The Effect of a Hydrophilic Polymer on Plant Water Status and survival of Transplanted Pine Seedlings

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Summary. Two experiments were conducted to assess the ability of a water-absorbing synthetic polymer to reduce water stress injury of seedlings of *Pinus pinea* L. under greenhouse and field conditions. In both experiments, two rates of hydrated hydrogel, corresponding to 200 and 400 cm³ of stored water, and a control treatment without hydrophilic polymer were tested. Survival periods for the pine seedlings were 1.4 and 2.0 times longer for the 200- and 400-cm³ treatments, respectively, than for a control treatment in a greenhouse assay. In the field assay, only differences in seedling survival between both hydrogel treatments and control were measured. Leaf water potential values of control plants were significantly lower than hydrated polymer treatments in both experiments. From these results, we conclude that the use of hydrophilic polymers may be an important method of increasing the success of reforestation in semiarid regions.

Anthropogenic effects on vegetation and, to a minor extent natural fires, are relatively frequent, and fire has been considered a major stress factor in Mediterranean environments (Mar-

garis and Mooney, 1981; Rundel, 1981). Under Mediterranean conditions, two main forest communities can be supported: evergreen sclerophyllous forests and shrublands, which are dominated by woody resprouts that regenerate quickly after disturbances (Savé et al., 1993), and coniferous forests, which are characterized by frequent, light ground fires with less than a 25-year cycle caused by a rapid buildup of flammable fuels on the ground surface and regular inputs of lighting for ignition. These fires kill hardwood seedlings and help maintain pine dominance (Folch, 1981). When the fire regime is more frequent, soil erosion and desertification increase (Kruger et al., 1983; Margaritis and Mooney, 1981), and then reforestation practices are used to reduce these environmental problems. Plant vigor (Egnell and Örlander, 1993; Pallardy and Rhoads, 1992), environmental conditions (Terradas and Savé, 1992), and nursery culture (Arnott et al., 1993) are critical to the successful establishment of tree seedlings. Water stress may be caused by the lack of soil moisture or inability of the soil to absorb or transport water, poor root-soil contact, low soil temperatures, or nonfunctional or small root systems (Egnell and Örlander, 1993).

The development of water-absorbing synthetic polymers, or hydrogels, may improve the water balance, hence, the survival and growth of plants in arid and semi-arid regions (Callagan et al., 1989). Hydrogels can improve water-holding capacity, aeration, and drainage of substrates and reduce watering requirements of plants (Larnont and O'Connell, 1987; Orzolek, 1993; Tu et al., 1985).

Experiments were designed to compare the effects of two hydrogel rates and a control on pine seedling survival and drought-stress avoidance under greenhouse and field conditions.

Materials and methods

One-year-old seedlings of *Pinus pinea* were subjected to drought stress in a greenhouse (Savé et al., 1985). Seedlings were planted in plastic bags (8 cm in diameter and 12 cm high) in a mixture of 1 sand :1 pine mould (v/v) and watered to excess three times a week for 2 months before the experiment started. Twelve seedlings for each treatment then were transplanted into 17-cm-diameter (2.9-liter) pots and

maintained in the greenhouse. The polyethylene bag was removed at transplanting time. The substrate was kept intact to avoid injury to roots. Sand was used as substrate in the pots and was added to the bottom of the pot to a depth of 5 to 6 cm. The hydrated hydrogel was placed above the sand, and the pine seedling were transplanted into the pot with additional sand. Three treatments were established, each corresponding to the three different rates of the hydrated synthetic polymer (VITERRA, Schering AG, Pflanzenschutz, Berlin, Germany), which supplied 0 (control), 200, and 400 cm³ of stored water to the medium. Before the desiccation period (12 July to 9 Sept.), pots were watered to excess. During the experiment, temperatures ranged from 20 to 35 C and relative humidity was maintained at 60% $\pm$ 10%. On days 0, 2, 5, 9, 13, 16, 24, 32, 38, and 60 of the drought-stress period, survival rate and leaf water potential (Ψ) were measured with a pressure chamber (Soilmoisture 3005) (Savé et al., 1993) at 8:00 AM solar time on 10 fully expanded leaf samples taken from each treatment. The field study plot was located in La Vail del Teix on the karstic Garraf Serra (41°20'N, 1°90'E) 20 km south of Barcelona (Catalunya, Spain). The experimental plot had a southwest exposure and was located on a steep slope. The soil was thin with many rocks, and has been classified as a fersialitic soil. The average annual rainfall is 690 mm. The experimental period extended from 29 Apr. to 20 Sept. 1986. Rainfall was 223 mm and the average temperature was 18C. The study site suffered a severe fire 5 years before this experiment began. The vegetation, a maquis, can be included in the phytosociological association *Quercetum cocciferae* Br. Bl. 1924 subas. *rosmarinetosum* Br. Bl. 1935 (Folch, 1981). Holes were dug 30 $\times$ 30 $\times$ 30 cm, hydrated synthetic polymer (VITERRA) was placed in the holes, and the pine seedlings were transplanted into the holes. Three different rates of hydrated synthetic polymer supplied 0 (control), 200, and 400 cm³ of stored water to the medium. Three replications and 10 seedlings per plot were used for this experiment. Percentage tree survival was measured periodically during the experiment. Leaf water potential was measured at 8:00 AM solar time on days 0, 12, 19, 33, 47, 91, and 143 after transplanting

