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Effects of clearing and herbicide treatments on coniferous seedling establishment and growth in newly planted Mediterranean forests

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Abstract

The clearing of the natural vegetation and herbicide applications are commonly used to facilitate the establishment and growth of coniferous seedlings in newly planted forests in the Mediterranean region. Casual observations in Israel indicated that these operations drastically reduce biomass and species diversity of the herbaceous vegetation in the first years. The subjective impressions created by the effect of the herbicides have caused several public confrontations between foresters and conservationists in Israel. Less vegetation control may reduce tensions. However, no quantitative data was available on tree seedling performance under lower amounts of herbicide applications than those typically used for the region. The aim of the present study was to evaluate coniferous seedling establishment and growth under different intensities and frequencies of simazine applications in newly afforested areas in the Judean Mountains, Israel. Two experimental sites differing in soil types, temperature and rainfall were selected. In each site of 0.7 ha, 6-months-old seedlings of *Pinus brutia*, *Pinus pinea* and *Cupressus sempervirens* were planted at standard densities. The results for both experimental sites showed that seedling mortality significantly increased with decreasing intensities and frequencies of simazine applications. However, height and crown diameter of the surviving seedlings were not always significantly correlated to the amounts of herbicide sprayed in the adjacent areas. Standard current management practices showed highest seedling establishment success. The present study provides for the first time in Israel meaningful insights into the early stages of coniferous seedling establishment in newly planted Mediterranean forests after disturbance by clearing and simazine applications.

Keywords: Eastern-Mediterranean forest; Israel; Forest management; Seedling survival; Simazine

1. Introduction

Plant clearing and the application of herbicides are common tools used in forest management (Haywood, 1994; Aldrich and Kremer, 1997). The Jewish National Fund (JNF, the Forest Service in Israel) has been practising the clearing of the natural vegetation and herbicide applications with two main purposes: (a) to facilitate the establishment and growth of coniferous seedlings in newly planted forests by reducing the competitive influence of the indigenous herbaceous vegetation and (b) to prevent the formation of combustible material on roads and fire breaks in the

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forest. Casual observations in Israel indicated that these operations in newly planted forests drastically reduced biomass and species diversity of the herbaceous vegetation in the first years (Sternberg et al., 1999). The subjective impressions created by the effect of the herbicides have caused several public confrontations between foresters and conservationists in Israel. Less vegetation control may reduce tensions. However, no quantitative data was available on tree seedling performance under lower amounts of herbicide applications than those typically used for the region. Indeed, few studies have considered establishment success in newly planted forests of eastern-Mediterranean communities.

The objective of the present study was to evaluate coniferous seedling establishment and growth under different intensities and frequencies of simazine applications in newly afforested areas in the Judean Mountains, Israel.

The questions posed in this study are: (1) How clearing and simazine treatments affects coniferous seedling establishment and growth in newly planted Mediterranean forests? (2) Is there any correlation between seedling mortality, height and crown diameter with decreasing intensities and frequencies of simazine applications? (3) Does soil type, temperature and rainfall differences between experimental sites affects seedling performance?

This study was part of a larger project investigating the changes in natural vegetation after disturbance by aboveground plant removal and herbicide applications in newly afforested areas in the Judean Mountains (Sternberg, 1994; Sternberg et al., 1999). Here, we present the effects of these operations on coniferous seedling establishment and growth.

2. Materials and methods

2.1. Study sites

Two experimental sites were set up in newly afforested areas in the Judean Mountains. The first site was set up in September 1989, near Moshav Yishi (34°58′E, 31°50′N) located at an elevation of 220 m above sea level, on Rendzina soil on Eocene chalk (soil names follow Dan et al., 1970). The climate is Mediterranean, with a mean annual temperature of 19.8°C (maximum 24.9°C and minimum 14.7°C) and 493 mm annual rainfall falling mostly in winter (National Meteorological Service).

The second site was established a year later, in September 1990, near Moshav Matta (35°03′E, 31°43′N) located at an elevation of 620 m above sea level, on Terra Rossa soil on Cenoman hard limestone (Dan et al., 1970). The climate is also Mediterranean, with a mean annual temperature of 17.5°C (maximum 22.4°C and minimum 12.7°C) and 537 mm annual rainfall (National Meteorological Service).

