APPLICATION OF WATER-STORING CROSS-LINKED POLYMER TO FORESTRY PRACTICES IN THE SUDAN

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ABSTRACT

In order to investigate ways of increasing the success of tree raising and planting, Broadleaf P4 has been used experimentally in the Sudan. A series of experiments involving trees of economic importance tested its effects on:

a) water loss from sandy soils
b) tree seed germination and early survival
c) tree seedling survival in the nursery
d) the survival of transplanted young trees
e) growth under varying irrigation regimes

The addition of polymer to sandy soils increased the water holding capacities of the soils while reducing the rate of water loss. The increases in plant establishment (up to 72%) and increased dry weight (due to reduced water stress) achieved by the polymer under a daily irrigation regime suggest that the polymer could be important in tree nurseries and irrigated plantations.

The polymer significantly increased the period of survival of tree seedlings in the nursery by up to double when considerable water stress was generated either by irrigating infrequently or by adding only very small amounts of water regularly.

The polymer also increased the chance of survival of transplanting young trees. When irrigation was intermittent to simulate irregular rain events or pump failure, the polymer enabled 57% of the trees to survive whereas all of the control trees died.

1 - EFFECT OF POLYMER ON WATER LOSS FROM SANDY SOILS

In order to assess the effectiveness of Broadleaf P4 in retaining water, the polymer was added to 3-litre pots of local sandy soil. Three replicated treatments each of 6 seeds per pot, 2 pots per replicate, were applied: clean sand (control - PO), sand + P4 at 0.2% v/v, sand + P4 at 0.5%. Each pot was weighed, raised to field capacity and then weighed again. The pots were then set out in the Khartoum Green Belt Nursery at Soba, where they were weighed each day.

It was found that the polymer had significant effects on both the water held by the sand (field capacity) and the rates at which the sand dried out. At any given time over the 23-day trial period, more water was available in the pots of the polymer treatments than in those of the control. (Fig 1).

2 - GERMINATION AND ESTABLISHMENT

Seeds of *Acacia Senegal, A. mellifera* and *Prosopis chilensis* were chosen to measure the effect of polymer on seed germination and establishment. In one series of pots, 0.2% v/v of P4 was mixed with the soil before potting the seeds: a second series remained as the control with no polymer added. Each of the two treatments was subjected to two irrigation treatments. In treatment I0, no further water was added to the pots after the seeds were sown and the pots brought to field capacity. In treatment I1, one litre of water was added to each pot each day.

No seeds of any of the three species germinated when no water was supplied after sowing; a mean of 50% of seeds of all three species germinated under the polymer treatment when water was added each day, whereas a mean of only 36% germinated without polymer (Table 1).

Because some of the seedlings died, the balance between germination and death of seedlings was regarded as the percentage establishment of seedlings. When water was added each day to seeds of *A. senegal*, establishment reached 42% and 54% respectively for control and treated (Table 1). *Acacia mellifera* attained 38% and 46% establishment respectively and *P. chilensis* attained 29% and 50% establishment respectively (Table 1).

Seedlings in polymer-treated sand showed higher percentages of establishment than those in the control. This was achieved by increased seedling survival rather than by higher germination.

3 - EFFECT OF POLYMER ON SURVIVAL OF *A. SENEGAL*

Two experiments were carried out in the Khartoum Green Belt Nursery at Soba, using standard nursery facilities and practices, to test the effect of the polymer at two concentrations (0.2% v/v and 0.5% v/v) on the survival and height growth of gum arabic seedlings. In one experiment, water stress was generated by varying the frequency of irrigation (field capacity every day – I1; field capacity every second day - I2; field capacity every third day - I3 and field capacity every week - I4) (Table 2) whereas in the second, the amount of water supplied daily was varied (100% field capacity - I1.1; 50% field capacity - I1.2; 25% capacity - I1.3 and 10% field capacity -I1.4) (Table 3).

As the quantity of the daily-added water decreased, the survival periods of seedlings decreased (Table 3). There was a clear buffering effect of the polymer so that the mean survival period was double in seedlings of polymer treatment P4, 0.5 than in the control when water stress was the most severe (Table 3). When water stress was generated by varying the frequency of irrigation, the same trends were observed but the maximum polymer-induced increase in survival period was nearly 3 fold (Table 2).

