar, Jalandhar	26.7 ^h	40.0 ^c	0.0 ^c	6.7 ^e	0.0 ^h	Banker
F41	Alipur, Hoshiarpur	26.7 ^h	26.7 ^g	0.0 ^c	6.7 ^e	3.3 ^g	Banker
F42	Saprai, Jalandhar	20.0 ^j	33.3 ^e	0.0 ^c	23.3 ^a	0.0 ^h	Cooling unit
F43	Baaridpur, Sangrur	20.0 ^j	10.0 ^l	0.0 ^c	6.7 ^e	3.3 ^g	Cooling unit
F44	Thamanwal, Jalandhar	20.0 ^j	20.0 ⁱ	0.0 ^c	6.7 ^e	0.0 ^h	Banker
F45	Chak chela, Jalandhar	23.3 ⁱ	23.3 ^h	6.7 ^a	6.7 ^e	3.3 ^g	Cooling coil
F46	Lallian kalan, Jalandhar	26.7 ^h	23.3 ^h	0.0 ^c	0.0 ^g	6.7 ^f	Banker
F47	Udhopur, Jalandhar	6.7 ⁿ	6.7 ^m	3.3 ^b	0.0 ^g	0.0 ^h	Banker
F48	Chohak, Jalandhar	3.3 ^o	40.0 ^c	0.0 ^c	0.0 ^g	0.0 ^h	Banker
F49	Dhogri, Jalandhar	23.3 ⁱ	36.7 ^d	6.7 ^a	3.3 ^f	16.6 ^c	Cooling coil
F50	Kular, Jalandhar	26.7 ^h	30.0 ^f	0.0 ^c	0.0 ^g	3.3 ^g	Banker
P-value		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	
LSD (p = 0.05)		0.56	0.56	0.29	0.43	0.39	

*Mean value in the experiment superscript with same letters (in column) are not significantly different ($P>0.05$) according to Fisher's Least Significant Difference; **Incidence was calculated from 30 randomly selected tubers from each seed-lots during 2015-16

Table 2: Field performance of seed lots collected from different villages of Punjab state during 2015-16

