Suppression of Chir pine Regeneration by *Imperata cylindrica* (L) P. Beauv. in Hazara Civil Division

P.H. Haydock-Wilson, *A graduate Forestry student, at forestry Institute, University of Oxford.*
A. R. Beg, *Forest Botanist, Pakistan Forest Institute, Peshawar.*

Abstract

Regular burning, canopy removal and clearance of ground cover on the slopes have led to colonisation by the bladey grass *Imperata cylindrica* (L.) P. Beauv. a pan-tropical weed. Plots with and without the presence of *Imperata* were sampled over six sites along a single watershed. The number and biomass of Chir pine (*Pinus roxburghii* Sargent) seedlings of all ages were found to be markedly less in plots where *Imperata* ground cover exceeds 75%. Over the range of sites, however, other factors of the pine's regenerative ecology appear to dwarf this effect and analysis of variance showed the difference to be non-singificant.

Mycorrhizal growth intensity on the seedling roots was also assessed at different depths in the soil in each sample plot and an attempt was made to correlate this with soil phenol concentration. Results were inconclusive and lend no support to the hypothesis positing allelopathic suppression of mycorrhiza by phenols secreted by *Imperata.*

No recommendations for management are made, as the problem of *Imperata* colonisation does not apear pressing, relative both to the wider problem of forest clearance in the area, and to the cost of any possible solution.

Introduction

Chir pine (*Pinus roxburghii* Sargent) dominates the subtropical forest zone of the western Himalayan foothills. That it is virtually the major tree species found between 800 to 2000 metres is attributed to its exceptional resistance to fire (Champion, *et al.* 1965) In Hazara, the Forest Department manages the chir on a shelterwood system. Allowing the forest to regenerate naturally except where watersheds are threatened by rapid denudation. Increased pressure on the slopes for grazing and firewood has caused a general decline in the chir forest and, less obviously wide spread failure of natural regeneration. Particularly damaging appears to be the firing of the ground layer by graziers in the dry season, to remove the pine needles and prevent their animals slipping on the steep slopes. Each summer, the area is subject to uncontrolled brush fires.

A further effect of the combined pressure of heavy grazing, canopy removal, and seasonal burning is the steady invasion of the area by the bladey grass *Imperata cylindrica* (L.) P. Beauv. *Imperata* is a vigorous perennial grass, which propagates itself through thick underground rhizomes. Observations of Mohan and Puri (1956) on difficult regeneration on sites with rich grass growth in the Indian Punjab and Himachal Pradesh and work in the Philippines indicating allelopathic suppression and ousting of *Pinus khasya* led the second author to seek a similar explanation for the pattern of chir seeding mortality in the Siran Forest Division of Hazara. Data collected by P.F.I. workers in 1987 (P.F.I. annual Progress Report pp 271-272) suggests a decline in seedling numbers with increasing age in the *Imperata*- colonised areas and a complete absence of seedlings older than four years. The second author framed the hypothesis that toxic secondary compounds released by *Imperata* stems and leaves accumulate at depth in the soil such as to suppress mycorrhiza associated with growing seedlings, and that mortality followed the resulting inability of the weakened root-uptake system to supply nutrients to the rapidly-developing shoot. The group of compounds thought the most likely candidates for this allelopathic sabotage are the phenols, known to be present in large concentrations in *Imperata* stems and leaves. (Abidi, 1983)

The study area is located in compartments 4 and 5 of "guzara" forests in the upper Siran Range and lies on a watershed between two tributary valleys, joining the Siran from the North-East at Dariel and 6 km above Shinkiari. The average altitude of the site is roughly 1400 m with maximum gradient of 45%. The local people exploit the forest through grazing of cattle and goats, felling and lopping of mature pines and poles, and tapping resin from the trunks of mature trees. This area was selected because it was not affected by a particulary damaging fire which destroyed ground cover over most of the Siran Valley in 1987.