Trends in height increments over the 31 days of the experiment differed from those of survival. Height increments were affected dramatically by irrigation treatments varying from 100 to 0.8% in the control (Table 4).

4 - EFFECT OF POLYMERS ON SURVIVAL AND GROWTH OF TRANSPLANTED *EUCALYPTUS MICROTHECA*

One-year-old *E. microtheca* seedlings were transplanted into large porous clay pots containing a 3:1 mix of sand and fresh river silt to simulate planting out from the nursery. Two replicated treatments were given: soil without polymer (PO), soil with P4 at 0.2% v/v (P4, 0.2). After planting, the pots were raised to field capacity by adding 1l of water and four irrigation treatments were initiated. Irrigation treatment I0 received no further water; I1 received 0.5l every day, I2 every third day and I3 every 6th day. The pots were arranged in a randomised block design with 7 replicates. The experiment was terminated after one month and the fresh and dry (105 C for 24 hrs) weights were determined for each surviving tree (Tables 5 & 6).

All the trees died when water was not added after initially raising the transplants to field capacity but the polymer additive doubled the period of survival. However, the most dramatic effects of the polymer additive were shown when water was added each six days to simulate intermittent rain events or the failure of an irrigation pump. All of the control plants died before receiving the first irrigation but the buffering capacity of the polymer allowed most trees to survive until water was added and then recovery took place enabling about 70% survival to be achieved after 28 days (Fig. 2).

When water was added every day or every third day, the plants in the control treatments suffered considerable transplant shock, losing many leaves. The transplant shock was clearly evident when the diffusive resistances of two leaves per tree were measured using a portable diffusive resistance porometer. The diffusive resistances of leaves on control plants were high following transplanting (Fig. 3). This indicates stomatal closure to prevent water loss from stressed plants and there will be a corresponding decrease in the rate of photosynthesis and growth. Trees growing with the polymer additive showed no such transplant shock, maintaining physiologically active leaves (Fig. 3). This suggests that growth would be greater than in the control treatment. Indeed, such enhanced growth was evident when fresh and dry weights were measured (Tables 5 and 6).

The range of independent experiments summarised here show that Broadleaf P4 consistently increased the survival and growth of trees and it would seem therefore, that polymers have a part to play in tree raising and planting.

TABLE 1

Percentage establishment of three species of tree seedlings over a 50-day period. 1000 ml water was added per pot each day. PO: no polymer added to the soil. P4: polyacrylamide added at 0.2% v/v.

	PO	P4
Acacia senegal	42	54
Acacia mellifera	38	46
Prosopis chilensis	29	50
Mean	36	50

Statistical results of Kruskal-Wallis one-way analysis of variance (Siegel, 1956):

Differences between PO and P4 are significant, $P < 0.05$, on all 3 species.

TABLE 2

Mean period of survival (days) of *Acacia senegal* tree seedlings over 31 days. Seedlings grown in soil (PO) and soil with polyacrylamide (P4) added at 2 concentrations (0.2 and 0.5% v/v). Four irrigation treatments were given.

	PO	P4, 0.2	P4, 0.5	Mean for each I treatment. [a]
I1(field capacity every day)	25.8	31.0	25.8	27.5
I2 (field capacity every 2nd day)	22.0	23.4	20.4	21.9
I3 (field capacity every 3rd day)	9.8	26.4	16.0	17.4
I4 (field capacity every week)	7.2	8.8	10.8	8.9
Mean for each polymer treatment [b]	16.2	22.4	18.3	19.0

a significance of difference between column treatments at $P < 0.001$ = 12.45

b significance of difference between line treatments at $P < 0.001$ = 5.65

TABLE 3

Mean period of survival (days) of *Acacia senegal* tree seedlings over 45 days. Seedlings grown in soil (PO) and soil with polyacrylamide (P4) added at 2 concentrations (0.2 and 0.5% v/v). Four irrigation treatments were given.

	PO	P4, 0.2	P4, 0.5	Mean of each I treatment. [a]
I1.1 (100% field capacity every day)	45.0	45.0	45.0	45.0
I1.2 (50% field capacity every day)	37.4	45.0	38.2	40.2
I1.3 (25% field capacity every day)	23.8	29.4	28.4	27.2
I1.4 (10% field capacity every day)	5.0	8.4	10.0	7.8
Mean for each polymer treatment [b]	27.8	32.0	30.4	30.1

a significance of difference between column treatments at $P < 0.001$ = 16.23

b no significant difference between line treatments at $P > 0.05$; treatment I1.4 significantly different at $P < 0.001$ when analysed on an ANOVA sub-plot routine.