The rainy season in both sites begins in October–November and ends in April–May. At least 6 months of dry weather characterize the region.

Both areas were located on north-facing slopes. The two sites differed in biotic and abiotic characteristics, such as edaphic conditions, temperature and rainfall. However, a dwarf shrub-type plant community developed in both areas, with differences in species composition. Dominant species at the Yishi site, before the clearing operations, were represented by dwarf shrubs such as *Sarcopoterium spinosum* (L.) Spach (28%) and *Majorana syriaca* (L.) Rafin. (10%), annual grasses such as *Avena sterilis* L. (11%), perennial grasses such as *Hyparrenia hirta* (L.) Stapf (8%) and annual legumes such as *Vicia palaestina* Boiss. and *Trifolium purpureum* Loisel. (5 and 4%, respectively). At the Matta site, dominant species included a tree and a shrub species (*Quercus calliprinos* Webb., 6%, and *Pistacia lentiscus* L., 5%, respectively), dwarf shrubs such as *S. spinosum* (24%) and *Cistus creticus* L. (9%), annual grasses such *A. sterilis* (12%) and *Hordeum spontaneum* C. Koch (7%) and annual legumes such as *Trifolium stellatum* L. (5%).

2.2. Experimental design

The study was conducted in two areas of 0.7 ha, where 36 quadrats of 12 m×12 m were respectively marked. The pre-planting operations (clearing of the perennial vegetation) at Yishi and Matta site started respectively, in October 1989 and October 1990. The clearing of the aboveground biomass was carried out by hand using shovels and hoes. The herbicide used in the experiment was simazine (2-chloro-4,6-bis(ethylamino)-s-triazine). It is a soil-acting triazine herbicide with presumed non-selective effects (Ivens, 1989).

The quadrats were arranged in respect to a randomized complete block design with four treatments and nine blocks as replicates (Greig-Smith, 1983). The treatments were: (A) clearing+simazine treatment in autumn before planting, with standard dose (5 kg/ha) and again next autumn with the same dose (October 1989/1990 at the Yishi site and October 1990/1991 at the Matta site); (B) clearing+simazine treatment only before planting, with one standard dose (5 kg/ha); (C) clearing+simazine treatment applying half of the standard dose (2.5 kg/ha) before planting and the remaining amount (2.5 kg/ha) in autumn of the next year; (D) clearing only, no simazine treatment (control). Treatment A, was the standard management procedure for these areas.

The different herbicide doses were manually applied on the quadrats with a back-pack sprayer and washed into the soil by the first rain.

The Yishi site was planted in November 1989 at standard densities of 900 seedling/ha, with 6-months-old saplings of *Pinus brutia* Ten. Nursing sites or planting locations were arranged with 2 m of separation between them. The Matta site was planted in November 1990, at similar densities as at Yishi, with mixed saplings of *Pinus pinea* L., *P. brutia* and *Cupressus sempervirens* L. All seedlings after planting were tagged and numbered.

Species nomenclature follows Feinbrun-Dothan and Danin (1991).

2.3. Sampling

Seedlings height and crown diameter were measured using metal rulers. Crown diameter was measured 20 cm above the ground, considering the maximal width distance between branches. Seedlings were regularly recorded on 10–15, 14–19, 12–17 and 19–24 April in 1990–1994, respectively, during the peak season of primary production. Dead saplings were counted and removed from the sites to prevent any confusion.

2.4. Statistical analysis

Analyses of variance (ANOVA) were used to determine differences among treatments in seedling survival, height and crown diameter. The analyses were carried out in respect to a randomized complete block design with four treatments and nine blocks as replicates (α=0.05) (Sokal and Rohlf, 1995). The Tukey HSD (honestly significant difference) test was used to compare differences of means among treatments for all pairs of combinations (α=0.05) (Tukey, 1953; SAS Institute, 1990).

