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Effect of Petrol Fuel Contamination on the Growth of Mature Scots Pine, *Pinus sylvestris* L., Trees

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Abstract The radial increment and crown status of mature Scots pine trees growing in polluted and unpolluted sites were compared. In 1996, as a result of some malfunction, unleaded petrol penetrated into the soil next to a plantation. Detailed geological and hydrological studies revealed the route of the spread of contamination and extent of the pollution. The trees growing in polluted sites revealed strong depletion of radial growth starting immediately after pollution. Such depletion lasted 2–3 years before the ring widths stabilised at a low level. After a few years the radial increment increased, and now do not differ from the increment of trees in the unpolluted sites.

Keywords Crown status · Petroleum contamination · Tree ring

Contamination of soil by petroleum hydrocarbons is a serious problem worldwide (Schwab et al. 2006). It is known that petroleum causes plant stress either directly or indirectly. Studies examining the influence of hydrocarbons on plants are numerous (Banks and Shultz 2005; Rosso et al. 2005). However, few studies are concerned with woody plants. Furthermore, this research surveyed trees at the seedlings stage (Nicolotti and Egli 1998; Rentz et al. 2003), so there is a lack of information about the impact of petroleum on adult trees. Considering both the ecosystem services of large trees and whole forests as well as the commercial value of timber, the impact of petroleum can be a serious problem. In this paper, we present the results of comparisons of the growth patterns and crown statuses of mature Scots pines (*Pinus sylvestris* L.) trees growing in polluted and unpolluted sites.

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Materials and Methods

The study was performed near the town Międzychód (northwestern Poland, 52°37′27″N, 15°55′48″E) on artificial Scots pine stands of 53 and 57 years of age. These stands were planted in former arable lands, which were typical single-layered monocultures managed for wood production. The average tree diameter was 21.8 cm and average height was 20.8 m. According to local forest administration, the stands showed no symptoms of damage caused by natural environmental factors (e.g., pest activity, wind or frost damage). The geological settings consist mostly of sands since the ground water table is around 5 m.

The stands were located next to a fuel storage station. In January 1996, a malfunction caused around 70 tonnes of unleaded petrol to penetrate into the soil and ground water. Geological and hydrological studies revealed detailed routes of the spread of contamination and extent of pollution.

Based on maps of the contamination areas, four sampling sites were established. Two were located in unpolluted parts of the stands (sites 1 and 2) and two in polluted ones (sites 3 and 4). The sites were spaced about 50 m apart, each site consists of a circular plot with 250 m^2 area. In all the plots, diameters of the trees at breast height and

Table 1 Mean values, standard deviations (S.D) of RW at each site and results of ANOVA

Calendar year	Site								*F*	*P*
	1		2		3		4			
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.		
1991	1.35	0.65	1.98	0.70	1.75	1.14	0.99	0.29	2.74	0.059
1992	1.49	0.60	1.71	0.69	1.62	0.97	1.06	0.58	1.41	0.256
1993	1.58	0.85	1.66	0.65	1.58	0.87	1.02	0.73	1.28	0.298
1994	1.58	0.62	1.66	0.51	1.75	0.83	1.23	0.72	1.03	0.392
1995	1.53	0.79	1.55	0.83	1.09	0.47	1.19	0.61	1.34	0.279
1996*	1.74	1.03	1.62	0.69	1.30	0.48	1.23	0.68	1.13	0.351
1997	1.74[a]	0.69	1.40[a]	0.59	0.77[b]	0.26	0.91[b]	0.54	6.54	0.001
1998	1.37[a]	0.60	1.52[a]	0.56	0.63[b]	0.23	0.74[b]	0.42	8.31	0.000
1999	1.49[a]	0.66	1.40[a]	0.68	0.38[b]	0.21	0.82[b]	0.49	9.08	0.000
2000	1.50[a]	0.90	1.29[a]	0.60	0.38[b]	0.28	0.73[b]	0.51	6.81	0.001
2001	1.51[a]	0.76	1.10[a]	0.58	0.41[b]	0.29	0.73[b]	0.56	6.79	0.001
2002	1.35[a]	0.73	1.01[a]	0.60	0.38[b]	0.26	0.73[b]	0.49	5.59	0.003
2003	1.38[a]	0.66	1.10[a,b]	0.72	0.51[c]	0.31	0.65[b]	0.54	4.69	0.008
2004	1.19[a]	0.65	1.09[a,b]	0.93	0.56[c]	0.45	0.64[b]	0.47	3.93	0.048
2005	1.12	0.77	0.76	0.65	0.59	0.60	0.49	0.44	1.86	0.16
2006	0.76	0.64	0.57	0.67	0.70	0.95	0.76	0.69	0.12	0.947

Values followed by different letters are significantly different at $p < 0.05$ (LSD test), asterisk denote year of malfunction

tree heights were measured. There were 25 trees in sites 1 and 3, 29 trees in site 2, and 32 trees in site 4. The current tree vitality was assessed based on the crown status (Eichhorn et al. 2004). The growth of trees was quantified by measuring width of yearly increment rings (later referred to as *RW*). For the last purpose, we took the cores by increment borer from 10 trees in each plot. The cores were dried, mounted and sanded. They were then scanned and tree rings were measured with an accuracy of 0.01 mm. The significance of differences in the average values of ring width between sites in each calendar year, as well as the differences between plots in crown status, was tested by one-way ANOVA.

Results and Discussion

Most tress were slightly defoliated (41% of trees) or without defoliation (38%). We did not confirm crown discolouration. No significant differences were found between plots in crown status.

Up to 1996, there were no significant differences in the average ring width (*RW*) between sites. Since 1997, the *RW* decreased rapidly in the polluted sites (3 and 4) and differed significantly from the *RW* of trees in unpolluted sites (1 and 2). The decrease in tree growth lasted for two (site 4) or three (site 3) years before the width stabilised at a low level. The growth depression was especially deep in site 3; however, after 3 years the *RW* began to increase. The significant difference in *RW* between sites disappeared in 2005, 9 years after the pollution event. The average values of *RW* for each study site in the period 1990–2006 are shown in Table 1.

Analysis of the previous growth of trees revealed a stable reduction in the *RW* at all sites, which is a typical growth pattern of Scots pines of this age (Jaworski 2004), and annual fluctuations, which are related to changes in the climatic conditions in each year. The strong growth depression in polluted sites that started immediately after the pollution event is also distinct (Table 1).

The petrol influenced the reduction of tree growth in many ways. First, some compounds of petroleum are toxic (Suprayogi and Murray 1999). The soil in the study site was sandy, and in such permeable soil the depth of penetration of Scots pine roots can reach 6–7 m (Jaworski 2004), meaning they would have come into direct contact with contaminated ground water. Second, hydrocarbons due to their hydrophobic nature could diminish water and nutrient uptake by the roots (Li et al. 1997). It is also known that roots of plants avoid growth in areas containing hydrocarbons (Adam and Duncan 1999). Moreover, petroleum strongly influences mycorrhizal fungi and soil micro-organisms (Robertson et al. 2007), which in turn affect tree growth. The trees in our study might be especially vulnerable to the effect of drought because of the general low availability of water in the soil, caused its permeability, and interactions with mycorrhizal fungi because former arable land is usually deficient in natural mycorrhizal inoculum (Hacskaylo 1973).

Ten years after the pollution event the trees show no visible symptoms of decreasing vitality. The crown status is above the average value for Poland (Anonymus 2007). When comparing the observed average tree diameters and heights with values in the yields tables of Szymkiewicz (2001), the quality of the standing crop can be stated as good.

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