

EFFECTS OF POLYACRYLAMIDE
AND A FERTILIZER ON GERMINATION
AND SEEDLING GROWTH
OF *AMMOPHILLA ARENARIA* (L.) LINK
I. AT 5% SOIL MOISTURE CONTENT

by

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SUMMARY. — The influence of polyacrylamide and an anorganic fertilizer, separately and combined, on the germination and seedling growth of *Ammophila arenaria* (L.) Link was examined. Polyacrylamide slightly increases the rate of germination. Both products decrease the evapotranspiration. Polyacrylamide has an insignificant effect or no effect at all upon shoot growth of seedlings, but a significant positive effect upon their root growth. Fertilizer has a positive effect upon shoot growth. Neither cumulative effect on total biomass, nor differences in rate of development of the leaves was recorded. With a very low soil moisture content (5%), when plants are under continuous drought stress, the positive effects of polyacrylamide and fertilizer on total biomass of seedlings are negligible. Nevertheless, root growth is enhanced.

SAMENVATTING. — De invloed van polyacrylamide en anorganische meststof, afzonderlijk en in combinatie, op de kieming en groei van kiemplanten van *Ammophila arenaria* (L.) Link, werd nagegaan. In aanwezigheid van polyacrylamide neemt de kiemingssnelheid lichtjes toe. Beide producten verminderen de evapotranspiratie. Polyacrylamide heeft een niet significant negatief effect tot helemaal geen effect op de spruitgroei van kiemplanten, maar een significant positief effect op de wortelgroei. Anorganische meststof heeft een positief effect op de biomassa van de spruit. Er kon geen significant positief effect van een van beide producten op de totale biomassa productie vastgesteld

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worden. Evenmin konden verschillen in ontwikkelingsnelheid van de bladeren gevonden worden. Bij zeer lage bodemvochtigheid (5%), wanneer de planten bijna voortdurend onder droogtestress staan, zijn de positieve effecten van polyacrylamide en meststof op de totale biomassa-productie verwaarloosbaar. Wel is sterkere wortelontwikkeling vastgesteld.

INTRODUCTION

Ammophila arenaria (Marram grass) plays an important role in the development of sand dunes (e.g. HUISKES 1979). In some parts of Western Europe dunes are threatened, due to tourism, industrialisation, construction activities etc. Consequently, the damaged dunes have to be fixated and stabilized. Normally, transplants of Marram grass are used (HOBBS *et al.* 1983), but transplanting is a laborious and expensive technique. While the sowing of Marram grass in protected areas, could be an alternative, the natural establishment of *Ammophila arenaria* from seed seems to be problematical (GEMELL *et al.* 1953 : 133, HUISKES 1977). Usually seedlings die within a few weeks after germination, because of desiccation, excessive sand burial or sand erosion. The use of hydroabsorbant polymers could increase the survival of Marram grass seedlings. The known properties of those "hydrogels", e.g. increase of the water holding capacity and decrease of the erodibility of the soil (DE BOODT 1987), could be of some use to help the young seedlings through their first "critical" weeks.

The mechanism of soil conditioning by polymers is based on flocculation (DE BOODT 1979). In a high-pH soil polyanion polymers flocculate more easily with higher salt concentrations than with lower ones (WALLACE *et al.* 1986).

Within the scope of a research program for using polymers to recover the natural vegetation in the dunes of the Belgian coast (DANNEELS *et al.* 1987, DANNEELS & VAN COTTHEM 1990), some laboratory experiments with *Ammophila arenaria* were established. The purpose of the experiments was twofold : 1) to gain information about the germination and growth of *Ammophila* seedlings, and 2) to study the effect of an anionic polymer (polyacrylamide) in combination with an anorganic fertilizer.

WALLACE and WALLACE (1986a, 1990) have shown that there can be interactions between polymer soil conditioners and organic amendments ; this was an other topic of our research work.

MATERIALS AND METHODS

Four combinations of a chemical soil conditioner (polyacrylamide) and/or an anorganic fertilizer were tested (Table 1), each combination with four replicates per harvest (5 harvests, total 90 pots). A potassium propenoate-propenamamide copolymer (Viterra® Plantagel (2), produced by Aglucon, Düsseldorf-Germany) and an anorganic fertilizer Poly Crescal® (2) (also produced by Aglucon, Düsseldorf) were used, containing 14.0% N (9.7% ammonium-N, 4.3% nitrate-N), 10.0% P₂O₅, 14.0% K₂O, 0.7% MgO and the following trace elements : 0.052% B, 0.0001% Co, 0.041% Cu, 0.103% Mn, 0.0037% Mo and 0.023% Zn.

