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Heavy infection of *Melampsora* leaf rust on *Populus deltoides*

This paper reports heavy and widespread infection of Melampsora rust on poplar (Populus deltoides) in most of its growing region in south of the Indian Himalayan foothills. The results of a field survey and clonal variation of commercially grown clones and germplasm are presented in the form of rating of the rust infection. Nurseries have been categorized on the basis of Rust Infection Index (RII). Clones rated between 0-10 scale of Infection Rating (IR) have shown wide variation. Nurseries located around the core area of intensive poplar culture had higher RII compared to those in fringe locations. Similarly, wide variation has been recorded in IR of clones maintained in the germplasm. Clone W110 had maximum IR in most locations in the core area of poplar culture.

Key words: *Melampsora* rust, *Populus deltoides*, Rust Infection Index (RII), Infection rating (IR).

Melampsora rust-a serious threat to poplar culture in India

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Introduction

Poplar (*Populus deltoides* Bartr. ex Marsh) is an industrially important tree grown by numerous farmers along with agriculture crops on their farmland in northwestern India. The tree has largely met the multifunctional expectations of farmers, foresters, wood based industry, scientists, financial institutions, insurance sector and policy planners. The tree is considered useful for meeting the raw material needs of a very large wood based industry, diversification of harmful paddy-wheat rotation to multiple cropping, creating evergreen revolution by making the agriculture crop production land-use sustainable, increasing biodiversity on farm land, increasing tree cover to meet the objectives of Indian Forest Policy, generating employment in rural locations and industrial units, meeting energy needs of firewood for domestic and industrial sector, fast mitigation of carbon by sequestering it in trees and locking it in forest products, and as a mean for ameliorating environment. In many locations, the tree has made a significant impact in transforming rural agriculture farming with integrated agri-sylvan landscape, and in creating significant green cover never ever seen before its introduction around five decades back (Dhiman, 2012a; 2012b). It is grown as a cash crop and is harvested at a short rotation of four years onward depending on the farmers' financial needs, wood demand and supply, wood prices in open markets, etc.

Poplar is one of highly sensitive tree and is attacked by a large number of insects and pathogens. Leaf rust is one of the serious disease of poplars in many countries. In India, it has been invariably reported on number of poplar species from hills and foot hills. Rust infection in plains was sporadic in nature and that too largely on evergreen clone 65/27 which did not attain a serious threat for causing economic losses to poplar (*P. deltoides*) and its growers. During October, 2016 reports started pouring in from number of poplar growing locations regarding the appearance of yellow/brown powder on the leaves, those being the signs of *Melampsora* rust. An extensive survey was conducted for rust infection in poplar nurseries from the region of intensive poplar culture (RIPC) as defined by Dhiman (2012a).

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Leaf rust disease in poplars is caused by a number of species belonging to *Melampsora* genus. *M. larici-populina*, *M. allii-populina*, *M. medusae-populina* and *M. ciliata* are the main species reported to cause leaf rust to poplars in India (Pandey *et al.*, 1996; Singh *et al.,* 2012). Of these, *M. ciliata* is the most common, widely and predominantly reported species causing serious infection (Sharma *et al.,* 2005). Samples of infected leaves collected from the field nurseries were sent to the Forest Pathology Lab, Forest Research Institute, Dehradun for identification of the causal organism. Initial findings indicated the relatedness of the fungi with *M. medusae* (Pandey, 2020 pers. Comm.). However, number of attempts, thereafter, gave mismatching sequences indicating some suspicion on the identity of causal organism. The work is still in progress to find out its exact identity (Pandey, 2022 pers. Comm.). This paper reports the rust infection (based on the generic name of infecting fungi) on different poplar clones from different field locations including its germplasm. The study also captured disease infection trends during the last five years (2017-2021).

Material and Methods

Rust infection was studied on a dozen clones in 29 sampled poplar nurseries grown by Wimco Seedlings (the single largest producer of poplar saplings in the country) across the RIPC (Table 1), 26 commercial clones grown in one location at R&D Centre of WIMCO Seedlings at Bagwala, Rudrapur and 575 clones maintained in the germplasm bank at the same centre. These clones belong to mainly *P. deltoides* with a couple of them to other species. There were 24,45,978 number of saplings in 29 nurseries during October-November, 2016 when the disease was first detected and survey conducted. These nurseries were established in the states of Punjab (PB), Haryana (HRY), Uttarakhand (U.K.) and Uttar Pradesh (U.P.) (Table 1). The selected clones grown in nurseries were based on their preference/ demand from growers in different locations. Out of total stock, 42.17% share was of clone W110, 17.71% of W109, 10.76% of W81, 10.43% of WSL22 and 9.73% of G48 clone. Clone W110 was grown in 29 nurseries, W109 in 19 nurseries, W81 in 22 nurseries, WSL22 in 21 nurseries and G48 in 20 nurseries. Clone W110 was the only clone that was grown in all the 29 nurseries.

Poplar germplasm contains 575 clones maintained at Wimco Seedlings, Rudarpur- and is the richest in India. It contains indigenously developed clones by Wimco Seedlings under the series WSL (Wimco Seedlings Limited), W (Wimco), named (Udai, Kranti and Bihar) and numbered (1000003103); those developed by U.P. Forest Department (now U.K.) under the series- L (like L34, etc.,) and some others (Dhiman

Table 1: Details of surveyed field nurseries in different locations.