Imperata cylindrica was present on the slopes, distributed in patches not corresponding to any observable environmental pattern. Mature pine, of thirty years and above, formed an open canopy, under which dense patches of 10 to 20 year old poles alternated with areas of vigorous regeneration and patches of bare ground. This discontinuous distribution, in space and time, was suggestive of recent variations in reproductive ecology.

Materials and Methods

Six sites were selected for sampling in the study area, within one kilometre of each other, delineating two sample plots of 5m x 5m, corresponding to the areas of maximum and minimum *Imperata* cover on the site. From each sample plot, all chir pine seedlings of age one to five years were collected, care being taken to keep the root system of each intact.

Mycorrhizal growth index (MGI) at soil depth classes corresponding to 5 cm intervals was assessed for each sample plot by holding each seedling root up to a calibrated board and scoring 0, 1 or 2 for, respectively, no mycorrhiza, some mycorrhiza and vigorous mycorrhizal growth, estimated by eye for each depth class and tallied for all the seedlings in the sample.

The seedlings were washed and sorted into age classes (1 to 5) based on characteristic branching patterns and the number of seedlings of each age class recorded for each sample. Cutting each seedling at the 'bole' , values for root biomass, shoot biomass and total biomass for each age class/sample were obtained using a spring balance.

Finally, a 50 cm pit was dug vertically in the centre of each sample plot and soil samples were extracted at depths of 5, 10, 15, 20, 25, 30, and 35 cm.

The soil samples collected were analysed by the Department of Chemistry, Peshawar University. Each sample was oven-dried at 110° C for two hours and weighed. Standard quantities were then treated with 20 ml of 10% N_aOH solution and the mixture shaken on a Gallenkamp flask shaker for 15 minutes. The suspended particles were allowed to settle, then filtered off. The absorbance of the solution was measured using U.V./ visible spectrophotometry at 275 nm. The concentration of phenols in the solution was calculated from a calibration curve based on the absorptive spectrum of standard solution of phenols at different concentrations. Due to the limited time, estimation were only made for samples from sites III, IV, V and VI.

Results and Discussion

The results obtained from the sample plots are given in tables 1 to 8.

Significance of the relationship between *Imperata* presence and chir regeneration.

Analysis of variance (anova) was carried out on three sets of data representing regeneration intensities.

1. Number of seedlings (Table 1)

2. Total seedling biomass (Table 2)

3. Total root biomass (Table 3)

The tests were based on the split-plot design adopted for sampling with six replications (sites), two treatments (*Imperata* present/absent) and five levels (seedling age class). F-values of analysis of variance are given in table 4.

Table 5 shows that seedling number, total biomass and total root biomass in the non-*Imperata* samples consistently exceed those in the *Imperata* areas, yet only in analysis for root biomass, is this difference statistically significant at 5% probability level. This can be ascribed to the enormous differences between blocks, sites sample in the survey. Table 6 gives some sites data but no single factor appears to adequately explain the variation. Since grazing is fairly uniform in the area, the variation could probably be due to microclimatic conditions. If the highest mortality is caused, by dehydration of the seedlings in the hot season, more seedlings should survive on sheltered north-facing slopes with good canopy cover. Edaphic factors are also involved.

In analysis for seedling number, the difference between age classes is significant at 1% level and the reduction in number of seedlings with age is seen in tables 1 and 4. However, there is no significant interaction between presence of *Imperata* and seedling age class, and, therefore, the effect of *Imperata* is not age discriminating. Further, this does not support the hypothesis earlier made which predicts heavy mortality among older seedlings in *Imperata* areas.

Role of mycorrhiza and soil phenol concentration in suppression of chir regeneration.

Table 7 shows observed mycorrhizal growth index (MGI) at seven depths in each of the sample plots. The data were statistically analysed along the lines of those mentioned above; the levels representing depth in the soil in this case.