3. Results

3.1. Seedling height and crown diameter

Changes in seedling height and crown diameter in *P. brutia* at Yishi and Matta experimental sites are presented in Fig. 1. No significant differences in height and crown diameter were noted among treatments in both sites in the first 6 months after being planted (1990 and 1991 at Yishi and Matta, respectively). Considering that seedlings at the time of planting were 6-months-old, the first sampling season was carried out on 1-year-old seedlings. Mean height considering all treatments for *P. brutia* at Yishi and Matta were 16.7 and 17.5 cm, respectively. Significant differences in height and crown diameter among

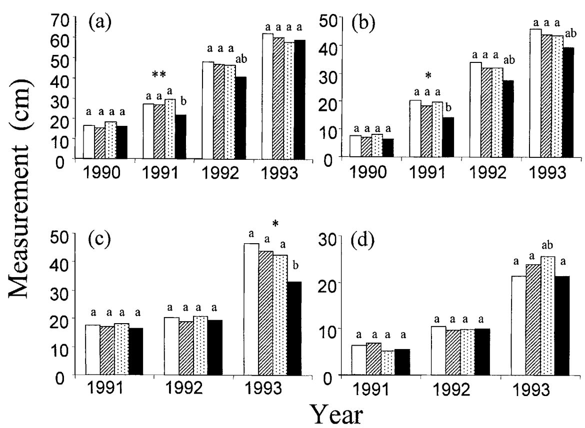

Fig. 1. The effects of clearing and simazine treatments on height and crown diameter of *P. brutia* seedlings. Height (a,c) and crown diameter (b,d) at Yishi and Matta sites, respectively. Treatments: A (□) clearing+simazine treatment before and a year after planting (5 kg/ha); B (▨) clearing+simazine treatment only before planting (5 kg/ha); C (⁚⁚) clearing+simazine treatment before and a year after planting (2.5 kg/ha); D (■) control (clearing with simazine treatment omitted). Treatments were compared using one-way ANOVA. $*$ indicates $P<0.05$, $**$ $P<0.01$. Treatments bearing the same letter are not significantly different at $P<0.05$.

treatments were noted in the second year after planting (1991) at Yishi (Fig. 1a and b). Seedlings growing in plots where simazine was not applied (treatment D, control) were significantly shorter and thinner compared to quadrats where the herbicide was applied ($F_{3,23}=5.37$, $P=0.0013$ and $F_{3,23}=4.25$, $P=0.02$, respectively). This effect remained constant, although not significant, during the third and fourth sampling season. No important differences in height and crown diameter were noted among seedlings, growing where simazine was applied, independently of intensity or frequency of application. At Matta, significant differences in height were observed only during the third growing season, 1993 ($F_{3,23}=4.19$, $P=0.033$, Fig. 1c). Also here, seedlings growing at sites where simazine was not applied (treatment D), were significantly shorter, particularly when compared to taller seedlings of treatment A. No significant differences in crown diameter among treatments were noted in *P. brutia* seedlings in any growing season (Fig. 1d). Seedlings of *P. pinea* showed no significant differences in height and crown diameter between treatments in any growing year (Fig. 2a and b), although individuals in plots with no herbicide application were slightly bigger. Similarly, saplings of *C. sempervirens* were not significantly different in height or crown diameter due to treatments (Fig. 2c and d).

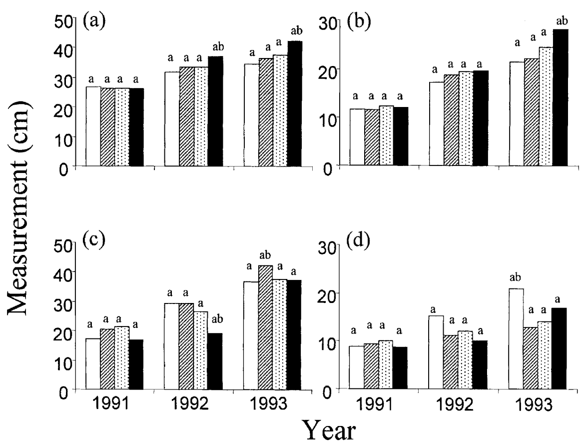

Fig. 2. The effects clearing and simazine treatments on height and crown diameter of *P. pinea* and *C. sempervirences* seedlings at Matta site. Height (a,c) and crown diameter (b,d) of *P. pinea* and *C. sempervirens*, respectively. Treatments: A (□), B (▨), C (⬚), and D (■). Key to clearing and simazine treatments as in Fig. 1.