State	District (latitude°N/Longitude°E)	Nurseries	Locations where poplar saplings are supplied
PB	Batala (31.82/75.19)	Khokhar	Amritsar, Batala, Gurdaspur, Tarantaran, Pathankot districts of PB and Parts of J&K.
	Hoshiarpur (31.51/ 75.91)	Chohal, Dadupur, Nagal Fida	Hoshirapur, Dasuya, Pathankot, Jallandhar, Kapurthala districts of PB, and parts of H.P and J&K.
	Ludhiana (30.90/75.85)	Dheri, Gausgarh	Ludhiana, Nawanshhar, Fatehgarh Shahib, Moga, Jallandhur, Rupnagar districts of PB and parts of Rajasthan.
	Rupnagar (30.96/76.52)	Kamalpur, Jahjj, Bheen	Rupnagar, SAS Nagar districts of PB and parts of H.P.
HRY	Yamuna Nagar (30.21/77.28)	Magarpur, Kail	All districts of Haryana and parts of H.P.
	Karnal (29.68/76.98)	Bibipur	Karnal, Panipat districts & other parts of HRY, and parts of U.P., especially Meerut and Shamli
U.K.	Haridwar (29.86/77.89)	Paniyala, Kadarpur	Haridwar and Dehradun districts of U.K. and parts of U.P.
	U.S.N. (28.97/77.39)	Jaspur, Bagwala	U.S.N. district of U.K., and parts of U.P.
U.P.	Saharanpur (29.98/77.50)	Sorana, Gokulpur	Shaharanpur and Muzafarnagar districts of U.P. and Dehradun and Haridwar of U.K.
	Buland Shahar (28.40/77.84)	Bartauli	Bulandshahar, Aligarh, Ghaziabad, Etah, Mainpuri, Hathras, Noida and Hapur districts of U.P.
	Meerut (28.97/77.67)	Gwara	Meerut, Muzafarnagar, Kansganj, Sambhal and Hapur, Alligarh districts of U.P., and parts of National Capital Region of Delhi
	Rampur (28.80/79.02)	Nagaria	Rampur, Moradabad, and Badaun districts of U.P.
	Bareilly (28.41/79.38)	Bhojipura	Bareily, Badaun, and Pilibhit districts and some other adjoining parts of U.P.
	Pilibhit (28.69/79.83)	Rooppur	Pilibhit, and Shahajanapur districts of U.P., Parts of U.K. and Nepal.
	Shahajahanpur (27.84/79.88)	Dhakia	Shahajanpur, Hardoi, Lucknow, Sitapur and Farukabad districts of U.P.
	Lakhimpur (27.98/80.75)	Durgapur	Lakhimpur, Hardoi districts, parts of eastern U.P., Bihar & Nepal.

and Gandhi, 2012). Many individuals of the same clone having variation in some morphological and phenological traits noticed in some locations have been separately maintained in the germplasm. For example, G3 is a classical example which shows 5 variants. G-3 (plus), G-3 (TC), G-3 (Bhimtall), G-3 (Naukuchiatal), and the original G-3 (Australia) which are maintained as separate identities in the germplasm. Five saplings were maintained for each clone and each sapling was rated for rust infection.

Poplar nurseries in the field were established by first growing plants from mini cuttings (5-7 cm long 1-2 nodal stem cuttings from last year grown saplings) in containers (root trainers) during February-March, 2016 and then planting the containerized plants in open nursery beds during April-May 2016. The germplasm nursery at Bagwala, Rudrapur, U.K. was created by planting containerized plants in open nursery beds during mid June, 2016. A simplified rating scale was developed in which a score was allotted from 0 to 10 based on severity of rust infection on the lower leaf surface. The Infection Rating (IR) score allotted was 0 for no visible infection, 1 for upto 10%, 2 for 11-20%, 3 for 21-30%, 4 for 31-40%, 5 for 41-50%, 6 for 51-60%, 7 for 61-70%, 8 for 71-80%, 9 for 81-90%, and 10 for 91-100% area infected on lower leaf surface (Fig. 1 to Fig. 6). A minimum of one yellow spot cm^{-2} (1x1 cm block) was considered while estimating the percentage area infected by the rust. In some clones and some nurseries where there was a very heavy infection, uredospores could also be seen on the upper leaf surface. In such cases, rust infected upper surface was not considered for calculating IR. RII for each nursery was calculated by allotting proportionate weight-age to the number of saplings in each clone. In commercial clones grown at R&D Centre, a detailed screening of five saplings in each of 26 clones was carried out for disease infection on three different dates *viz*., 18-19 October (D1), 28-29 October (D2) and 6-7 November, 2016 (D3). The parameters recorded were rust rating of all leaves on three dates, height and diameter of saplings, leaf number/sapling and average surface area/leaf on each of three dates. As there was no uniformity in number of leaves in each sapling and clone, the data on IR was compiled for the top 1/3rd, mid 1/3rd and bottom 1/3rd leaves on each sapling for analysis purpose. Twenty five leaves of assorted clones and sizes varying from 2.9 cm

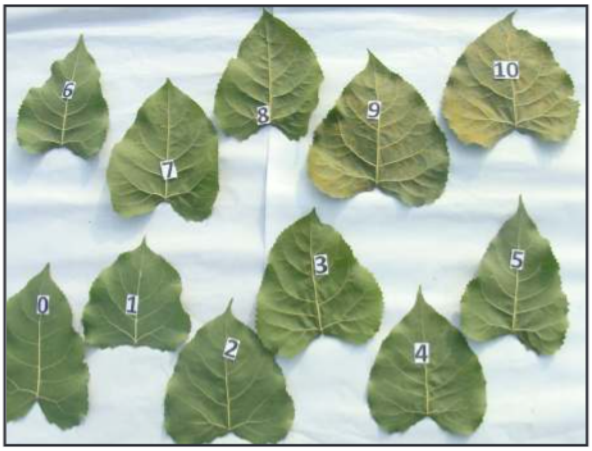

Fig. 1: Rust infected leaves (ventral surface) from 0 to 10 rating

Fig. 3: Rust infected ventral (left) and dorsal surfaces (right)

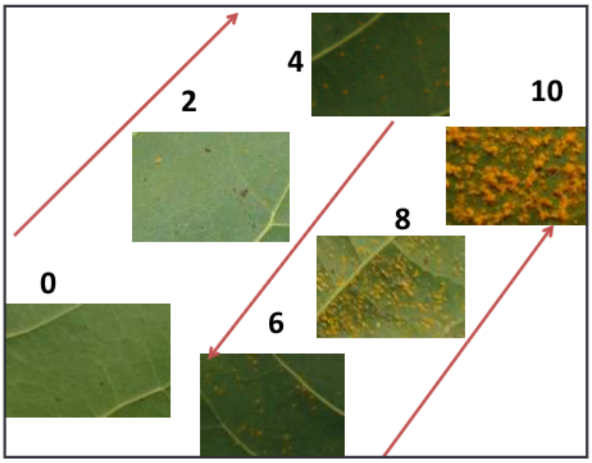

Fig. 2: Close up of rust infected leaves (ventral surface).

Fig. 4: Different stages of rust infected leaves-the last one being recently shed

Fig. 5: Heavily infected W110 clone in one of the field nursery (left- nursery, right -close up of leaf)

Fig. 6: Rust on coppice shoots (left) and in field plantations (right)

to 17.2 cm in length and 2.1 cm to 15.8 cm in width were first traced on the square graph paper, their area was calculated and the best fit regression equation given below was developed to estimate the average leaf area in each clone.

Leaf area = -328+100 L- 21.7 W+64.8 L*W; R^2 Adj.=99.9%

Where, L= length (cm) of leaf, and W =width (cm) of leaf.

The RII for different nurseries was calculated using the following formula

$$RII = \frac{Sub((N1C1)*IR1)+(N2C2)*IR2\ldots\ldots.(NnCn)*IRn)}{Sub\ (N1 + N2\ldots Nn)} \times 100$$

Where, N1C1… NnCn= Number of saplings in C1…Cn clone, IR1…IRn= IR for C1..Cn clone.