Table 1. Number of seedlings

T_2(seedling age)	Replications (Site No.) I	II	III	IV	V	VI	Total
T_1=0 (Imperata absent)							
1	24	88	8	32	123	58	333
2	5	17	14	32	103	50	221
3	1	2	18	17	48	24	110
4	1	1	9	6	21	14	52
5	1	1	4	3	17	2	28
Total	32	109	53	90	312	148	744
T_1=I (Imperata present)							
1	15	56	4	50	73	48	246
2	2	1	6	36	52	53	150
3	1	0	3	5	23	22	54
4	0	0	1	1	5	9	16
5	0	0	0	2	3	2	7
Total	18	57	14	94	156	139	473
Grand Total	50	166	67	184	468	287	1217

Table 2. Total seedling biomass (gm)

T_2 (Age)	Replication (Site No.) I	II	III	IV	V	VI	Total
T_1= 0 (Imperata absent)							
1	28	148	18	48	187	90	519
2	14	57	54	110	377	175	787
3	15	28	136	120	333	138	770
4	33	20	142	74	241	136	646
5	65	26	90	104	402	39	726
Total	155	279	440	456	1540	578	3448
T_1= I (Imperata present)							
1	35	85	10	58	98	80	366
2	19	5	23	102	171	158	478
3	16	0	24	12	153	134	357
4	0	0	16	40	93	86	207
5	0	0	0	56	72	25	143
Total	70	90	73	248	587	483	1531
Grand Total	225	369	513	704	2127	1061	4979

Table 3. Total root biomass (gm)

T_2 (Age class)	Replications (Site No.) I	II	III	IV	V	VI	Total
T_1=0 (Imperata absent)							
1	10	44	7	17	67	33	178
2	6	30	22	48	132	64	292
3	7	9	65	47	135	48	301
4	15	9	58	26	88	60	266
5	35	15	32	43	123	16	264
Total	73	97	184	181	545	221	1301
T_1= I (Imperata present)							
1	12	28	3	20	27	27	117
2	11	2	7	38	62	60	180
3	9	0	8	12	55	46	130
4	0	0	6	5	25	27	63
5	0	0	0	18	23	8	49
Total	32	30	24	93	192	168	529
Grand Total	105	127	208	274	737	389	1830

Table 4. F-values of analysis of variance

Source	df	F - Values		
		Seedling No.	Seedling biomass	Root biomass
Blocks	5	7.18**	4.46 n.s.	5.39*
Treatments	1	3.66 n.s.	5.41 n.s.	8.69*
Error	5	15.34*	1.25 n.s.	2.28 n.s.
Levels	4	0.20 n.s.	0.91 n.s.	0.91 n.s.
Levels and treatments	4			
Error	40			

n.s. — Non - significant
* — Significant at 5% level
** — Highly significant at 1% level

Table 5. Site-sum data: Seedlings

Imperata Absent 0 150m² / Imperata present I 150m²

Age class	No. of seedlings (gm)	Root biomass (gm)	Shoot biomass (gm)	Total biomass (gm)	Root/shoot biomass ratio	Mean total biomass (gm)	
1	333 / 246	178 / 117	341 / 249	519 / 366	0.52 / 0.47	1.6 / 1.5	
2	221 / 150	292 / 180	495 / 298	787 / 478	0.59 / 0.60	3.6 / 3.2	
3	110 / 54	301 / 130	469 / 227	770 / 357	0.64 / 0.57	7.0 / 6.6	
4	52 / 16	266 / 63	380 / 144	646 / 207	0.70 / 0.70	12.4 / 13.0	
5	28 / 7	264 / 49	462 / 94	726 / 143	0.57 / 0.52	26.0 / 20.4	
Total	744 / 473	1301 / 529	2147 / 1012	3448 / 1531	0.61 / 0.52	4.6 / 3.2	

Table 6 Site environmental data

Imperata absent: O (upper value in each cell); Imperata present: I (lower value in each cell)

		Replications (Site No.)					
		I	II	III	IV	V	VI
Slope Angle	O	20°	25°	20°	25°	15°	30°
	I	15°	25°	25°	25°	20°	25°
Aspect	O	SE	SE	S	SW	NE	N
	I	N	SE	SE	S	NE	NE
Canopy cover	O	5%	30%	0	0	30%	10%
	I	5%	20%	0	0	35%	20%
Imperata Cover	O	5%	10%	10%	0	10%	15%
	I	75%	95%	85%	80%	100%	70%

Soils: Light sandy loam over soft shale regolith.

