sputter-coated with gold in a sputter coater (JE 1100). Samples were kept in the desiccator until examination by SEM (JEOL, JSM 5200) at 20 kV and micrographs were taken.

Mycelium of *U. segetum tritici* was totally overgrown by *T. koningii*, which sporulated abundantly after 4 days. SEM observations also showed overgrowth of *T. koningii* on the hyphae of *U. segetum tritici* (Figure 1 *a*). The antagonist formed penetration pegs with slightly enlarged tips at a few places (Figure 1 *b*). Sometimes hook-like projections were also seen penetrating the host mycelium (Figure 1 *c*). The mycelium of *U. segetum tritici* was suppressed and lysed. The collapse and lysis of host pathogen may be attributed to the production of antifungal substances. The disorganization of the host cells and concomitant changes in the cells of the parasite have been established for *Trichoderma* spp. and *Gliocladium* spp[1,3]. Benhamou and Chet[4] demonstrated through SEM that coiling of the antagonist (*T. harzianum*) around its host (*R. solani*) was an early event preceding hyphal damage.

The present study revealed that the physical contact between the two fungi followed by lysis of the host cells seems to be the mechanism of biological control of *Ustilago segetum tritici*.

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Ecology of forest fires in chir pine (*Pinus roxburghii* Sarg.) forests of Garhwal Himalaya

Research over the last five decades has proved fire as a part of normal 'climate' in most of the terrestrial ecosystems of the world. Therefore, biotic communities adapt to and compensate for this integral factor, just as they do for other ecological factors[1], e.g. temperature, rainfall, humidity, etc. It is believed that if properly used fires can be a management tool of great value. The effects of fire on vegetation depend on a number of factors, e.g. topography of the landscape, the structure of vegetation, fire intensity and its mode of spread, types of fuel and fuel loading, season of burning, post fire precipitation etc.

In any terrestrial ecosystem fire can be of natural origin (lightning, volcanic eruption, spontaneous combustion and spark produced by rock slides) or man-caused[2,3]. Of the total incidents of forest fire in this Garhwal Himalayan region, 63% were man-caused intentional and remaining 37% were accidental[4–6]. Intentional fire is started traditionally by the natives in the pine forests and associated grazinglands mostly during summer season to enhance forage. In addition to this, graziers, school boys, forest contractors and forest personnel for various reasons cause intentional forest fire. Among the important causes of accidental forest fire are fire escaped during burning of crop remains from the agricultural fields, flames escaped from fire lines during controlled burning by forest department, a live cigarette or bidi butt thrown by a careless passerby, motor road repairs, cooking and campfire activities, respectively, of pilgrims and tourists etc[4–6].

Among the two types of forest fire viz., surface fire and crown fire or wild fire[1], most of the pine and other forests experience surface fire in the Garhwal Himalaya. The total burnt area under an event of forest fire seldom exceeds 4–5 km^2 in any pine forest stand of this region. Usually the frequency of fire in the forests has been observed to be 2–5 years while 11% pine forests of the region experience fire annually[5,6]. Surface fire follows two main mode of spreading. It may travel down from hill top to hill base, generally at a slow pace, or it may ascend up from hill base to top. The ascending blaze spreads at high speed (difficult to control) but the effects on vegetation generally remain lower. However, sometimes ascending flames culminate in severe crown fire.

In Garhwal Himalaya forests situated between 300 m and 2000 m above m.s.l. can be considered as fire prone. The region between 1000 and 1800 m above m.s.l. is mainly dominated by chir pine (*Pinus roxburghii*), forests representing densely populated zone of the region. People derive fodder and other forest produce for their subsistence living from the surrounding chir pine forests. The pine forests having relatively thin canopy provide congenial environment for the growth of herbaceous vegetation comprising grasses, sedges, legumes and other non leguminous species. The herbaceous vegetation shows maximum diversity under pine forests than any other forests of the region[7]. The average peak herbaceous biomass production (used as fodder) from the chir pine forests of this region has been estimated as much as 3.31 t per ha[7]. The pine needles are collected for animal bedding and are used as manure after decomposition. The average litterfall from the chir pine forests has been estimated as 8.5 t per ha per year[7]. Besides, timber, tylosed wood, tree bark, fuel wood, etc. are also collected from the pine forests.

Pine forests of the world, African savannas and Mediterranean shrublands are considered as fire adapted/dependent ecosystems because their continued existence depends on the periodic occurrence of fire[2]. In this re-

gion too, it would be difficult to find any pine forest stand which has no prior fire history[7]. Species growing in such ecosystems develop various reproductive and anatomical adaptive characteristics namely, dormant buds embedded in fire-resistant foliage, soil and bark; quick sprouting; increased flowering serotinous cones; increased seed liberation; stimulated germination and thick fire-resistant bark[2]. In the chir pine forests some other prominent species present are *Lyonia ovalifolia*, *Myrica esculenta* (tree), *Rhus parviflora*, *Crataegus crenulata* (shrub) and *Chrysopogon aciculatus*, *Heteropogon contortus*, *Arundinella nepalensis* (grass), *crotalaria albida*, *Desmodium microphyllum* (legume) and *Anaphalis* spp. *Ajuga parviflora*, *Micromeria biflora* (other non leguminous forbs) which have been identified as fire resistant[7].

Studies on pyrology suggest that surface fire (low intensity fire) is not necessarily damaging to the forest as this helps in reducing combustible material to minimum and thus reduces the chances of severe crown fire (generally thought to be harmful in any landscape[3]). It also helps to open the locked up nutrients in the biomass pool quickly, breaks the dormancy of the seeds and buds of many species, and promotes the growth of herbaceous vegetation. However, in the Himalaya where fragility remains to be the dominant factor in all types of ecosystems, further indepth researches are required to study the ecological implications of fire before recommending it as a management tool. On the other hand, crown fire (wild fire) generally destroys the ecosystem and it takes many years before the system becomes productive from man's point of view[1]. The destruction caused by this type of fire during the summer season in the Himalayan forests to the flora and fauna is greater than any other anthropogenic pressure on these forests e.g. for fodder, fuelwood and other products. Severe fire is detrimental to sequester the efforts made through afforestation, regeneration, and conservation programmes in this region. The crown fire which is mostly the result of ascending surface fire often spreads from the pine forests to the adjacent oak forests (generally located at the higher ranges, ecologically important and socially valued) and destroys the canopy, disturbs nutrient cycling, thus affecting ecosystem structure and function. Opening up of the oak forests through fire provides suitable conditions for the pine (an early successional, low nutrient demander and shade intolerant species) to invade the oak forests which is posing a serious threat to the ecological balance of this region[8,9]. Thus, one can establish a clear relationship among man, fire, pine forests and replacement of the oak forests in this part of the Himalaya.

Presently, there are no concrete strategies to prevent fires in the Garhwal Himalayan forests except by controlled burning by the forest department (with the help of few fire butchers) much before the onset of summer season and fire fighting by the local people in the event of a fire outbreak. Further, the controlled burning by forest department to minimize the chances of severe fire in the pine forests during summers has little significance because maximum litterfall (fuel loading) in this forest occurs during the summer season (May and June)[7].

Considering the above situation and realizing that the existing control measures are not adequate and also our scientific knowledge about the effects of fire on the Himalayan forest ecosystems is limited, in-depth and long term scientific studies should be carried out to understand the proper role of fire in the functioning of pine forest ecosystems of the region.

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