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Fig. 1. Effect of several rates of hydrated hydrogel (400, 200, and 0 cm³ of stored water) on leaf water potential of *Pinus pinea* seedlings submitted to a period of drought under greenhouse conditions. Each value is the mean of 10 observations. Vertical bars are $\pm$ SE.

as described for the greenhouse experiment. Analyses of variance for measured parameters were computed.

Results and discussion

Results obtained in the experiment under greenhouse conditions (Fig. 1) showed a similar pattern in Ψ for all treatments; except for a clear difference in time response, there were no significant differences in Ψ between

treatments until day 13. From day 13, Ψ decreased until it reached about -3.5 MPa, at which time seedlings died due to tissue dehydration (Aussenac and El Nour, 1985; Hinckley et al., 1978; Levitt, 1980). This Ψ value was reached on days 32, 42, and 60, for the 0-, 200-, and 400-cm³ treatments, respectively, and, consequently, viability at time of seedling establishment increased 31% and 88% from the con-

trol to the 200- and 400-cm³ treatments, respectively. Similar desiccation patterns produced by different treatments could indicate that the hydrogel acts as a supplementary source of water, available only for the plant from some threshold Ψ value of -0.5 to -0.7 MPa. Above this value, water stored in the hydrogel is not available for plant use, as was shown in the first 13 days of the experiment (Gehring and Levis, 1980). This could be attributed to polymer characteristics; about 90% of the water held by the polymer is released at tensions of -0.01 to -0.2 MPa (Bunt, 1988). These negative values of xylem water potential at root level could be reached when some degree of stress is developed at the canopy level (Weatherley, 1982), according to the soil-plant-atmosphere water continuum (Passioura, 1982).

In the field experiment (Fig. 2), Ψ showed similar trends as those described in the greenhouse experiment, but there were changes following environmental conditions (rain, fog, cloudiness) (Table 1) and evaporative demand of the atmosphere (Hinckley et al., 1978; Nobel, 1983). Thus, control plants from day 33 always showed significant lower values than the 200- and 400-cm³ treatments. The significant increase in xylem water potential detected on day 33, 59% and 66% for the 200- and 400-cm³ treatments, respectively, might increase plant use of water stored in hydrogel (Gehring and Levis, 1980; Tu et al., 1985).

This increase occurred at Ψ values (about -0.5 to -0.7 MPa) similar to those in greenhouse experiment. Seedling losses were detected only in the control treatment: 7% and 21% for days 33 and 47, respectively. There were no additional losses. This result seems to indicate that hydrogel improves the survival of field-transplanted seedlings (Callagan et al., 1989).

Our results agree with those from other experiments on other species at earlier growth stages and with other water-absorbing synthetic polymers (Callagan et al., 1988, 1989; Gehring and Levis, 1980; Lament and O'Connell, 1987; Taylor and Halfecre, 1986; Tu et al., 1985; Wang, 1989; Wang and Gregg, 1990). The positive results of both experiments, under extreme and mild drought stress, could be important because the hydrophilic polymer may reduce the loss of transplanted seedlings and give improved

Fig. 2. Changes over a 3-month period in leaf water potential of transplanted *Pinus pinea* seedlings treated with several rates of hydrated hydrogel (400, 200, and 0 cm³ of stored water). Each value is the mean of 10 observations. Vertical bars are $\pm$ SE.

Table 1. *Environmental parameters in the field study plot located in La Vail del Teix on the karstic Garraf Serra (41°20' N, 1 90' E) 20 km South of Barcelona (Catalunya, Spain) during the experimental period 29 Apr. 1986 to 20 Sept 1986.*

Date	Rainfall (mm/month)	Dew (days/month)	Fog (days/month)
April	72.6	8.0	3.0
May (days 1-31)	21.5	11.0	5.0
June (days 32-61)	9.0	3.0	14.0
July (days 62-93)	15.0	3.0	17.0
August (days 94-122)	35.5	0.0	29.0
September (days 123-152)	69.0	0.0	26.0

seedling viability. The advantages that hydrogels could provide may be important in arid and semiarid areas where rainfall is <350 mm per year and is erratic in distribution. However, as has been pointed out by Callagan et al. (1989), the impact of hydrogels will likely be restricted to early growth stages in the nursery or field following transplant, since root systems will grow out of the polymer zone.

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