The recorded data for the sapling height (Ht), collar diameter (Cl), number of leaves (LN), leaf area (LA) of top (T), mid (M) and bottom (B) leaves on three dates viz., D1, D2 and D3 was subjected to analysis of variance for drawing inferences. Coefficients of correlation were developed among studied traits to correlate IR with others. Each site and clone was grouped into five categories according to IR/RII as given in Table 2 below.

Table 2: Classification of nursery sites and clones among different categories.

Sr. No.	IR/RII	Category
1	No infection (0)	Highly resistant(HR)
2	Light infection(0.1-2.5)	Resistant(R)
3	Moderate infection(2.6-5.0)	Susceptible (S)
4	Heavy infection(5.1-7.5)	Moderately susceptible (MS)
5	Very heavy infection(>7.6)	Highly susceptible (HS)

Results and Discussion

Field survey/field nurseries

The data on IR on different clones grown in different locations across the poplar growing region is given in Table 3. IR varies from location to location and clone to clone. No rust infection was recorded on any of the clones in nurseries located in Batala and Ludhiana districts in PB; Karnal in HRY; Lakhimpur, Bulandshahar, Shahajahanpur and Meerut districts in U.P. Whereas, heavy infection was recorded in Yamunanagar (HRY), Haridwar and Udham Singh Nagar (U.S.N.) districts (U.K.), Nawanshahar and Hoshiarpur districts (PB) and mild infection in Bijnor and Muzafarnagar districts (U.P). Maximum infection (7.14 IR) was recorded in Jaspur nursery (U.K.) followed by 5.62 in Bheen with S.A.S Nagar (PB), 5.43 in Jhajj, Roopnagar (PB), 5.30 in Paniyala (U.K.), 4.99 in Kadarpur (U.K.), 4.12 in Nagla Fida (PB), 3.53 in Chohal (PB), and 3.52 in Chandain (U.P.) nurseries. The present study indicates that the rust infection is more in locations which have a very intensive and dense poplar culture. Dhiman (2014) mentioned three concentrated triangles of intensive poplar culture within the RIPC. These triangles are located around water resources *e.g.*, first region around Satluz-Beas rivers in Punjab, second around Yamuna-Ganga rivers in Haryana, U.P. and U.K. and third in the Tarai region around Rudrapur-Rampur-Pilibhit and along Gola and Ram Ganga tributaries of river Ganga. Maximum rust infection was reported from nurseries grown around these three triangles. There are cases where higher percentage of susceptible clones tends to shift rating towards higher susceptibility ranking. The trend is more clear in case of W110 clone which was grown in all the nurseries across the poplar growing region and high values of IR in this clone from the three triangles mentioned above confirms this trend. The overall IR for W110 for all nurseries was 5.12, whereas, maximum IR of >9.0 was recorded in Rahon, Jhajj, Kamalapur, Bheen, Magarpur, Kadarpur, Sorana

Table 3: IR for clones and RII for different nurseries.

Nursery/Clone	W110	W109	W108	W83	W81	WSL22	WSL32	WSL39	Udai	G48	S7C8	S7C15	RII
Khokhar	0.0	0.0			0.0	0.0				0.0			0.00
Dheri	0.0	0.0	0.0		0.0	0.0	0.0	0.0		0.0			0.00
Gausgarh	0.0	0.0	0.0		0.0	0.0	0.0	0.0					0.00
Chohal	8.5	7.5				0.2				0.2			3.53
Dadupur	8.0	6.0			0.0	0.0				0.0			3.00
Nangal Fida	8.0	6.5			0.1	0.1				0.0			4.12
Rahon	7.0	6.5			2.0	0.0				0.0			2.69
Jhaji	9.0	7.5				0.1							5.43
Kamalpur	9.0	8.0			0.1	0.1							4.22
Bheen	9.3	8.5				0.2	0.1	0.1		0.1			5.62
Magarpur	9.0	8.0				0.1			0.0	0.1			1.83
Kail	8.0	7.0			3.0	0.3				0.2			1.79
Bibipur	0.0	0.0			0.0	0.0	0.0			0.0			0.00
Kadarpur	9.8	8.0				0.5							4.99
Paniyala	8.5	2.0			2.0								5.30
Sorana	9.0	8.0		4.0	0.5	0.5		2.3		0.1			3.28
Jaspur	9.5					0.5				0.2			7.14
Bagwala	7.3	5.5	3.4	7.6	4.7	2.4	4.1	5.6	1.7	1.1	2.3	2.9	2.34
Gokulpur	7.5	7.0				0.3				0.2			2.52
Chhapar	4.0		2.0	1.5	1.0					0.2			0.94
Mohanpur	3.0		2.0	1.0	0.5					0.1			1.82
Bhojipura	3.0	2.0			1.0							0.0	1.75
Nagaria	0.5				0.1								0.45
Chandain	6.1	4.3	2.4	5.5			3.0						3.52
Rooppur	4.5			1.2	0.0			0.0					1.32
Dhakia	0.0				0.0				0.0	0.0			0.00
Durgapur	0.0			0.0	0.0	0.0	0.0						0.00
Bartauli	0.0			0.0		0.0			0.0	0.0			0.00
Gwara	0.0				0.0	0.0		0.0		0.0			0.00
Average	5.12	5.11	1.63	2.60	0.75	0.25	1.02	1.14	0.44	0.13	2.26	1.47	2.16

and Jaspur nurseries, all of which lie in the three triangles of the RIPC as mentioned above. Further, 8.0-9.0 IR in this clone was recorded in Chohal, Dadupur, Nagal Fida, Kail, and Paniyala nurseries, whereas, Rahon, Bagwala and Gokulpur nurseries were having IR between 7.0 to 8.0. Chandain had 6.1 IR, while; Khokhar, Dheri, Gausgarh in PB, Bibipur in HRY and Dhakia, Durgapur, Bartauli and Gwara in U.P. recorded no infection in this clone. In fringe areas of poplar culture (away from the three triangles), a very low or no rust infection was recorded on any of the clone. Different scales are used for scoring diseases infection depending upon large number of factors (Schreiner, 1959; Manandhar *et al.,* 2016). The RII developed here gives proportionate weight-age to all clones and their population size grown in any location in proportion to the total population examined.