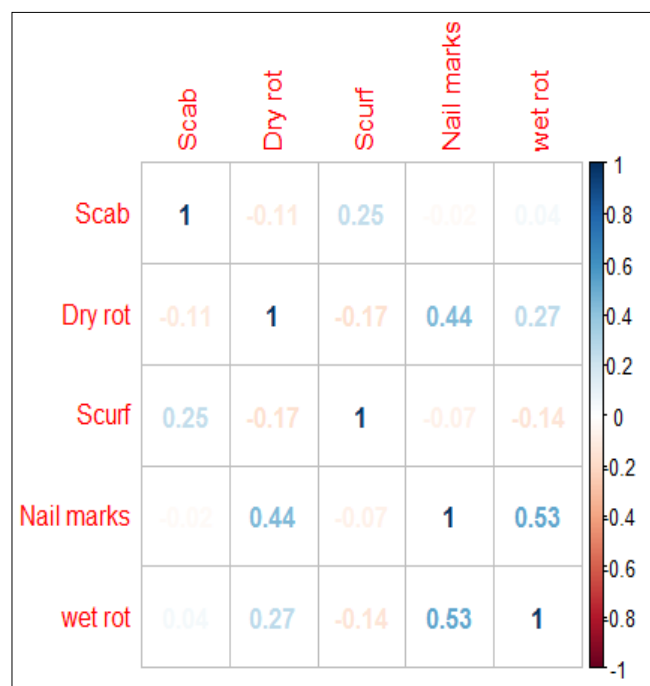
Sample	Geographical location (village/district)	Incidence (%)**						
		Rhizoctoniastem-canker	Scurf		Scab		Russet scab	
		29/01/15	29/01/15	03/03/15	29/01/15	03/03/15	29/01/15	03/03/15
F1	Shalanagar, Jalandhar	7.7 ^z	18.5 ^e	18.6 ^f	1.9 ^e	2.0 ^g	2.6 ^{lmno}	2.9 ^l
F2	Shekupur, Patiala	16.4 ^j	11.0 ^{jk}	10.0 ^{uvw}	0.0 ^g	5.5 ^c	4.0 ^g	5.5 ^{gh}
F3	Ramgarh	9.1 ^y	5.3 ^{pq}	12.2 ^{no}	0.0 ^g	2.0 ^g	2.2 ^{nopqr}	3.1 ^{kl}
F4	Kapurthala	14.3 ^m	10.5 ^k	11.5 ^{pq}	1.8 ^e	1.0 ^h	3.5 ^{ghi}	3.8 ^j
F5	Mehrapur	12.0 ^{pq}	2.0 ^t	10.5 ^{rst}	0.0 ^g	0.0 ⁱ	3.0 ^{ijk}	3.5 ^{jk}
F6	Madar, Jalandhar	7.7 ^z	5.6 ^p	5.0 ^B	0.0 ^g	2.0 ^g	6.2 ^{de}	7.0 ^f
F7	Nurmahal, Jalandhar	4.4 ^E	1.0 ^u	9.2 ^{wx}	0.0 ^g	2.0 ^g	2.5 ^{lmnop}	2.0 ^m
F8	Kala bahian, Jalandhar	6.7 ^A	1.0 ^u	6.9 ^z	2.9 ^d	0.0 ⁱ	1.5 ^{tuvw}	3.0 ^{kl}
F9	Passan, Jalandhar	11.3 ^{rs}	4.8 ^q	16.2 ⁱ	3.6 ^c	6.7 ^b	5.7 ^e	5.7 ^g
F10	Jalandhar, Jalandhar	7.9 ^z	9.5 ^l	12.2 ^{no}	4.8 ^b	0.0 ⁱ	5.7 ^e	5.1 ^{hi}
F11	Shalanagar, Jalandhar	5.4 ^{BC}	9.5 ^l	11.9 ^{op}	2.0 ^e	3.0 ^f	0.7 ^x	1.0 ⁿ
F12	Kassochahal, Jalandhar	5.3 ^{BC}	12.5 ⁱ	5.0 ^B	2.1 ^e	2.0 ^g	3.2 ^{ijk}	3.0 ^{kl}
F13	Gokalpur	4.5 ^{DE}	2.9 ^s	5.8 ^A	2.0 ^e	3.0 ^f	2.8 ^{klm}	2.9 ^l
F14	Nagalpurdil, Jalandhar	20.3 ^f	1.9 ^t	15.5 ^j	2.9 ^d	4.8 ^d	2.8 ^{klm}	2.9 ^l
F15	Shahjhanpur, Ludhiana	12.0 ^{pq}	0.0 ^v	21.3 ^d	0.0 ^g	0.0 ⁱ	2.9 ^{klm}	2.8 ^l
F16	Quadian, Gurdaspur	36.4 ^a	0.9	19.3 ^e	0.0 ^g	1.8 ^g	8.8 ^b	12.8 ^b
F17	Sherpur, Sangrur	9.0 ^y	2.8 ^s	9.7 ^{vw}	0.0 ^g	2.0 ^g	3.2 ^{ijk}	3.9 ^j
F18	Gonachak, Jalandhar	14.1 ^m	22.6 ^c	19.4 ^e	0.0 ^g	0.0 ⁱ	3.8 ^{gh}	3.9 ^j
F19	Kohala, Jalandhar	13.3 ⁿ	15.2 ^g	17.5 ^g	0.0 ^g	3.9 ^e	1.9 ^{qrstu}	3.9 ^j
F20	Lambra, Jalandhar	15.0 ^l	12.4 ⁱ	11.0 ^{qr}	0.0 ^g	0.0 ⁱ	2.0 ^{pqrst}	2.0 ^m
F21	Nathuchahal,	10.6 ^{tu}	5.6 ^p	17.6 ^g	0.0 ^g	0.0 ⁱ	2.8 ^{klm}	2.9 ^l
F22	Quadian, Gurdaspur	18.0 ^h	8.6 ^m	10.2 ^{stuv}	2.0 ^e	2.8 ^f	3.3 ^{hij}	2.8 ^l
F23	Ballan, Rupnagar	22.5 ^d	13.7 ^h	26.6 ^b	0.0 ^g	0.0 ⁱ	7.0 ^c	7.6 ^e
F24	Gakhal, Jalandhar	5.0 ^{CD}	4.9 ^q	9.9 ^{uv}	0.0 ^g	4.0 ^e	8.4 ^b	8.9 ^c