Table 1

*The different treatments of the substrate
(dune sand)*

combination	treatment
1	control
2	polyacrylamide 50 g/m ²
3	fertilizer 10 g/m ²
4	combination of polyacrylamide 50 g/m ² + fertilizer 10 g/m ²

The non-perforated pots (polyethene 10.6 cm × 12.0 cm) contained 1200 g of untreated air-dried (0.3% soil moisture content), sieved (Ø = 1 mm) dune sand (Table 2). With 500 g sand 0.66 g polyacrylamide (PAM) was mixed. On top of this mixture 600 g of the same untreated sand was added. 50 caryopses of Marram grass were sown in 5 rows (to enable quick counting of the seedlings) and were covered with 100 g of sand (6 mm). Earlier research (VAN HAVER 1986) had shown that covering the seeds with 6 mm of sand gives optimal germination results.

The anorganic fertilizer was added as a solution, made by diluting 3.25 g in 1 l of distilled water and every pot of the fertilized series was irrigated with 40 ml of that solution.

The experiments were carried out in a growth chamber of the Botanical Garden of the University of Ghent. Daytime air temperature

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during the experimental period ranged from 28 to 35°C, while night temperature ranged from 18 to 25°C (Fig. 1). The relative air humidity varied from 20 to 40% during the day and from 35 to 70% during the night (Fig. 1).

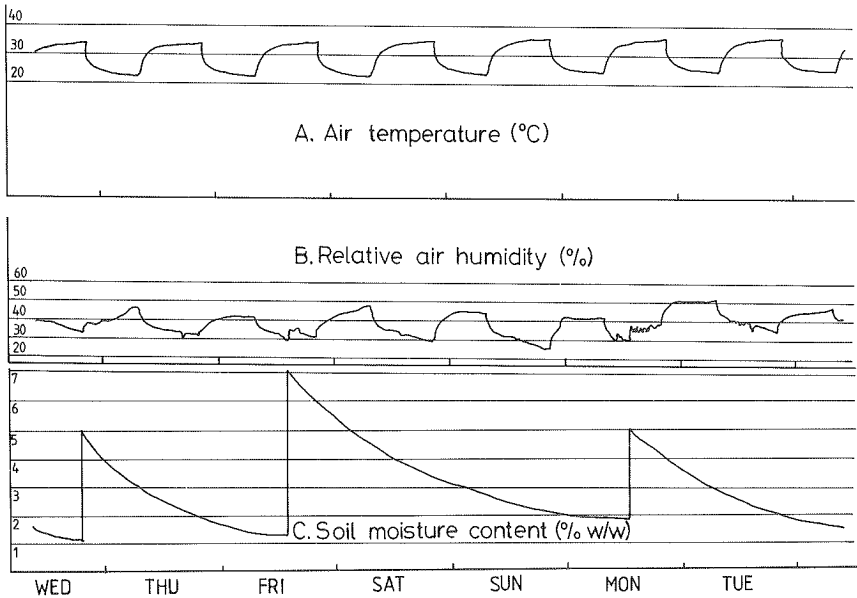


FIG. 1. — Temperature, air humidity and soil moisture content during one week of the experiment. The variations during the whole experimental period are larger than illustrated here.

Table 2

*Chemical analysis of the substrate
(dune sand)*

N (mg/ 100 g)	42.9
P (ppm)	164.9
K (ppm)	366.7
Ca (ppm)	23970
Mg (ppm)	618
Fe (ppm)	3334
% O.M.	0.15
% CaCO ₃	7.3
pH (H ₂ O)	8.09
conductivity (μS)	65

The light intensity under the high pressure mercuryiodide lights (Philips G92/2MP/T, 400 W) varied from 102 to 153 $\mu\text{mol.m}^2.\text{s}^{-1}$ (PAR = Photosynthetic Active Radiation). The illumination was rendered more homogenous by using screens covered with aluminium foil. The differences in light intensity were thus reduced to 33% (56% without aluminium screens). To diminish the effects created by possible differences in light intensity and temperature on plant growth, a randomized block design was used.