Each nursery has been classified into different categories based on the average RII calculated from total plant inventory of all the grown clones (Table 4 and Table 5). According to this classification, no nursery falls in HS and HR categories, though a couple of clones grown in many nurseries had high susceptibility to rust fungi. It is assumed that the locations around these nurseries have similar clonal mix in plantations and therefore the rust infection could have similar infection on old poplar trees as well. The nursery locations having more than 5.0 RII (MS) were Jhajj, Bheen, Paniyala and Jaspur, whereas, those in S were Sorana, Gokulpur, Chandain, Kadalpur, Kamalapur, Rahon, Chohal, Dadupur, and Nagal Fida. Both density of poplar culture and climatic conditions especially less humidity in these regions may be responsible for less infection. Rust infection depends on geographical area, physiological strains, climatic conditions and effect of environment on host pathogen relationship. Locations around the core areas of intensive culture are probably a breeding ground for the pathogens including that of *Melmposora* rust. Khan (1994) recorded the infection of rust variability according to location and plant material grown. Rust infection has been associated with moderate temperature between 20-30 °C, high humidity, stomata density and crown density (Prakash and Heather, 1985; Sharma and Khan, 2000). The density of sapling population in nurseries is over 10,000/acre and therefore such crowding could have helped in the fast spread of the disease. Multi-locational nursery data suggest that non of the clone was either disease free or completely infected in all the studied nurseries which could be due to the weather conditions and locations of the nurseries during the survey.

Based on overall rating throughout the RIPC, non of the clone falls in HR and HS category, while 9 clones were in R, 1 in S, and 2 in MS category (Table 5). Clones W110 and W109 were overall rated in MS category though they were also in HS category in many nurseries. Among all the clones, the most susceptible was W110 clone which has IR varying from 0.0 in unaffected locations to as high as 9.8 in most severely affected site, followed closely by W109 and others.

Clones W110 and W109 were found in HS category in 13 and 7 nurseries respectively and thus categorized as most susceptible clones in the present study. The same clones along with W83 were graded as MS category in 3, 5 and 2 nurseries respectively and thus these need a careful monitoring in future (Table 6). Other four clones *viz*., W108, W81, WSL32 and WSL39 were

Table 4: Categorization of nursery sites as per average RII among all clones

Sr.No.	RII Category	Nurseries
1	Disease free (HR-0)	Khokhar, Deri, Gausgarh, Dhakia, Bibipur, Durgapur. Batrauli. Gwara.
2	R (0.1-2.5)	Rooppur, Bhojipura, Nagaria, Bagwala, Mohanpur, Chhapar, Kail, Magarpur.
3	S (2.6-5.0)	Sorana, Gokulpur, Chandain, Kadalpur, Kamalapur, Rahon, Chohal, Dadupur, Nagal Fida.
4	MS (5.1-7.5)	Jhajj, Bheen, Paniyala and Jaspur.
5	HS (>7.6)	Nil.

Table 5: Overall categorization of clones by name in IR categories

Sr. No.	Infection rating	Clones
1	HR(0)	Nil
2	R (0.1-2.5)	W108, W81, WSL22, WSL32, WSL39, Udai, G48, S7C8, & S7C15
3	S (2.6-5.0)	W 83
4	MS (5.1-7.5)	W110, W109
5	HS (>7.6)	Nil

Table 6: Categorization of each clone by number of nurseries in IR categories

RII Category	W110	W109	W108	W83	W81	WSL22	WSL32	WSL39	Udai	G48	S7C8	S7C15	Total
HR (0)	8	3	2	2	9	9	4	4	3	9		1	54
R (0.1-2.5)	1	2	3	3	9	12	1	2	1	10	1	1	46
S (2.6-5.0)	4	1	1	1	2		2	1					12
MS (5.1<7.5)	3	5		2									10
HS (7.5)	13	7											20
Total	29	18	6	8	20	21	7	7	4	19	1	2	142

grouped in S category in some selected locations and these could also be kept under observations for rust monitoring in due course. Poplar culture could be sustained with the remaining clones under production and inclusion of new resistant ones from the germplasm.

W110 is now widely accepted clone and is grown in all nurseries across the poplar growing region. From this study this clone has emerged as the most susceptible one and hence its existence in any location might have helped in spreading the infection of rust to other clones.

IR in commercially grown clones in one location

The data on morphological traits and rust rating on upper, mid and lower 1/3rd leaves recorded on three different dates is given in Table 7 and Table 8. All the recorded traits had significant variation among the clones. Maximum sapling height of 3.58 m was recorded in W111 clone followed by 3.46 in W112 clone, and 3.36 in S7C15 and W83 clones which was significantly higher than that recorded in many other clones including G48 with a minimum value of 2.12 m. Similarly, clones W111 and W112 recorded significantly higher collar diameter compared to G48 and G3 clones. Number of leaves per sapling recorded for each of three dates also had significant differences among clones within each date. The maximum leaves numbering 47 were recorded in case of 65/27 clone (evergreen) on first date of data recording, whereas, W83 clone recorded a minimum of 5 leaves per sapling on the third date of data recording. Number of leaves in clones decreased from first date of data recording to second one and then to third one. In all clones, the IR was less in bottom 1/3rd leaves and it was maximum in the mid 1/3rd leaves with a few exceptions in which case the maximum values were in upper 1/3rd leaves in some clones *viz*., W110, W109, St121, Udai, WSL 27, W108, S7C4, S7C8 and Ind. No. 59. During the year, demand for poplar saplings was very low due to crash in poplar wood prices and only a dozen clones were grown in the production system. When prices of poplar wood moves up many farmers start planting poplar and number of clones in that case also increases in the nursery production systems. Rust checks the growth and may results in die back of saplings and trees including branches (Sharma, 2009) and therefore its infection affects returns to poplar growers. The affect is more serious on young plants especially in its nurseries. Rust susceptible poplars may also succumb to secondary pathogens after several years of its infection and the plants may die after 3-5 years of heavy infection (Schreiner, 1959).

Leaf size is very large in case of clone W109 and W110, whereas small in case of WSL 39, S7C15, W 108, W112, G48 and Udai. It is inferred from the data that there is direct link between the leaf size and the IR in the present case. Sharma *et al.* (2005) revealed that the rust infection was significantly related with the stomata density which varies from clone to clone. It was also reported to be correlated with the variation on leaf flushing time and genotype grown (Sharma and Sharma, 2004). There is well documented variation for