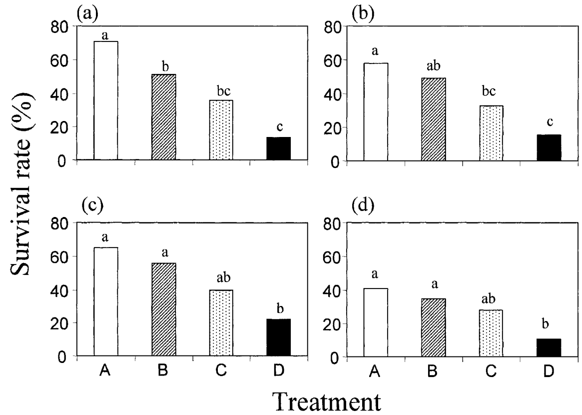

Fig. 3. The effects clearing and simazine treatments on seedling survival rates. Yishi site: *P. brutia* (a); Matta site: *P. brutia* (b), *P. pinea* (c), *C. sempervirens* (d). Treatments: A (□), B (▨), C (⬚) and D (■). Key to clearing and simazine treatments as in Fig. 1. Treatments were compared using one-way ANOVA and a subsequently HSD test. Treatments bearing the same letter are not significantly different at $P<0.05$.

3.2. Seedling survival

Changes in seedling survival due to treatments at Yishi and Matta study sites are presented in Fig. 3. Survival rates in *P. brutia* seedlings at Yishi, 4 years after planting were significantly higher ($F_{3,23}=34.2$, $P=0.001$) on treatment A. Survival decreased with decreasing intensity and frequency of simazine, being lowest (17%) on the controls (treatment D, Fig. 3a). At Matta, similar survival trends were noted for 3 years after planting as mortality was significantly lower on treatments with higher herbicide doses. Survival of *P. brutia* seedlings was significantly higher on treatment A, and lowest on the controls ($F_{3,23}=5.8$, $P=0.008$, Fig. 3b). Similarly, survival rates in *P. pinea* and *C. sempervirens* were significantly higher on treatment A and B compared to controls ($F_{3,23}=4.5$, $P=0.029$ and $F_{3,23}=4.2$, $P=0.031$, respectively) (Fig. 3c and d).

4. Discussion

The results for both experimental sites, independently of the seedling species, showed that seedling mortality significantly increased with decreasing intensities and frequencies of simazine applications. The mechanisms involved in this phenomenon were directly related to release from competition as simazine sensitive species (mainly annuals of the Papilionaceae, Gramineae and Asteraceae families, but also some hemicryptophytes) were temporally removed, increasing resources availability (i.e., light and water) to the planted seedlings (Tomkins and Grant, 1977; Armesto and Pickett, 1985). The opposite effect was noted in the controls where the clearing operations (removal of all perennial vegetation) released competition from dominant species, favoring the colonization and establishment of annual species around the nursing sites or planting locations (Litav et al., 1962; Sternberg et al., 1999). Consequently, competition between coniferous seedlings and annual vegetation increased, leading to lower survival rates than in quadrats where simazine was applied. As annuals showed higher growth rates than coniferous saplings, they were probably able to dry up the upper soil layer leading to seedling mortality. This phenomenon was important during the first 2 years, as most of seedling mortality occurred in this period. As coniferous seedlings grew with time, and developed a bigger root system that probably enabled them to escape from competition with annuals, thus mortality decreased.

Height and crown diameter of the surviving seedlings were not always significantly correlated to the amounts of herbicide sprayed in the adjacent areas. *P. brutia* seedlings were generally superior in height and crown diameter in plots with higher amount of simazine (Fig. 1). However, surviving seedlings of *P. pinea* on the controls, although few, were relatively taller and showed wider crown diameter than treatment A. This indicates that size played a key role in seedling survival. Only relatively big seedlings, were able to overcome annuals competition and survive, independently of simazine applications. This result may be of importance if a reduction in herbicide doses is intended, considering its potential secondary negative effects such as the contamination of underground water table (Glenn and Angle, 1987; Stearman and Wells, 1997) or changes in the invertebrate community (soil macro- and micro-fauna) (Prasse, 1985). In this case, planting older or bigger seedlings with a more developed root system should increase their chances to survive and get established.