TABLE 4

Mean height increment (expressed as % of initial height) of *Acacia senegal* tree seedlings (n=5) surviving over 31 days. Seedlings grown in soil (PO) and soil with polyacrylamide (P4) added at 2 concentrations (0.2 and 0.5% v/v). Four irrigation treatments were given.

	P0	P4, 0.2	P4, 0.5	Mean for each I treatment [b]
I1 (field capacity every day)	100.0	107.6	112.0	106.5
I2 (field capacity every 2nd day)	63.5	69.6	59.6	64.2
I3 (field capacity every 3rd day)	7.7	57.0	31.2	31.9
I4 (field capacity every week)	0.8	3.3	16.4	6.8
Mean for each polymer treatment [b]	43.0	59.4	54.8	52.4

a significance of difference between column treatments at $P < 0.001 = 30.48$

b significance of difference between line treatments at $P < 0.05 = 7.68$

TABLE 5

Mean dry weight (g) per tree of *Eucalyptus microtheca* over 28 days. Trees grown in soil (PO) and soil with polyacrylamide (P4) added at 0.2% v/v. Four irrigation treatments were given. *Only data for trees surviving at the end of the experiment are included.

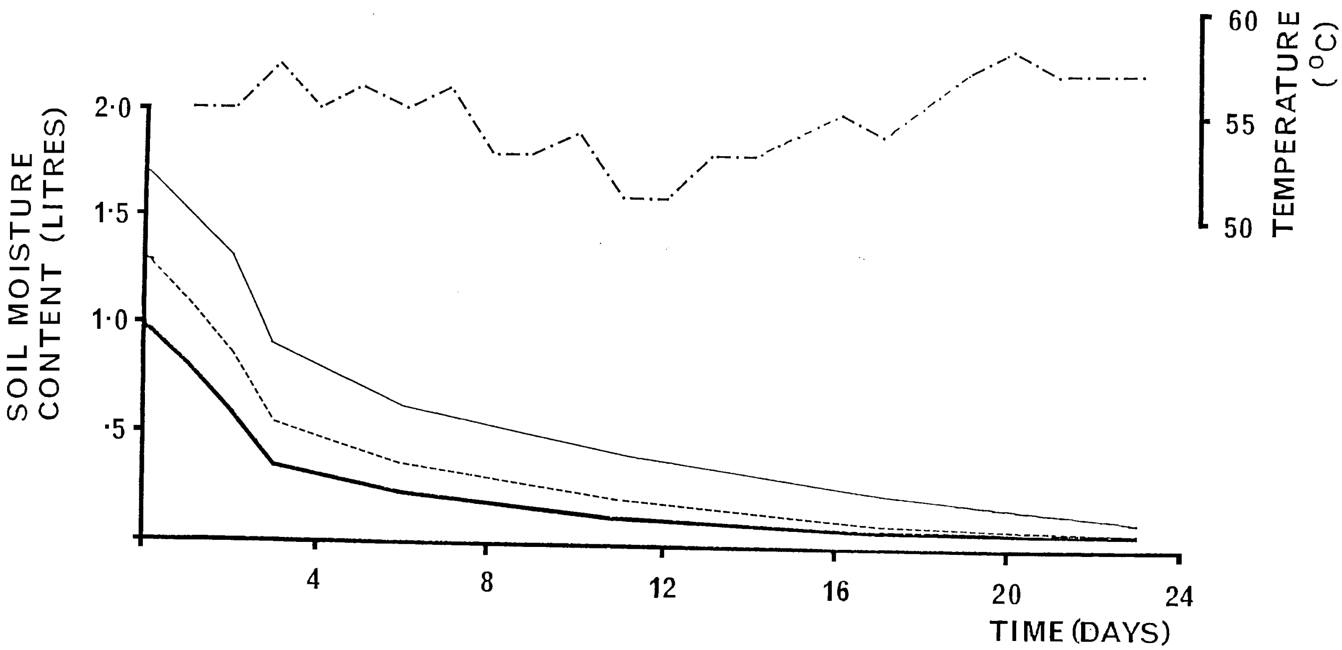
	PO	P4, 0.2	Mean for each I treatment
I1 (0.5 l every day)	2.1	2.9	2.5
I2 (0.5 l every 3rd day)	1.8	2.8	2.3
I3 (0.5 l every 6th day)	-*	2.9	2.9
I0 (no water)	-*	-*	-*
Mean for each treatment	1.95*	2.84*	2.39*