Table 7: Clonal variation on morphological traits and IR among commercial clones

Clone/ trait	Ht (m)	CD (cm)	Area/ leaf (cm^2)	No. of leaves per plant on different dates				IR on D1, D2 and D3 dates		
				D1	D2	D3	Avg	D1	D2	D3
W110	2.62	1.38	237.5	37.0	36.6	6.20	32.7	7.12	8.68	6.32
W109	2.66	1.32	328.8	34.8	34.8	22.80	33.7	7.84	6.78	3.01
G3	2.20	0.94	198.6	20.8	20.8	13.60	21.7	1.02	0.96	0.71
G48	2.12	0.98	197.3	27.8	27.8	21.80	32.3	1.26	1.31	0.64
St121	2.44	1.10	186.6	28.8	28.8	21.60	30.0	3.89	2.54	0.97
Udai	2.56	1.20	179.9	36.0	36.0	22.40	36.3	2.79	2.13	0.78
Bahar	2.52	1.20	209.3	31.2	31.2	21.20	37.3	1.70	1.95	0.93
Kranti	2.46	1.24	247.9	28.8	28.8	19.60	28.7	1.80	1.55	0.69
WSL 22	2.80	1.50	223.6	31.8	32.2	21.40	31.7	3.52	2.95	1.15
WSL 27	2.46	1.12	196.2	25.4	25.4	11.20	24.0	2.89	3.35	1.81
WSL 32	2.68	1.34	208.4	34.4	34.4	13.00	31.7	3.72	3.61	2.65
WSL 39	3.08	1.78	166.6	31.6	31.6	26.60	32.7	5.82	7.46	4.08
WSL A/26	2.38	1.08	198.3	37.0	37.0	28.00	43.0	1.97	2.60	0.95
WSL A/49	3.01	1.45	199.9	31.4	31.4	29.20	34.7	4.03	5.35	2.98
W 62	2.68	1.24	194.1	28.4	28.4	21.00	31.3	2.43	2.68	1.78
W81	3.06	1.56	237.2	40.2	40.2	31.80	44.7	5.18	6.38	2.74
W83	3.36	1.78	221.0	37.4	37.6	5.60	28.3	7.81	9.26	6.40
W 108	3.22	1.50	176.2	32.6	32.6	22.60	35.0	8.36	3.58	2.50
S7C4	2.32	1.10	201.4	32.0	31.0	24.60	32.7	2.56	2.53	0.56
S7C8	2.46	1.28	182.0	31.6	31.6	24.40	30.7	2.09	1.81	0.42
S7C15	3.36	1.58	151.0	36.4	36.4	31.40	38.3	3.20	4.06	1.37
L 34	2.52	1.18	189.1	30.8	30.8	24.40	35.3	1.34	1.35	0.45
Ind. 59	2.32	1.12	342.4	22.0	22.0	19.60	24.3	0.93	0.89	0.13
W112	3.46	1.58	165.8	35.4	35.4	32.40	37.3	1.58	1.63	0.44
65/27	2.96	1.22	192.4	47.0	46.6	43.40	51.7	0.49	0.84	0.18
W111	3.58	1.74	132.8	36.4	36.4	34.00	38.0	1.31	1.52	0.76
SE Diff	0.253	0.234	25.42	4.22	4.24	4.345	6.85	0.55	0.82	0.62
CD.05	0.49	0.46	49.82	8.27	8.31	8.52	13.43	1.08	1.61	1.22

Table 8: Clonal variation in IR among top, mid and bottom leaves on different dates.

Clone/Plant position	Top			Mid			Bottom			Overall Average
	D1	D2	D3	D1	D2	D3	D1	D2	D3	
W110	4.68	6.84	9.94	7.42	8.62	10.0	3.72	5.40	9.92	7.39
W109	5.74	7.82	10.0	4.84	6.30	9.20	1.18	1.80	6.06	5.88
G3	0.42	1.14	1.58	0.72	1.04	1.10	0.44	0.88	0.82	0.90
G48	0.64	1.12	2.06	0.84	1.20	1.90	0.38	0.54	1.00	1.07
St121	1.26	2.22	8.12	1.48	1.86	4.26	0.46	0.94	1.50	2.45
Udai	1.32	1.74	5.32	1.28	1.54	3.60	0.32	0.72	1.30	1.90
Bahar	0.74	1.12	3.26	0.94	1.76	3.66	0.34	0.64	1.86	1.53
Kranti	0.52	1.00	3.90	0.72	0.98	2.98	0.18	0.32	1.56	1.35
WSL 22	1.26	1.88	7.46	1.48	1.90	5.52	0.36	0.58	2.52	2.54
WSL 27	1.20	0.92	7.46	1.24	1.70	7.10	0.24	0.40	4.80	2.89
WSL 32	2.25	4.22	7.86	1.72	2.06	7.06	0.60	0.92	6.46	3.72
WSL 39	2.70	5.20	9.90	5.40	7.06	9.92	1.96	2.52	7.72	5.82
WSL A/26	1.02	1.24	4.82	1.26	1.56	4.98	0.40	0.50	1.94	1.97
WSL A/49	1.72	1.88	7.70	4.08	4.20	7.80	2.16	2.34	4.42	4.03
W 62	0.80	1.12	6.52	1.06	1.28	5.70	0.52	0.90	3.96	2.43
W81	3.96	5.40	9.94	4.82	5.52	8.80	1.52	1.74	4.96	5.18
W83	3.82	7.54	10.0	8.46	9.30	10.0	4.74	5.44	9.04	7.81
W108	1.32	2.72	8.00	1.20	2.16	7.36	0.60	1.00	5.90	3.36
S7C4	1.26	2.76	9.74	0.76	1.38	5.48	0.08	0.30	1.32	2.56
S7C8	1.26	2.42	8.46	0.56	0.98	3.90	0.00	0.18	1.12	2.09
S7C15	1.34	2.02	9.20	2.00	2.52	7.60	0.62	0.76	2.74	3.20
L 34	0.74	1.18	4.70	0.68	1.02	2.34	0.14	0.32	0.92	1.34
Ind. 59	0.92	1.04	3.36	0.44	0.60	1.60	0.06	0.14	0.20	0.93
W112	0.90	1.24	5.88	0.58	0.90	3.40	0.02	0.20	1.10	1.58
65/27	0.10	0.28	0.68	0.52	0.84	1.16	0.16	0.18	0.24	0.49
W111	1.06	1.08	2.82	6.84	0.96	2.80	0.34	0.52	1.42	1.31
SE Diff	0.559	0.705	1.713	0.651	0.66	1.87	0.92	0.61	1.133	0.55
CD.05	1.10	1.38	3.36	1.28	1.29	3.67	1.80	1.20	2.22	1.08

these traits in the studied clones (unpublished) which could not be presented here for the want of space.