The first two weeks soil moisture was kept at 15% daily. During the third week after the experiment's start, the soil moisture content was decreased by 1% per day, from 15% to 5%. From the fourth week on, the pots were irrigated 3 times per week : at Friday the water content was brought to 7%, at Monday and Wednesday to 5%. The 7% at Friday was necessary to prevent drought stress damage. With every irrigation the quantity of water consumed during the previous period was measured. In that way total water consumption (evapotranspiration) could be determined.

The seedlings were counted daily. From the moment a pot contained 20 seedlings all subsequent new seedlings were removed ; thus all measurements were carried out on 20 plants per pot.

At a point 4, 6, 8, 10 and 12 weeks after sowing, measurements were executed on 4 pots per treatment. The shoots were cut (at soil level) and kept in ethanol 70%. The roots were washed on a 1 mm sieve and after determining the root dry weight (24 hours at 105°C), the ash-free organic root weight was measured by ashing the roots in a muffle furnace at 650°C for six hours (BÖHM 1979, DANNEELS *et al.* 1987). Total shoot length, and total length of every leaf was measured. Afterwards, the shoot dry weight (24 hours at 105°C) was measured.

RESULTS

1. *Germination* (Table 3, Fig. 2)

In between the 7th and the 9th day after sowing, a significantly ($P < 0.05$) higher number of seedlings was recorded in the presence of PAM and with the combination of PAM and anorganic fertilizer. Ten days after sowing only the PAM treated pots show significantly more seedlings. Eleven days after sowing, no more significant differences ($P < 0.05$) were recorded.

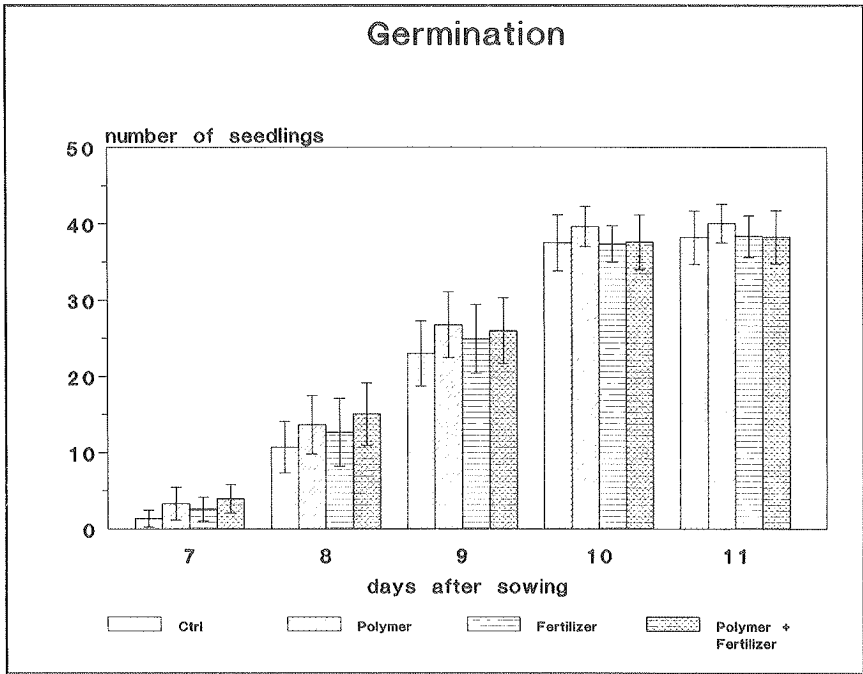


FIG. 2. — Number of seedlings per pot from the 7th to the 11th day after sowing (vertical lines indicate Standard Deviation).

2. *Water use* (Table 3, Fig. 3)

During the first two weeks, soil moisture content was kept at 15% (w/w) in all pots. Consequently during the first 4 weeks of the experiment no differences in evapotranspiration were recorded. From the sixth week on, the control pots consumed significantly more water than the treated pots. The pots treated with the combination of PAM and fertilizer consumed significantly ($P < 0.05$) less water than those treated with PAM and fertilizer separately.

3. *Shoot biomass* (Table 3, Fig. 4)

From the tenth week on, shoot biomass production in the control and fertilizer treated pots was higher than with PAM or the combination of fertilizer and PAM. Due to the high standard deviations the differences are not significant ($P < 0.05$).