TABLE 6

Mean fresh weight (g) per tree of *Eucalyptus microtheca* over 28 days. Trees grown in soil (PO) and soil with polyacrylamide (P4) added at 0.2% v/v. Four irrigation treatments were given. *Only data for trees surviving at the end of the experiment are included.

	PO	P4, 0.2	Mean for each I treatment
I1 (0.5 l every day)	4.2	5.4	4.8
I2 (0.5 l every 3rd day)	3.3	5.5	4.4
I3 (0.5 l every 6th day)	-*	5.6	5.6*
I0 (no water)	-*	-*	-*
Mean for each polymer treatment	3.8*	5.48*	4.64*

Figure 1. The effect of Broadleaf P4 on the field capacity and water content of sandy soils in plastic pots over 26 days together with temperature (broken-and-dotted line). P0: thick solid line; P4, 0.2: thin broken line; P4, 0.5: thin solid line.



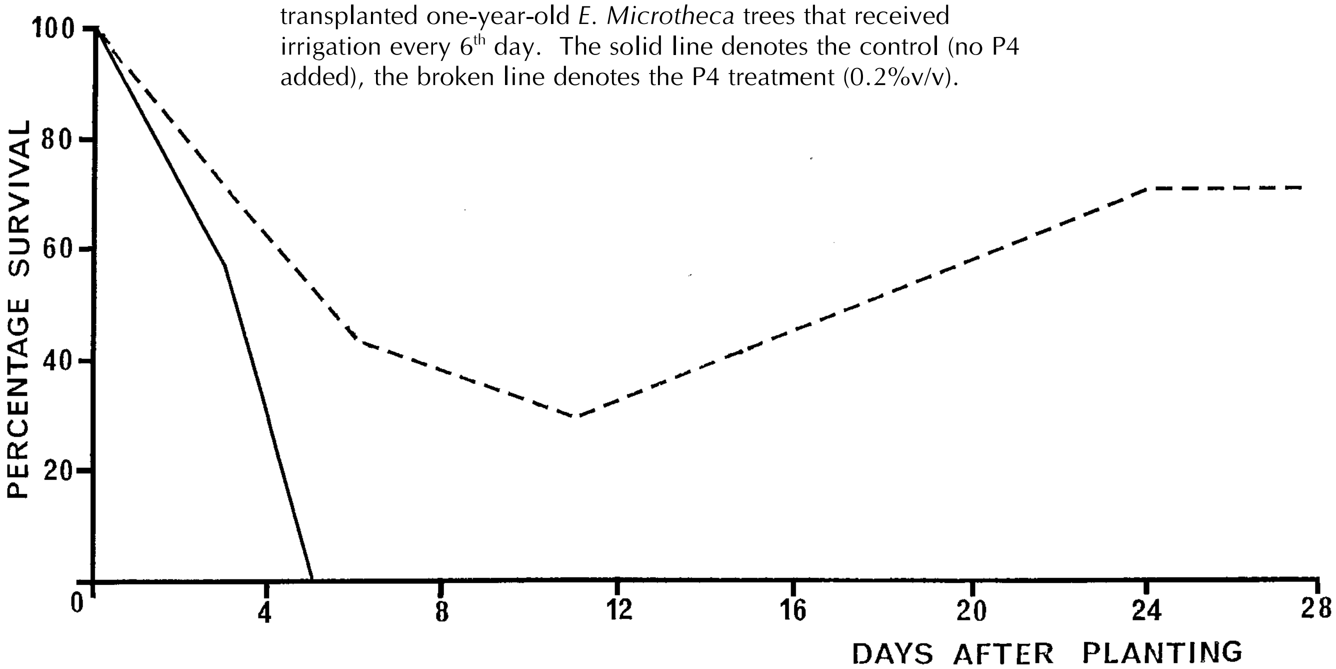


Figure 2. The effect of Broadleaf P4 on the survival and revival of transplanted one-year-old *E. Microtheca* trees that received irrigation every 6th day. The solid line denotes the control (no P4 added), the broken line denotes the P4 treatment (0.2%v/v).