Coefficients of correlation developed from 390 observations of 26 clones among different studied traits *viz*., IR on date one (RD1), IR on date 2 (RD2), IR on date 3 (RD3), Leaf number/sapling on date1 (LD1), leaf number/sapling on date 2 (LD2), leaf number/sapling on date 3 (LD3), surface area/leaf on date 1 (AD1), surface area/leaf on date 2 (AD2), surface area/leaf on date 3 (AD3), IR of top 1/3rd leaves for 3 dates (AT), IR of mid 1/3rd leaves for 3 dates (AM) and IR of bottom 1/3rd leaves for 3 dates (AB3) show highly significant r value (P<.000) (Table 9). There were little differences in r values for IR for D1, D2 and D3 dates within top, mid and bottom leaves and hence their correlations for individual dates are not included in the Table 9. There were positive and significant coefficients of correlation between IR and leaf fall during first and second date of data recording indicating that the rust infection continued to increase on other leaves of saplings. There is clonal variation in leaf fall among poplar clones (Dickmann *et al.,* 2001). How far the premature leaf fall occurred in the rust infected clones could not be established due to the inherent limitations of maintaining same clones without rust infection and recording simultaneous observations on this trait.

Evaluation of poplar germplasm

There was a wide variation in susceptibility/ resistance to *Melampsora* rust among different species

Table 9: Coefficients of correlation among different studied traits.

	RD1	RD2	RD3	LD1	LD2	LD3	AD1	AD2	AD3	AT	AM	AB
RD2	0.983											
RD3	0.749	0.791										
LD1	0.279	0.269	0.215									
LD2	0.280	0.270	0.219	0.999								
LD3	-0.37	-0.37	-0.31	0.502	0.499							
AD1	0.999	0.982	0.751	0.284	0.286	-0.366						
AD2	0.982	1.000	0.793	0.268	0.269	-0.374	0.982					
AD3	0.776	0.809	0.980	0.228	0.232	-0.289	0.778	0.811				
AT	0.824	0.860	0.898	0.244	0.249	-0.311	0.825	0.860	0.915			
AM	0.937	0.942	0.871	0.296	0.298	-0.286	0.938	0.943	0.910	0.868		
AB	0.906	0.913	0.808	0.204	0.203	-0.426	0.907	0.915	0.808	0.725	0.881	
AVG	0.945	0.962	0.913	0.270	0.272	-0.351	0.946	0.963	0.936	0.925	0.979	0.913

All values of coefficients of correlation were significant (P<0.000).

and clones maintained in the germplasm. Out of a total of 575 clones, 33 clones were in HR, 487 in R, 43 in S, 7 in MS, and 5 in HS categories (Table 10). No rust infection was recorded on individuals of *P. alba, P. ciliata, P. nigra* and *P. deltoides* X *P. ciliata* and these species were therefore disease free. A very little rust infection was recorded in case of *P. sauveolens.* Commercial clones grown at low latitudinal locations in India belong to *P. deltoides* which have shown infection to varying degrees. *P. ciliata*, a native poplar does not tolerate high temperature at low latitudes and is therefore not grown in the RIPC. However, a hybrid developed between *P. deltoides* and *P. ciliata* (Dhiman *et al.,* 2018) is now successfully growing in plains which was disease free having no infection (HR) and could be included in the commercial cultivation in future after its field trials. It is also a valuable genetic material for making back crosses with commercial grown clones for transferring this resistance to new clones. Clones belonging to highly resistant (HR) category and to resistance (R) category could be introduced in commercial nurseries to replace the most susceptible ones. There is some difference in the IR of some clones in a trial of commercial clones and the same clones grown in germplasm bank. The trial of commercial clones was conducted in a well replicated statistical design on a different field, whereas, all individuals germplasm clones were planted together on a different field. Different field conditions and cultural operations in two fields could have resulted in minor differences between the two.

The exact identity of the causal organism of *Melampsora* fungus causing such a wide scale infection in field nurseries and plantations is yet to be established. The oldest record of *Melampsora* rust in India is on native *P. ciliata* from the Himalayas caused by *M. ciliata* (Barclay, 1891). Latter, this fungus was also found infecting the introduced and extensively grown *P.*

Table 10: IR of 575 clones in poplar germplasm bank.