F25	Hazara, Jalandhar	11.3 ^{rs}	3.9 ^r	16.0 ^{ij}	0.9 ^f	2.0 ^g	2.9 ^{klm}	3.0 ^{kl}
F26	Saraikham, Nakodar	21.1 ^e	29.5 ^b	31.7 ^a	2.6 ^d	3.8 ^e	5.7 ^e	5.8 ^g
F27	Puna	3.4 ^F	2.9 ^s	6.0 ^A	0.0 ^g	0.0 ⁱ	0.0 ^y	0.0 ^o
F28	Jamsherkhas,	12.7 ^o	3.7 ^r	5.1 ^B	4.0 ^c	9.2 ^a	7.1 ^c	8.2 ^d
F29	Uggi, Jalandhar	10.0 ^{vw}	1.8 ^t	14.7 ^k	0.9 ^f	2.0 ^g	0.0 ^y	4.8 ⁱ
F30	Madar, Jalandhar	5.6 ^B	2.8 ^s	15.5 ^j	1.9 ^e	3.9 ^e	2.4 ^{mnopq}	2.9 ^l
F31	Talwandibharo, Jalandhar	5.0 ^{CD}	2.0 ^t	16.8 ^h	0.0 ^g	0.0 ⁱ	0.0 ^y	3.0 ^{kl}
F32	Dharmkot, SBS Nagar	15.8 ^k	1.9 ^t	14.7 ^k	0.0 ^g	2.9 ^f	2.5 ^{lmnop}	2.9 ^l
F33	Sitalpur, Jalandhar	23.3 ^c	30.7 ^a	15.5 ^j	4.0 ^c	4.9 ^d	1.0 ^{wx}	4.9 ⁱ
F34	Kassochahal, Kapurthala	6.9 ^A	2.8 ^s	11.0 ^{qr}	3.8 ^c	4.6 ^d	7.5 ^c	12.4 ^b
F35	Kohala, Jalandhar	23.7 ^c	7.8 ⁿ	22.0 ^c	1.9 ^e	4.0 ^e	3.9 ^g	3.8 ^j
F36	Mehatpur, Jalandhar	2.8 ^G	0.0 ^v	4.6 ^B	2.0 ^e	4.8 ^d	1.2 ^{vwxy}	1.9 ^m
F37	Kanga, Jalandhar	10.9 ^{stu}	19.8 ^d	10.3 ^{stu}	0.0 ^g	0.0 ⁱ	3.8 ^{gh}	3.7 ^j
F38	Kanga, Jalandhar	10.5 ^{uv}	1.0 ^u	13.5 ^m	4.8 ^b	3.8 ^e	4.8 ^f	4.8 ⁱ
F39	Dhogri, Jalandhar	17.3 ⁱ	1.0 ^u	10.7 ^{rs}	5.7 ^a	5.8 ^c	10.8 ^a	16.5 ^a
F40	Shalanagar, Jalandhar	24.4 ^b	9.6 ^l	19.8 ^e	1.9 ^e	1.9 ^g	0.0 ^y	0.0 ^o
F41	Alipur, Hoshiarpur	11.1 st	3.8 ^r	8.7 ^x	0.0 ^g	0.0 ⁱ	6.4 ^d	8.7 ^{cd}
F42	Saprai, Jalandhar	14.6 ^{lm}	15.9 ^f	21.8 ^{cd}	0.0 ^g	0.0 ⁱ	1.8 ^{rstu}	2.0 ^m
F43	Baaridpur, Sangrur	9.8 ^{wx}	4.0 ^r	13.9 ^{lm}	1.0 ^f	2.0 ^g	0.0 ^y	0.0 ^o
F44	Thamanwal, Jalandhar	11.7 ^{qr}	11.3 ^j	14.1 ^l	1.0 ^f	1.0 ^h	1.6 ^{stuv}	2.1 ^m
F45	Chak chela, Jalandhar	19.4 ^g	6.5 ^o	14.4 ^{kl}	2.0 ^e	2.0 ^g	1.4 ^{uvw}	1.9 ^m
F46	Lallian kalan, Jalandhar	11.1 st	9.8 ^l	11.4 ^{pq}	2.9 ^d	3.9 ^e	1.8 ^{rstu}	1.9 ^m
F47	Udhampur, Jalandhar	16.0 ^{jk}	8.8 ^m	12.7 ⁿ	2.0 ^e	1.0 ^h	1.9 ^{qrstu}	1.0 ⁿ
F48	Chohak, Jalandhar	12.3 ^{op}	4.0 ^r	14.0 ^{lm}	0.0 ^g	0.0 ⁱ	2.1 ^{opqrs}	3.7 ^j
F49	Dhogri, Jalandhar	9.3 ^{xy}	2.8 ^s	7.5 ^y	2.0 ^e	4.7 ^d	0.0 ^y	0.0 ^o
F50	Kular, Jalandhar	12.5 ^{op}	8.6 ^m	13.9 ^{lm}	0.0 ^g	0.0 ⁱ	2.7 ^{klmn}	3.7 ^j
	Mean	12.5	7.6	13.5	1.4	2.4	3.3	4.2
	P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	LSD (p=0.05)	0.57	0.56	0.57	0.43	0.48	0.54	0.55