Anova #: mycorrhizal growth index

No.	Source	df	SSq	MSq	F-values
6	Blocks	5	12.147	2.429	5.90 Significant (at the rate of 0.05)
2	Treatments	1	1.839	1.839	6.22 -do-
	Error	5	1.760	0.352	
7	Levels	6	26.325	4.387	11.89 significant(at the rate of 0.001)
	Levels* Treat	6	1.914	0.319	0.86 non-significant
	Error	60	22.139	0.369	

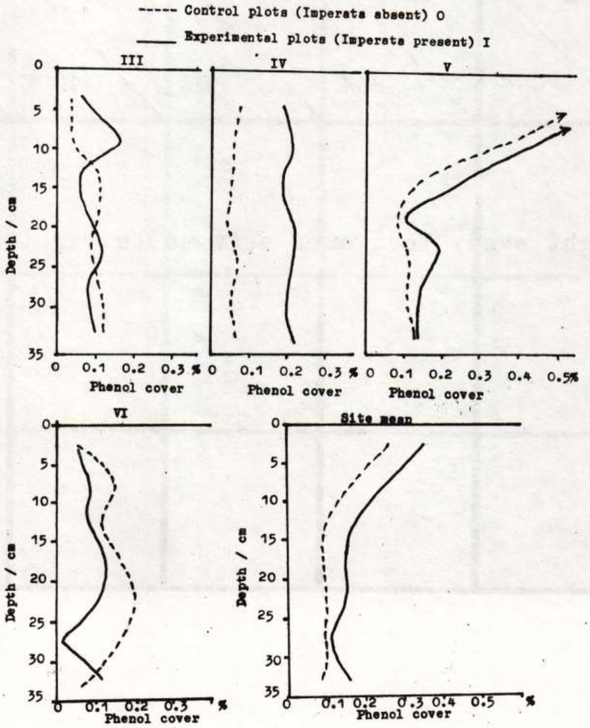
Both differences in MGI in between sites and *Imperata* and non *Imperata* areas are significant. The variation of MGI down the soil profile is also very highly significant. However, if the interaction is non-significant, which suggests that any effect of *Imperata* on mycorrhizal growth is not local to particular soil strata. Alternatively, the decline of organic activity with depth in the soil could have masked this effect.

MGI is by definition dependent on seedling number, but the problem of causation remains: is it the mycorrhizal symbiont that is limited by the availability of roots: or is MGI a true indicator of the capacity of the soil for mycorrhiza, and a governing factor of root growth? The techniques of the investigators were not sophisticated enough for an answer.

Figure 1 and table 8 show the phenol concentration distribution profiles, obtained for each of the sites II, IV, V and VI. Particularly high concentrations were found in the upper 10 cm of site V, both in *Imperata* and non-*Imperata* plots, and, that too corresponding to maximum vegetal cover. The totals for the *Imperata* and non-*Imperata* plots show a similar trend, phenol concentration diminishing with depth, indicating that phenols are retained in the upper horizon. The rate of leaching is, therefore,less than the combined effects of secretion and biological degradation of phenols in the upper layer,at least in site V.

The mean phenol concentration under *Imperata* (0.22%) is greater than that under plots without *Imperata* (0.17%)which suggests that *Imperata* does secrete phen-

Figure 1. Phenol distribution profiles



ols. The differences are however, statistically non-significant. Further, the phenol distribution bears no apparent relation to mycorrhizal growth index. The greatest density of mycorrhiza (in site V) corresponds to the highest phenol concentration which is not obeserved in all pots. Figure 2 shows the scatter diagram of MGI on phenol concentration.

