RELATIONSHIP BETWEEN LEAF FLUSHING TIME AND INITIATION OF LEAF RUST IN POPLAR

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The indigenous species of poplar (*Populus ciliata*) is widely distributed in the temperate Himalayas from Kashmir to Arunachal Pradesh between 1300 to 3500 m above sea level (Sharma 2000). Apart from indigenous species, exotic hybrids and species of *Populus*, namely, *P. nigra*, *P. deltoides*, *P.* × *euramericana*, *P. alba* and *P. tremula* are being grown in India (Khosla & Khurana 1982). *Melampsora ciliata*, an indigenous, heteroecious and microcyclic rust having only uredinial and telial stages, attacks *P. ciliata*, *P. alba*, *P. deltoides*, *P. nigra*, *P.* × *euramericana*, *P. yunnanensis* and *P. trichocarpa* (Anonymous 1979, Sharma & Sharma 2000). This rust species was also reported to occur in Nepal, attacking *P. ciliata*, and its risk of introduction into Europe has also been indicated (Vannini *et al.* 1996). This pathogen is widely distributed in Himachal Pradesh (western Himalayas) from 700 to 3130 m asl but so far no pathotypes have been reported. Studies of effects of leaf maturity and shoot age of clones of *Populus* spp. on susceptibility to *M. larici-populina* has shown that leaves of intermediate age have the greatest susceptibility to infection (Sharma *et al.* 1980). The variation in leaf flushing time of poplar genotypes (Mohanty 1997) and disease initiation (Khan 1994) have been observed and these findings form the basis for doing the present work. This observation was collectively studied to see the relationship between these aspects which may be utilised for future research.

Cuttings of the test clones, hybrids and species, with lengths of 18–23 cm, were planted at 45 × 45 cm spacing in a randomised block design in the nursery beds at 30° 52' N latitude and 77° 11' E longitude and 1350 m above sea level on 7 February 1999. All cuttings were obtained from vigourously growing plants maintained for propagation purpose. The clones, hybrids and species planted were Theog, Narkanda, Diyar, Chamoli-2, Chhatrari, Madhoni, Delcant, Nagni-2 (*P. ciliata* clones); *P. ciliata* hybrids (*P. ciliata* × *P. maximowiczii*), namely, 37M1, 53M1, 64M1, 84M1, 87M1, 96M1, 112M1, 2M2, 30M2, 53M2, CM2-5-20/91, CM2-10-7/91, CM2-4-15/91, CM2-13, CM2-39, CM2-46, CM2-84; and *Populus* spp., namely, *P. yunnanensis*, *P. deltoides* '19' and Hyb-3. These cuttings were planted in the nursery beds surrounded by hillocks/mountains and there were no semi-evergreen poplar trees in the vicinity, which could otherwise act as source of inoculum.

The phenological observations were made on two phenophases, namely, leaf emergence and fully expanded leaf. A particular phenophase starts when about 10% of individuals are observed in that phase and is complete when a maximum of 10% individuals have not entered that particular phase (Semalty & Sharma 1996). The observations were recorded thrice weekly. Leaf emergence was defined by the emergence of folded leaves from the bud while fully expanded leaf was marked with the emergence of complete leaf. Initiation of disease was recorded with the first appearance of urediniopustules on the leaf. Data on days to reach leaf emergence, fully expanded leaf and disease initiation were recorded after planting of cuttings.

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The data were subjected to the statistical analyses using standard procedures as described by Panse & Sukhatme (1985). The correlation between leaf flushing time and disease initiation was also determined.

The time taken after planting to reach the stages of leaf emergence, fully expanded leaf and disease initiation in clones and hybrids of *P. ciliata* and *Populus* spp. is presented in Tables 1 to 3. Among the *P. ciliata* clones Theog, Narkanda, Diyar and Madhoni took the least time of 40 days to reach leaf emergence while clone Nagni-2 took the longest time of 49 days. The least time of 57 days for emergence of fully expanded leaf was recorded in Diyar and Madhoni clones while the longest time of 74 days was recorded in Nagni-2 clone. Other clones took 58 to 61 days for the emergence of fully expanded leaves. Rust appeared on 25 June 1999, 138 days after planting in Theog clone while it appeared on 7 July 1999, 152 days after planting in Delcant clone (Table 1).