Category	Clones
HR (0)	W17, W21, W26, W36, W40, W41, W70, W88, W89, W91, W93, CP-82-1-19,CP-82-1-21, P 27, B-7/8,1/94, 4/94, 5/94, 9/95, 18/96, 13/99, 36/2000, 40/2000, 1, L 13, P-D-IN, Triplo, IC Punjab of *P. deltoides* and one individual each of *P. deltoides* X *P. ciliata*, *P. robusta*, *P. ciliata*, *P. nigra*, *P. alba* (33 clones).
R (0.1-2.5)	W1, W2, W4, W5, W6, W10, W14, W15, W16, W18, W19, W20, WSL22, W23, W24, W25, WSL27, W30, WSL32, W33, W34, W37, W38, WSL39, W42, W44, W45, W46, W50, W51, W52, W54, W55, W57, Wi58, W59, W60, W62, W63, W65, W66, W67, W68, W69, W71, W72, W73, W74, W75, W76, W77, W78, W79, W80, W81, W82, W83, W84, W85, W86, W87, W90, W92, W94, W95, W96, W97, W98, W99, W100, W102, W103, W104, W105, Wi107, W108, WSLA/26, WSLA/49, Udai, Kranti, Bahar, CP-82-1-12,CP-82-1-20,CP-82-1-24, CP-82-6-3, CP-82-6-5, CP-82-6-8, CP-82-6-13, CP-82-6-17, P-1, P-4, P-5, P-6, P-8, P-9, P-10, P-11, P-12, P-13, P-15, P-17, P-19, P-20, P-22, P-23, P-26, P 29, P-30, P-32, P-33, B-7/2, B-7/4, B-7/5, B-7/6, B-7/7, B-13/1, B-13/3, B-13/4, B-13/5, B-13/6, B-13/8, B-13/9, B-13/10, B-13/11, B-16/4, B-17/9, Ind-44 I, Ind-44 II, Ind-95, Ind-108, Ind-112, Ind-124, Ind-155, Ind-158, Ind-173 II, Ind-201 I, Ind-201 II, Ind-201, Ind-204, Ind-211 II, Ind-219, 2/94, 3/94, 1/95, 2/95, 3/95, 4/95, 5/95, 6/95, 7/95, 10/95, 11/95, 12/95, 13/95, 15/95, 16/95, 17/95, 2/96, 4/96, 5/96, 6/96, 8/96, 9/96, 11/96, 12/96, 13/96, 14/96, 15/96, 16/96, 17/96, 19/96, 20/96, 21/96, 22/96, 23/96, 24/96, 25/96, 26/96, 27/96, 28/96, 29/96, 30/96, 31/96, 1/97, 2/97, 3/97, 4/97, 5/97, 6/97, 7/97, 8/97, 9/97, 10/97, 11/97, 12/97, 13/97, 14/97, 15/97, 16/97, 18/97, 20/97, 22/97, 24/97, 26/97, 28/97, 30/97, 31/97, 32/97, 42/97, 43/97, 44/97, 45/97, 46/97, 47/97, 48/97, 49/97, 51/97, 52/97, 53/97, 54/97, 55/97, 56/97, 57/97, 59/97, 60/97, 62/97, 64/97, 66/97, 67/97, 68/97, 71/97, 72/97, 73/97, 74/97, 75/97, 76/97, 77/97, 78/97, 80/97, 1/98, 2/98, 3/98, 7/98, 8/98, 1/99, 2/99, 3/99, 6/99, 7/99, 10/99, 11/99, 14/99, 15/99, 16/99, 17/99, 1/2000, 2/2000, 3/2000, 4/2000, 5/2000, 6/2000, 7/2000, 8/2000, 9/2000, 10/2000, 13/2000, 14/2000, 16/2000, 17/2000, 18/2000, 19/2000, 20/2000, 21/2000, 22/2000, 23/2000, 24/2000, 27/2000, 28/2000, 30/2000, 31/2000, 32/2000, 34/2000, 35/2000, 37/2000, 38/2000, 39/2000, 41/2000, 45/2000, 46/2000, 47/2000, 48/2000, 49/2000, 50/2000, 51/2000, 1/2001, 2/2001, 3/2001, 4/2001, 5/2001, 6/2001, 7/2001, 8/2001, 9/2001, 10/2001, 11/2001, 12/2001, 13/2001, 37/2003, 38/2003, 39/2003, 40/32003, 41/2003, 42/2003, 44/2003, 46/2003, 47/2003, 48/2003, 49/2003, 50/2003, 51/2003, 52/2003, 1/2005, 2/2005, 3/2005, 4/2005, 5/2005, 6/2005, 7/2005, 8/2005, 9/2005, 10/2005, 11/2005, 12/2005, 1/2006, 2/2006, 3/2006, 4/2006, 5/2006, 6/2006, 7/2006, 8/2006, 10/2006, 12/2006, 13/2006, 14/2006, 16/2006, 1/2007, 2/2007, 3/2007, 4/2007, 5/2007, 6/2007, 8/2007, 9/2007, 10/2007, 11/2007, 12/2007, 13/2007, 14/2007, Ind-59/2009, 4, 6, 7, 62, 1000003001, 1000003004, 1000003030, 1000003103, 1000003272, 1000003014, 1000003018, L-14, L-29, L-30, L-34, L-34(TC), L-49, L-66, L-80, EL-74, Ranikhet, Solan No.1, Hyb-4, Hyb-U, P-D-74, P-D-75, T-1, T-1(40), T-1-24(90), T-19-24(40), 9-2, 47-7, 65-2, 70-3, 86-1, 90-2, 90-8, 96-6,97-7, 100-7, 100-10, # 9, # 10, # 13, # 14, # 19, # 31, # 36, # 42, # 47, # 48, # 49, # 51, # 62, # 76, # 80, # 88, # 98, # 100, # 102, # 103, 28/86, 200/85, Onda, 2000 Verdi, 6955, 3167, 3324, 6401, IC, 65/27, 110120, 110226, 110412, 112107, 112910, I-18, 64-243-3-5, 73-002-8, 73-002-16, 73-002-18, 82-26-5, 82-29-2, 82-33-3, 82-35-4-1, 82-42-5, 2, 104, S7C4, S7C7, S7C8, S7C13, S7C15, S7C15(Over), S7C15(TC), S7C20, S7C21, S13C11, St-29, St-61, St-63, St-66, St-67, St-70, St-71, St-75, St-100, St-121, St-148, St-163, St-171, St-240, St-261, St-273, St-282, St-285, St-288, G-3 (Plus), G-3 (TC), G-3 (Australia), G-3 (Bhimtal), G-3 (Naukuchiatal), G-48 (Australia), & G-48 (Bhimtal) of *P. deltoides* and one individual each of *P. nigra* (M), *P. sauveolens, P. tricocarpa* (487 clones)
S (2.6-5.0)	W8, W11, W12, W13, W47, W109, CP-82-6-1, P-2, P-28, Ind-84, Ind-100 I, Ind-100 II, Ind-173 I, 8/95, 1/96, 3/96, 7/96, 10/96, 69/97, 6/98, 44/2000, 43/2003, 45/2003, 13/2005, 9/2006, 11/2006, 15/2006, 7/2007, L-47, Hyb-2, 96-15, 100-8, # 64, # 74, # 90, # 94, 109/86, 154/86, S.N.F.-1300, 6238, 111510, 430-3, & St-109 (43 clones).
MS (5.1-7.5)	W110, CP-82-5-1, Ind-46, Ind-211 I, # 7, 28/13, & S-235-2, all of *P. deltoides* (7 clones)
HS (>7.5)	W3, 4/98, # 99, S-335X9-335-32-23 & 421/2, all of *P. deltoides* (5 clones)

deltoides in the plains (Rehill *et al.,* 1988; Singh *et al.,* 1983; Khan, 1994). The other rust species recorded on *P. deltoides* in the plains have been *M. medusae* (EPPO, 2020), *M. larici-populina* Kleb (Pandey, 1992), and *M. rordum* (Khan, 1999). A sporadic occurrence of the rust was recorded from some locations in plains on 65/27 clone of *P. deltoides*. The live leaves on this clone persist over the entire winter season on which the rust could be seen till bud break during next growth season. This clone has been regularly used as a root stock for grafting the reproductive buds of other clones for making hybrid crosses. Despite, this clone being grown intermixed with other commercial clones, the rust disease from this clone did not spread to others till the emergence of the current infection was noticed. This clone recorded a low IR (0.49) in the present study indicating towards the remote possibility of transferring the rust infecting fungus from this clone to other heavily infected ones. We have closely monitored the entire poplar germplasm for the last two decades and we did not notice spread of any rust to this extent so far. The identity of the causal organism for this rust disease needs to be confirmed at the earliest for its proper monitoring and designing management strategies.

Trends of rust infestation over the years

The heavy infection of the rust that was recorded during 2016 growing season, continued to reoccur in varying intensities each year. The first infection of the fungus every year is being recorded in the most susceptible clones especially in the core area of RIPC. For example, first place where infection of the rust was recorded was in Kadarpur (Roorkee dist. Haridwar) around middle of October, 2016 and it was on W110 clone. The brief of some salient observations made on the disease in poplar nurseries and plantations during the subsequent years is given below.

2017: There were no disease symptoms on the newly emerged foliage during the start of next growing season (March-April, 2017) anywhere. First symptoms of disease started appearing during the beginning of September on some susceptible clones in nurseries of Yamunanagar (HRY) and Saharanpur (U.P.). In tarai region of U.K. and U.P., first symptoms started appearing during the beginning of 2^{nd} week of October and by 12^{th} October, a fairly good infection was visible in W110 clone which gradually spread to other locations. The disease infection was a little higher during the year with rest of trends being similar to base year 2016. Some more observations were recorded during this year as follows.