Table 7. Mycorrhizal growth index

Imperata absent 0 / Imperata present I

Depth(cm)	Replications (Site No.) I	II	III	IV	V	VI	Total
5	24 / 1	17 / 14	30 / 2	21 / 24	108 / 80	14 / 16	214 / 137
10	5 / 9	84 / 46	33 / 11	66 / 34	166 / 87	29 / 30	383 / 197
15	1 / 4	15 / 24	12 / 5	45 / 6	77 / 13	12 / 10	198 / 62
20	1 / 2	7 / 2	2 / 2	17 / 1	19 / 2	1 / 0	47 / 9
25	0 / 0	2 / 0	0 / 0	3 / 0	5 / 0	0 / 0	10 / 0
30	0 / 0	0 / 0	0 / 0	1 / 0	1 / 0	0 / 0	2 / 0
35	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
Total	32 / 16	161 / 86	77 / 20	153 / 94	376 / 162	56 / 56	854 / 405

Table 8. Soil phenol distribution in different sites

Imperata absent(O) / Imperata present (I)

	Depth(cm)	III	IV	V	VI	Total
O	5	0.06	0.08	1.11	0.08	0.33
I		0.08	0.23	1.26	0.08	0.41
O	10	0.06	0.07	0.45	0.18	0.19
I		0.21	0.27	0.48	0.12	0.27
O	15	0.13	0.07	0.16	0.14	0.12
I		0.07	0.23	0.35	0.11	0.19
O	20	0.13	0.40	0.10	0.23	0.12
I		0.09	0.28	0.11	0.17	0.16
O	25	0.11	0.09	0.14	0.25	0.13
I		0.15	0.26	0.23	0.12	0.19
O	30	0.14	0.06	0.14	0.18	0.13
I		0.09	0.24	0.16	0.03	0.13
O	35	0.15	0.09	0.15	0.08	0.12
I		0.10	0.28	0.15	0.17	0.18
O	Total	0.11	0.07	0.32	0.16	0.17
		0.11	0.25	0.39	0.11	0.22