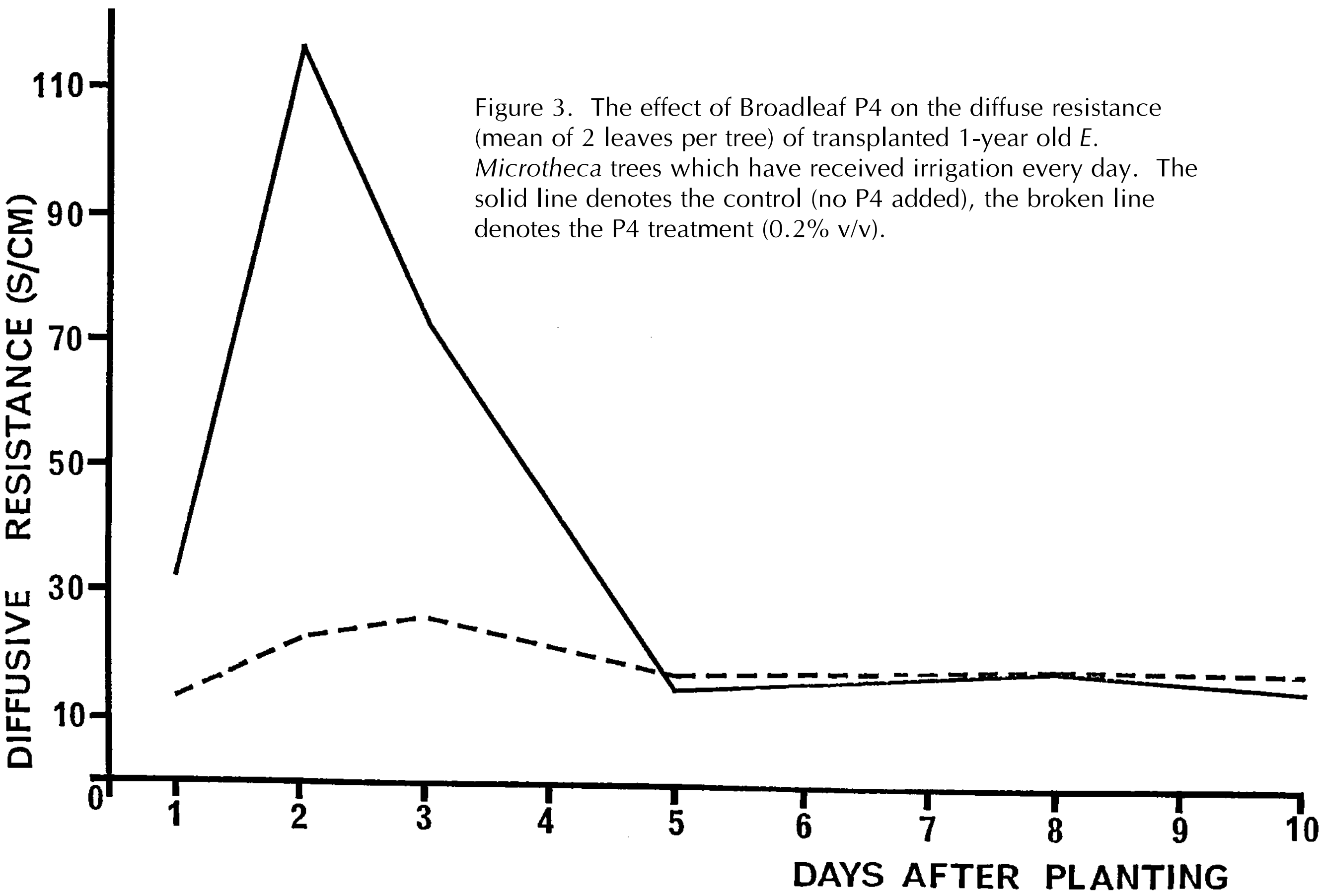


Figure 3. The effect of Broadleaf P4 on the diffuse resistance (mean of 2 leaves per tree) of transplanted 1-year old *E. Microtheca* trees which have received irrigation every day. The solid line denotes the control (no P4 added), the broken line denotes the P4 treatment (0.2% v/v).