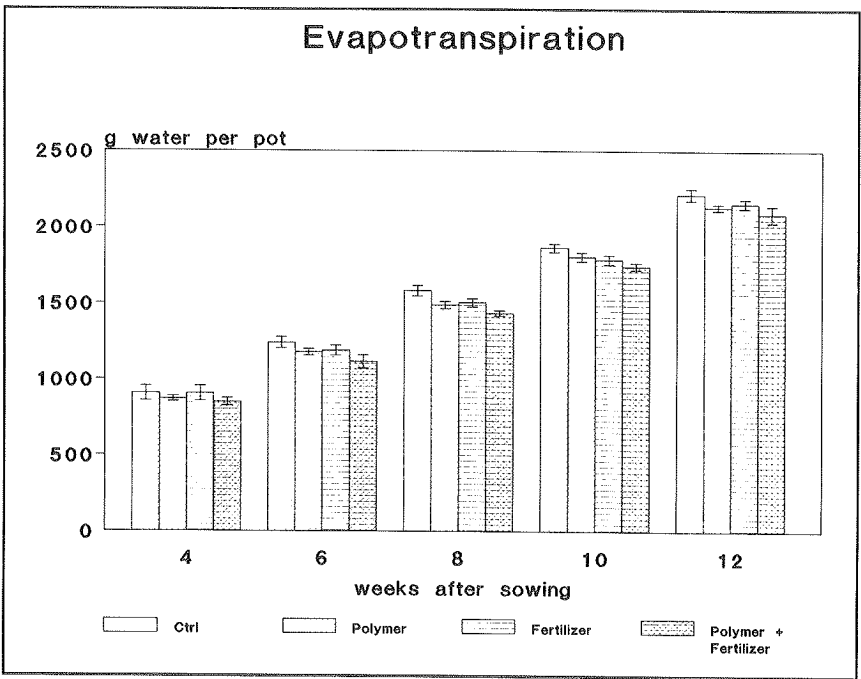


FIG. 3. — Water use in gram of water per pot (vertical lines indicate Standard Deviation).

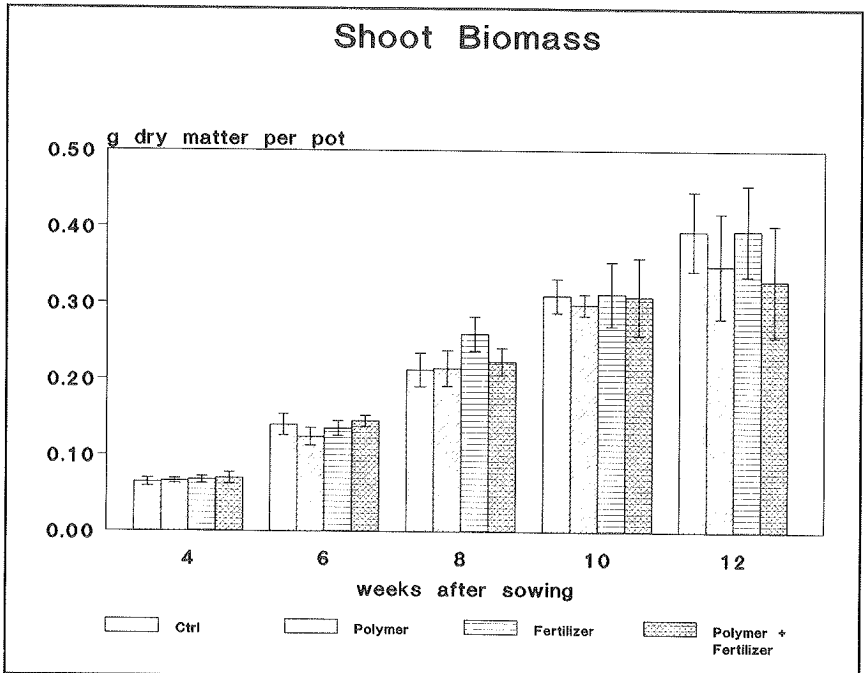


FIG. 4. — Shoot biomass production in grams of dry matter per pot (vertical lines indicate Standard Deviation).