Leaf emerged 51 days after planting in *P. yunnanensis* and 59 days after planting in *P. deltoides* '19' and Hyb-3 (Table 2). The first fully expanded leaf took 74 days to appear in *P. deltoides* '19' and Hyb-3, while in *P. yunnanensis* it took 75 days. Rust appeared in *P. deltoides* '19' on 17 June 1999, i.e. 130 days after planting while in *P. yunnanensis*, it appeared after 160 days.

Among the hybrids, CM2-39 and CM2-84 took the least time of 49 days for the emergence of leaves while 53M2 took the longest period of 56 days (Table 3). The first appearance of fully expanded leaf was recorded in CM2-39, 66 days after planting while the last, 74 days after planting in 53M2 and CM2-84. Hybrid 53M1 took the least time of 138 days for the initiation of rust while CM2-46 took 165 days, i.e. the longest time.

Correlations between leaf flushing time (leaf emergence and fully expanded leaf) and disease initiation in these poplar genotypes are given in Tables 4 and 5. Disease initiation was positively correlated with leaf emergence (0.4775) and fully expanded leaf (0.2485) in *P. ciliata* clones while negatively correlated in *P. ciliata* hybrids. Disease initiation in *Populus* species was negatively correlated with leaf emergence (- 0.6547) but positively correlated with fully expanded leaf (0.6547). Pooled correlation coefficients showed that

Table 1 Number of days to reach leaf flushing and initiation of leaf rust in clones of *Populus ciliata*

Clone	Days to reach leaf emergence	Days to reach fully expanded leaf	Days to reach disease initiation
Theog	40 (19 March 1999)	61 (9 April 1999)	138 (25 June 1999)
Narkanda	40 (19 March 1999)	61 (9 April 1999)	141 (28 June 1999)
Diyar	40 (19 March 1999)	57 (5 April 1999)	142 (29 June 1999)
Madhoni	40 (19 March 1999)	57 (5 April 1999)	151 (8 July 1999)
Chamoli-2	42 (21 March 1999)	58 (6 April 1999)	143 (30 June 1999)
Chhatrari	44 (23 March 1999)	59 (7 April 1999)	141 (28 June 1999)
Delcant	44 (23 March 1999)	59 (7 April 1999)	152 (9 July 1999)
Nagni-2	49 (28 March 1999)	74 (22 April 1999)	150 (7 July 1999)

Table 2 Number of days to reach leaf flushing and initiation of leaf rust in *Populus* spp.

Populus species	Days to reach leaf emergence	Days to reach fully expanded leaf	Days to reach disease initiation
P.yunnanensis	51 (30 March 1999)	75 (23 April 1999)	160 (17 July 1999)
P. deltoides 'Lux'	59 (7 April 1999)	74 (22 April 1999)	154 (11 July 1999)
P. deltoides '19'	59 (7 April 1999)	74 (22 April 1999)	130 (17 July 1999)

disease initiation was positively, though poorly, correlated with leaf emergence and fully expanded leaf.

Partial correlation coefficients between disease initiation and leaf flushing time in the poplar studied are presented in Table 5. Disease initiation was positively correlated with leaf emergence in *P. ciliata* clones and hybrids while the opposite was observed between fully expanded leaf and disease initiation. Pooled partial correlation coefficients showed that disease initiation was positively correlated with leaf emergence (0.0948) but negatively correlated with fully expanded leaf.

Multiple regressions between disease initiation and flushing time indicated that a unit change in leaf emergence and fully expanded leaf could influence disease initiation up to 0.036 and 0.842 units respectively (Table 6). The coefficient of multiple determinations (r^2) revealed that 76.32% variation in disease initiation was contributed by leaf flushing time.