Differences between experimental sites on soil type, temperature and rainfall generally did not affect seedling performance. However, survival rates at Matta were relatively lower than at Yishi. We assume that the reason for this phenomenon was related to soil depth and water availability in summer. At Yishi, planting was carried out in deeper and more developed terraces than at Matta. This allowed them to exploit water from deeper soil layers and overcome the dry season (summer), resulting in higher survival rates.

In general, this study shows that standard management practices (treatment A) showed highest seedling establishment success. To our knowledge, the present study provides for the first time in Israel insights into the early stages of coniferous seedling establishment in newly planted Mediterranean forests after disturbance by clearing and simazine applications.

Although not specifically covered by the present study, it is important to mention that the current planting policy for the studied region intends to incorporate local species in mixed cultures, avoiding alien monoculture plantations. Furthermore, simazine applications should be constrained to the nursing beds or planting locations, in order to reduce potential negative secondary effects on ecosystem functioning of the planted areas.

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References

Aldrich, R.J., Kremer, R.J., 1997. Principles in Weed Management, 2nd Edition. Iowa State University Press, Ames, IA.

Armesto, J.J., Pickett, S.T.A., 1985. Experiments on disturbance in oldfield plant communities: impact on species richness and abundance. Ecology 66, 230–240.

Dan, J., Yaalon, D., Koyumdjisky, H., Raz, Z., 1970. The soil association map of Israel (1:1 000 000). Israel J. Earth Sci. 21, 29–49.

Feinbrun-Dothan, N., Danin, A., 1991. Analytical Flora of Eretz-Israel. Cana Publishing Ltd., Jerusalem.

Glenn, S., Angle, J.S., 1987. Atrazine and simazine in runoff from conventional and no-tillage corn watersheds. Agric. Ecosyst. Environ. 18, 273–280.

Greig-Smith, P., 1983. Quantitative Plant Ecology. University of California Press, UK, pp. 23–24, pp. 46–47.

Haywood, J.D., 1994. Tenth-year results of herbaceous weed control in a loblolly pine plantation. Southern J. Appl. Forest. 18, 105–107.

Ivens, G.W., 1989. The UK Pesticide Guide. CAB International and the British Crop Protection Council, UK, pp. 447–448.

Litav, M., Kupernik, G., Orshan, G., 1962. The role of competition as a factor in determining the distribution of dwarf shrub communities in the Mediterranean territory of Israel. J. Ecol. 51, 467–480.

Prasse, I., 1985. Indications of structural changes in the communities of microarthropods of the soil in an agro-ecosystem after applying herbicide. Agric. Ecosyst. Environ. 13, 205–215.

SAS Institute, 1990. SAS/STAT Guide for Personal Computers, Version 6, 4th Edition. SAS Institute, Cary, NC.

Sokal, R., Rohlf, F., 1995. Biometry. The Principles and Practice of Statistics in Biological Research, 3rd Edition. Freeman, New York.

Stearman, G.K., Wells, M.J.M., 1997. Leaching and runoff of simazine, 2,4-d, and bromide from nursery plots. J. Soil Water Conserv. 52, 137–144.

Sternberg, M., 1994. Early successional pathways after disturbance with herbicide in herbaceous communities in young planted forests in the Judean Mountains. Ph.D. Thesis. The Hebrew University of Jerusalem, Israel.

Sternberg, M., Danin, A., Noy-Meir, I., 1999. Dynamics of Mediterranean vegetation following clearing and herbicide treatments in newly planted forests. J. Mediterranean Ecol. 1, 65–76.

Tomkins, D.J., Grant, W.F., 1977. Effects of herbicides on species diversity of two plant communities. Ecology 58, 398–406.

Tukey, J., 1953. A Problem of Multiple Comparisons. Princeton University Press, Princeton, NJ.