Table 3

*Results. The maximum number of seedlings is 50,
countings are based on 4 replicates.*

Dry weight and water use efficiency measurements are based on 4 replicates

Lengths are based on 80 measurements

	days after sowing	control	PAM	fertilizer	combination
germination (number of seedlings)	7	1.35 a*	3.30 bc	2.60 b	3.95 c
	8	10.70 a	13.65 b	12.65 ab	15.05 ab
	9	23.00 a	26.75 b	24.90 ab	26.00 ab
	10	37.50 a	39.65 b	37.35 a	37.60 a
	11	38.20 a	40.05 a	38.35 a	38.25 a
	weeks after sowing	control	PAM	fertilizer	combination
water use (g)	4	906.0 a	869.5 a	904.3 a	848.3 a
	6	1239.8 a	1177.0 b	1188.8 ab	1115.0 c
	8	1581.0 a	1487.5 b	1503.0 b	1433.8 c
	10	1962.8 a	1804.0 b	1785.0 b	1741.5 c
	12	2215.5 a	2132.3 bc	2154.0 b	2087.3 c
dry matter shoot (g)	4	0.0642 a	0.0659 a	0.0676 a	0.0698 a
	6	0.1399 a	0.1242 ab	0.1352 ab	0.1447 b
	8	0.2122 a	0.2142 a	0.2597 b	0.2233 a
	10	0.3098 a	0.2979 a	0.3121 a	0.3085 a
	12	0.3945 a	0.3492 a	0.3954 a	0.3295 a
dry matter root (g)	4	0.1749		0.2363	
	6	0.2312 a	0.2908 ab	0.3330 ab	0.3995 b
	8	0.2883 a	0.3147 a	0.3575 a	0.4483 b
	10	0.3235 a	0.4165 ab	0.3704 ab	0.4531 b
	12	0.3631 a	0.4871 b	0.3714 a	0.4453 ab
dry matter total (g)	4	0.2411		0.3040	
	6	0.3711 a	0.4150 ab	0.4682 ab	0.5442 b
	8	0.5005 a	0.5289 a	0.6171 b	0.6717 b
	10	0.6333 a	0.7144 a	0.6825 a	0.7616 a
	12	0.7576 a	0.8363 a	0.7668 a	0.7748 a
water use efficiency (total biomass)	4	0.2667		0.3388 a	
	6	0.3003 a	0.3528 a	0.3911 ab	0.4891 b
	8	0.3164 a	0.3555 ab	0.4110 b	0.4687 c
	10	0.3401 a	0.3956 ab	0.3821 ab	0.4377 b
	12	0.3423 a	0.3956 a	0.3563 a	0.3711 a
Total shoot length (cm)	4	10.74 a	10.96 a	10.99 a	11.54 b
	6	15.03 ab	14.48 ab	14.24 a	15.43 b
	8	15.92 a	17.77 b	17.72 b	17.24 ab
	10	18.82 ab	18.93 ab	18.07 a	19.78 b
	12	20.64 a	19.49 a	20.65 a	19.08 a

	weeks after sowing	control	PAM	fertilizer	combination
Length leaf 2 (cm)	4	6.86 a	6.64 a	7.07 a	7.27 a
	6	14.57 a	13.92 a	13.62 a	15.01 a
	15.73 a	17.53 b	16.89 ab	16.99 ab	
	10	16.70 a	15.54 b	15.92 a	18.07 b
	12	16.89 a	16.93 a	16.49 a	16.80 a
Length leaf 3 (cm)	4				
	6	5.68 a	5.15 a	6.21 a	5.86 a
	8	9.29 a	9.23 a	13.27 b	10.92 a
	10	17.68 a	16.84 a	16.73 a	16.73 a
	12	20.09 b	18.33 ab	20.13 b	16.95 a
Length leaf 4 (cm)	4				
	6				
	8				
	10	8.80 a	7.60 a	8.07 a	10.22 a
	12	10.03 a	9.76 a	10.79 a	9.69 a

* Means followed by the same letter within a row are not significantly different at the 5% level according to the LSD test.