Conclusions and Recommendations

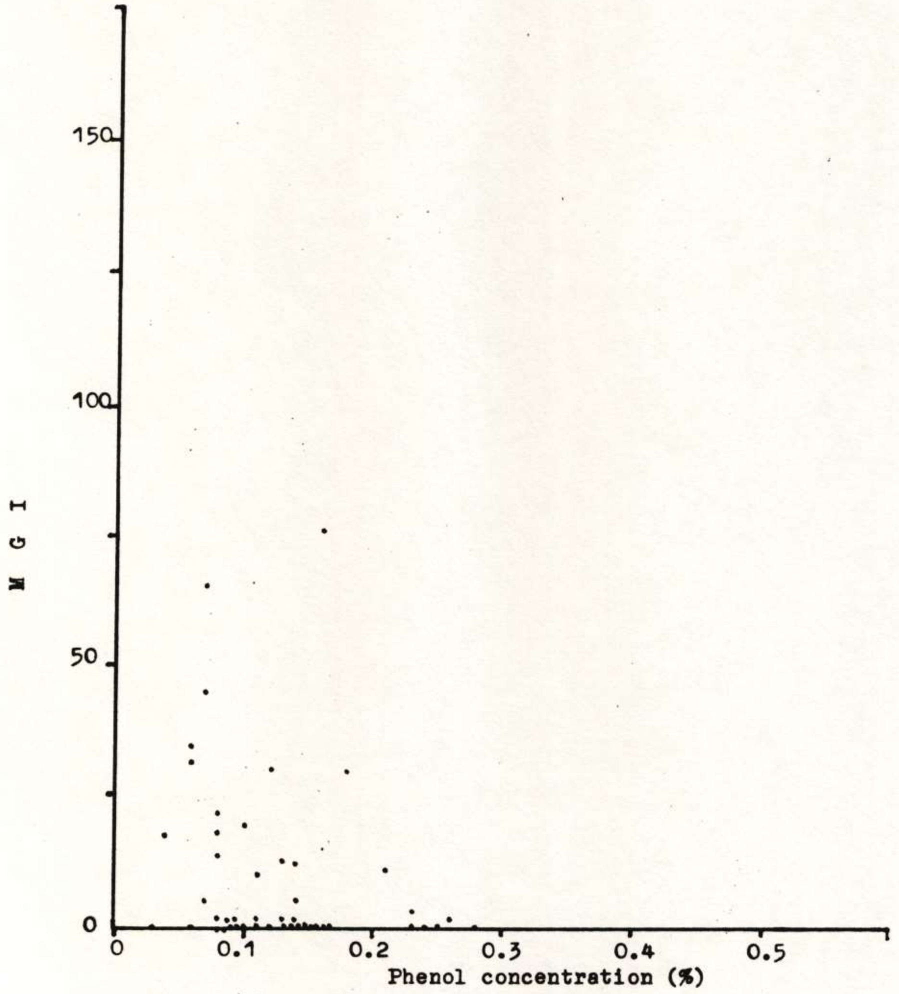
Imperata is a vigorous, fast-growing grass; its rhizomatous propagation and relative unpalatability contribute to its success in invading the region. Results from the field corroborate the assumption that its presence suppresses chir seedling, probably through competition with the seedlings for light and nutrients. Specimens of one year - old chir seedlings were found with roots completely entangled by thick *Imperata* rhizomes, and in one case a rhizome penetrated right through the main tap-root. Despite this, in many areas the effect of such competition is not enough to prevent sufficient seedlings attaining maturity to provide a full pine canopy.

If allelopathy is a component of the chir - *Imperata* ecology, it has yet to be explored. That phenols are a significant suppressive agent is not proved by this investigation. It may be that a limited class of phenolic compounds or some other compounds secreted by *Imperata* and toxic to chir which need to be investigated.

It may also be interesting to study chir pine seedling population dynamics, either in the field or under controlled conditions for a number of years. Already noted is the prevalance of clumps of uniformly aged chir poles in the area, which could be a function mainly of seed dispersal, germination or fires over the years.

Figure 2. Scatter plot of Mycorrhizal growth index(MGI) on phenol concentration.

- apparently random.



Experience in the Philippines, Nepal and elsewhere has shown that chemical control of *Imperata* in timber plantations is costly and difficult. On naturally-regenerating ranges the effort would be futile. Conversely, dense chir growth of up to 20 years old was seen on hillsides completely colonised by *Imperata,* though it is not known whether colonisation was relatively recent. Far more important, from the manager's viewpoint, is to control excessive burning by human agents, which has a direct effect on the viability of the forest.

Acknowldgement

The authors wish to thank Dr. Rasool Jan, Department of Chemistry, University of Peshawar, for capably supervising the analysis of soil phenols, Mr. Qasim Shah for helping with the statistics, and the staff of the Pakistan Forest Institute and the villagers of Batang village for their co-operation and hospitality, extended at various stages of this project.

REFERENCES

1. ABIDI,N. 1983. Allelopathic effects of *Imperata cylindrica*. M.Sc. thesis. Botany Department, University of Peshawar.

2. ANON, 1987. Annual Progress Peport. Pakistan Forest Institute, Peshawar. PP. 271-272.

3. CHAMPION, H.G., S.K. SETH AND G.M. KHATTAK 1965. Forest Types of Pakistan. Pakistan Forest Institute, Peshawar.

4. MOHAN, N.P. AND G.S. PURI 1956. The Himalayan conifers. V. The succession in chir pine forests of the Punjab and Himachal Pradesh. Ind. For. XVIIIC (7)