The breeding population of 367 seedling hybrids produced during the year had 1 seedling (G48 X W108 cross) in HR, 213 in R, 119 in S, 31 in MS and 3 in HS categories of IR. Observations recorded on W110 clone plantations of different aged groups in Tarai region had IR of 9.1, 9.3, 9.2, 9.2, 9.2, 9.6, 9.4, 9.5, and 9.3 in seedlings, 1, 2, 3, 4, 5, 6, 7 and 8 years old plantations respectively confirming that poplar of all ages is heavily infected with the disease. Reevaluation of germplasm again during the year, confirmed the trend of year 2016 with a few clones shifting among the next categories, W110 remained in HS category, whereas, W109 had a little less infection. Many commercially grown clones belonging to S7C series, those of WSL and W series were in R category.

2018: This year recorded heaviest infection even higher than the base year 2016. It was also seen at low intensities in some nurseries of fringe locations in RIPC. It was first time recorded in Meerut, Bulandshar, Amritsar, Karnal nurseries at a very low intensity. There was good rainfall during the year and that might had helped in its more spread. The rest of the trends were similar to the last two years.

2019 and 2020: Fringe area nurseries again had disease infection of low intensities, whereas, those of core areas of poplar culture had similar trends of high infection. Spray of nurseries with 0.1% Dithane initiated on the first appearing of symptoms and its repeated 4-5 sprays at around 10-12 days interval in core area nurseries started giving good results in checking the spread of disease. Dithane M45 was among a few fungicides suggested for control of *Melampsora* rust of poplar by Khan *et al*. (1988). Late planted nurseries with root trainer raised plants during April-May had a little less disease than those early planted in February with stem cuttings. Root suckers were observed to have high disease infection and their immediate removal during March-April was helpful in reducing the disease spread.

2021: The rust infection started quite early during the month of May in some nurseries in western side of RIPC especially around Balachaur and Ropar in Punjab due to unseasonal rains in April which might have created conducive conditions for rust multiplication. Soon ambient temperature increased and infection disappeared. During autumn, the disease reappeared about a month late as the overall monsoon got delayed and the infection was of a relatively low intensity than past years. Towards eastern side especially in tarai region, there was sever infection in autumn due to heavy rainfall in September. In many locations it was of the same scale of 2016 and 2018. The disease could be kept under control in nurseries with repeated sprays of fungicide. In some severely infested locations, some symptoms of the disease persisted even after sprays.

The disease is reoccurring on a wider geographical area where correlating its spread with site specific weather and climatic factors need to be taken up in future studies. The general trends captured on its spread and management, so far, have been:

- Reoccurrence of the rust is now common feature every year,

- Infection remained high in core RIPC and low or nil in fringe locations, and the trend was similar on plantations of all age groups,
- Rainfall and moderate temperature during autumn and even during spring being primary triggering factors for starting its infection and spread,
- Warm weather conditions (high temperature) without rains kept the disease under control,
- Delay and advance in rainfall results in delay and early infection,
- Disease sometimes appear in spring or early summers due to low temperature and high humidity which get disappeared on rising of the temperature and reappears again during next autumn months,
- Clones with larger leaf area are in general more susceptible,
- Dominant saplings more infected than suppressed ones, saplings on the outer periphery of nurseries are more infected than those inside nurseries,
- Clonal variation in rust infection is relative and under heavy infection many other clones in core areas also get infected may be to a lesser degree,
- Root suckers from last year nursery and coppice shoots from stumps of harvested poplar generally show early and heavy infection and,
- Nurseries regularly sprayed with fungicide kept the disease under some control and leaf fall of saplings in such nurseries has been normal.

The current practices for managing the diseases are restricted to the nurseries only. Maintaining good hygiene inside nurseries by removing unwanted competing plants; early removal of root suckers regenerated from last year plants, late plating of nurseries with root trainer plants compared to those planted with stem cuttings, spray of Dithane M-45 (0.1%) on first appearing the symptoms with additional 4-5 sprays thereafter, and planting the nurseries with relatively resistant clones are helping in the effective management of disease. On tall and older plantations, no such spray is yet attempted, though many farmers have now started avoiding planting of highly susceptible clones. The demand for other relatively less susceptible clones like W111, W112, W81 and a few others is now increasing and the share of highly susceptible W110 is gradually decreasing atleast in the core area of poplar culture.

Conclusion

This study captured only the general trends, detailed studies in different locations and correlating its further infection with local factors may be useful to understand further dynamics of the disease and its spread. Further studies are needed to see the effects on poplar growth and economical losses associated with it. There are already some reports of mortality of saplings in some heavily infected nurseries; a detailed study may help to estimate damage to infected poplar nurseries and plantations. Fungicide spray may be practical and appropriate at only nursery level, an integrated diseases management needs to be developed for plantations. Poplar breeding programme till date focused on screening hybrid seedling populations for leaf blight disease caused by *Bipolaris maydis* (Dhiman and Gandhi, 2012), the scope has been enlarged for rust screening.

पॉपुलस डेल्टोइड्स पर मेलम्पसोरा लीफ रस्ट का भारी संक्रमण

आर.सी. धीमान

सारांश

यह लेख भारतीय हिमालय की तलहटी के दक्षिण में अधिकांश क्षेत्र में मौजूद पौपलर (*पापुलस डेल्टोइड्स*) पर मेलम्पसोरा रस्ट के भारी और व्यापक संक्रमण की रिपोर्ट करता है। एक क्षेत्र सर्वेक्षण के परिणाम और व्यावसायिक रूप से उत्पादित क्लोनस और जर्मप्लाज्म की क्लोनल भिन्नता रस्ट संक्रमण की रेटिंग के रूप में प्रस्तुत की है। नर्सरी को रस्ट इन्फेक्शन इंडेक्स (आर आई आई) के आधार पर वर्गीकृत किया गया है। संक्रमण रेटिंग (आई आर) के 0 से 10 पैमाने के बीच रेट किए गए क्लोनों ने व्यापक भिन्नता दिखाई है। सघन पौपलर उत्पादन के मुख्य क्षेत्र के आसपास स्थित नर्सरीयों में सीमांत स्थानों की तुलना में उच्च आर आई आई था। इसी प्रकार जर्मप्लाज्म में अनुरक्षित क्लोनों के आई आर में व्यापक भिन्नता दर्ज की गई है। क्लोन W110 में पोपलर उत्पादन के मुख्य क्षेत्र में उगाए गए अधिकांश स्थानों में अधिकतम आई आर था।

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