Table 3 Number of days to leaf flushing and initiation of leaf rust in hybrids of *Populus ciliata*

Hybrid	Days to leaf emergence	Days to fully expanded leaf	Days to disease initiation
CM2-84	49 (28 March 1999)	74 (22 April 1999)	149 (6 July 1999)
CM2-39	49 (28 March 1999)	66 (14 April 1999)	154 (1 July 1999)
53M1	51 (30 March 1999)	68 (16 April 1999)	138 (25 June 1999)
2M2	51 (30 March 1999)	68 (16 April 1999)	142 (29 June 1999)
30M2	51 (30 March 1999)	68 (16 April 1999)	143 (30 June 1999)
64M1	51 (30 March 1999)	68 (16 April 1999)	149 (6 July 1999)
84M1	51 (30 March 1999)	68 (16 April 1999)	150 (7 July 1999)
CM2-5-20/91	51 (30 March 1999)	68 (16 April 1999)	150 (7 July 1999)
CM2-10-7/91	51 (30 March 1999)	68 (16 April 1999)	151 (8 July 1999)
87M1	51 (30 March 1999)	68 (16 April 1999)	151 (8 July 1999)
CM2-4-15/91	51 (30 March 1999)	68 (16 April 1999)	154 (11 July 1999)
37M1	51 (30 March 1999)	68 (16 April 1999)	161 (18 July 1999)
CM2-46	51 (30 March 1999)	68 (16 April 1999)	165 (22 July 1999)
112M1	53 (1 April 1999)	71 (19 April 1999)	152 (9 July 1999)
CM2-13	53 (1 April 1999)	71 (19 April 1999)	153 (10 July 1999)
53M2	56 (4 April 1999)	74 (22 April 1999)	151 (8 July 1999)

Table 4 Simple correlation coefficient (r^2) between disease initiation and leaf flushing time in *Populus* species/clones/hybrids

Flushing time	*P. ciliata* clone	*P. ciliata* hybrid	*Populus* spp.	Pooled
Leaf emergence	0.4775	- 0.0379	- 0.6547	0.1299
Fully expanded leaf	0.2485	- 0.0680	0.6547	0.0960

Table 5 Partial correlation coefficients (r^2) between disease initiation and leaf flushing time in *Populus* species/clones/hybrids

Flushing time	*P. ciliata* clone	*P. ciliata* hybrid	*Populus* spp.	Pooled
Leaf emergence	0.4769	0.0695	- 0.6547	0.0948
Fully expanded leaf	- 0.2481	- 0.1680	0.6547	- 0.0357

Table 6 Multiple regression equation showing relationship between disease initiation and leaf flushing time in *Populus* species/clones/hybrids

Regression equation	Coefficient of multiple determination r^2 (%)
$-12.54 + 0.036X_1 + 0.842X_2$ (10.85) (0.07) (0.08)	76.32

Figures in parentheses are standard errors of regression coefficients
X_1 = Leaf emergence
X_2 = Fully expanded leaf

Variations in flushing time and disease initiation of poplar have been reported (Khan 1994, Mohanty 1997) but not the relationship between flushing time and disease initiation. However, Sharma *et al.* (1980) have reported the effect of leaf maturity and shoot age of *Populus* spp. on susceptibility to *M. larici-populina*. The shortest period for initiation of rust in this study was recorded in *P. deltoides* '19', Theog and 53M1 and these genotypes may be rated as highly susceptible. Simple and partial correlations showed that variations in the disease initiation at different locations and in different genotypes could be ascribed to variations in flushing time as well as to prevailing microclimate of the area. In addition, the overall development of the disease also depends on the distance of source of infection and the prevailing pathotypes. Since no pathotypes of *M. ciliata* have been reported to occur in India, we conclude that variations in the disease initiation in different poplar genotypes grown under varied agroclimatic conditions are due to the variations in flushing time, microclimate of the site and distance from source of infection.

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