*Mean value in the experiment superscript with same letters (in column) are not significantly different ($P>0.05$) according to Fisher's Least Significant Difference; **Incidence was calculated from 30 randomly selected tubers from each seed-lots during 2015-16

Table 3: Morphological characteristics of microconidia, macroconidia and chlamydospore of different potato dry rot isolates

Isolate	<i>Fusarium</i> sp.	Macroconidia					Microconidia					Range of chlamydospore (μ m)
		Range (μ m)		Mean (μ m)		No. of septa	Range (μ m)		Mean (μ m)		No. of septa	
		L	B	L	B		L	B	L	B		
F5	<i>F. avenaceum</i>	51-73	3.8-4.5	62.0	4.2	3-5	7.5-17.0	1.6-2.6	12.3	2.1	1-2	-
F6	<i>F. avenaceum</i>	50-70	3.8-5.1	60.0	4.5	3-5	7.5-21.0	1.8-2.5	14.3	2.2	1-2	-
F7	<i>F. avenaceum</i>	52-79	4.1-5.1	65.5	4.6	3-5	8.5-15.0	1.6-2.8	11.8	2.2	0-2	-
F12	<i>F. avenaceum</i>	49-71	4.1-4.9	60.0	4.5	3-5	8.5-17.0	2.0-2.6	12.8	2.3	0-2	-
F15	<i>F. avenaceum</i>	50-70	4.0-4.6	60.0	4.3	3-5	9.2-15.0	2.1-2.7	12.1	2.4	1-2	-
F18	<i>F. avenaceum</i>	51-72	3.8-4.8	61.5	4.3	3-5	7.6-15.0	2.1-2.6	11.3	2.4	1-2	-
F19	<i>F. avenaceum</i>	50-68	4.1-4.9	59.0	4.5	3-5	8.1-15.0	2.1-2.6	11.6	2.4	1-2	-
F22	<i>F. avenaceum</i>	50-70	3.5-4.9	60.0	4.2	3-5	7.5-17.0	2.3-2.7	12.3	2.5	0-2	-
F23	<i>F. avenaceum</i>	50-80	3.5-4.0	65.0	3.8	3-5	7.5-15.0	1.8-2.7	11.2	2.3	1-2	-
F24	<i>F. avenaceum</i>	50-72	3.3-4.5	61.0	3.9	3-5	7.8-15.0	1.9-2.6	11.4	2.3	0-2	-
F25	<i>F. avenaceum</i>	50-85	3.8-4.5	67.5	4.2	3-5	7.5-15.0	1.6-2.6	11.2	2.1	0-2	-
F28	<i>F. sambucinum</i>	19-30	2.9-3.8	24.5	3.4	3	6.4-14.0	2.1-2.8	10.2	2.5	0-1	+ (9-14)
F31	<i>F. sambucinum</i>	19-28	2.8-3.5	23.5	3.2	3	6.1-14.5	2.1-2.8	10.3	2.5	0-1	+ (8.5-15)
F36	<i>F. sambucinum</i>	24-34	3.1-4.1	29.0	3.6	3-4	5.0-13.1	1.7-2.7	9.1	2.2	0-1	+ (9-14.5)
F37	<i>F. sambucinum</i>	28-48	3.6-5.8	38.0	4.7	3-4	6.0-7.0	2.6-3.2	6.5	2.9	0-1	+ (5.5-10.8)
F38	<i>F. culmorum</i>	24-45	3.3-3.8	34.5	3.5	3-4	-	-	-	-	-	+ (9-14.8)
F40	<i>F. sambucinum</i>	30-50	3.6-5.9	40.0	4.8	3	7.0-11.5	2.1-2.7	9.3	2.4	0-1	+ (7-13.5)
F41	<i>F. culmorum</i>	29-47	3.9-4.9	38.0	4.4	3-4	-	-	-	-	-	+ (8.5-13.2)
F42	<i>F. culmorum</i>	31-50	3.4-5.0	15.7	4.2	3-4	-	-	-	-	-	+ (9-14)
F44	<i>F. culmorum</i>	30-48	3.9-5.9	39.0	4.9	3	-	-	-	-	-	+ (7.7-14.0)
F45	<i>F. culmorum</i>	29-50	3.6-5.9	39.5	4.7	3	-	-	-	-	-	+ (9.1-13.5)
F46	<i>F. culmorum</i>	30-50	3.6-4.9	40.0	4.3	3-4	-	-	-	-	-	+ (7-11)
F48	<i>F. culmorum</i>	28-49	4.0-7.0	38.5	5.1	3-4	-	-	-	-	-	+ (8.2-12.4)
F49	<i>F. culmorum</i>	24-34	3.1-4.1	29.0	3.6	3-4	-	-	-	-	-	+ (9-14.5)
F50	<i>F. culmorum</i>	28-45	3.2-4.9	33.6	4.1	3-4	-	-	-	-	-	+ (7.6-11.2)

L- length, B- breadth

**Fig 1:** Pearson correlation (r) between nail marks/injury and tuber diseases during the year 2015**References**

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