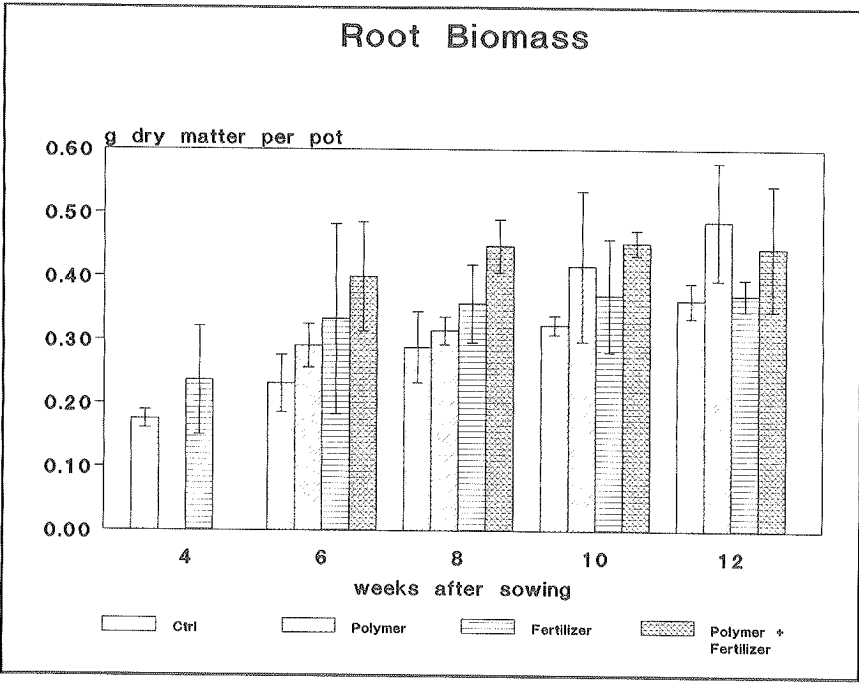


FIG.5. — Root biomass production in grams of dry matter per pot (vertical lines indicate Standard Deviation).

4. Root biomass (Table 3, Fig. 5)

Six and eight weeks after sowing, the root biomass in the pots treated with the mixture of PAM and fertilizer was significantly higher than in the pots with other treatments. The increase of root biomass was faster in the presence of PAM than in the other treatments. Consequently, after 12 weeks the largest amount of root biomass was found in the PAM-treated pots, followed by that found in the combination-treated ones.

5. Total biomass production (Table 3, Fig. 6)

Until week no. 8 the following sequence of increasing production was recorded : control, PAM, fertilizer, combination. From the 10th week on, the increase in the presence of PAM was faster than for the other treatments while the rate of increase for the combination slowed down.

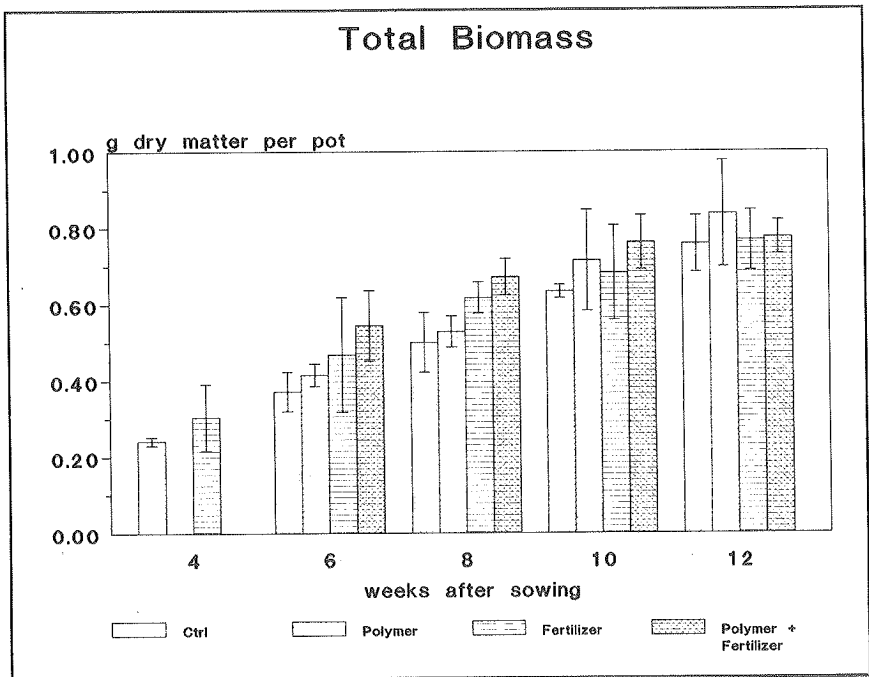


FIG. 6. — Total biomass production in grams of dry matter per pot (vertical lines indicate Standard Deviation).

6. *Water Use Efficiency for the total biomass production* (Table 3, Fig. 7)

The same tendencies as for total biomass production were recorded.

7. *Total shoot length* (Table 3, Fig. 8)

Four weeks after sowing, the seedlings growing in the combination were very small, but significantly ($P < 0.05$) longer than those growing in the other treatments. Presumably this is a prolonged effect of the somewhat faster germination in the presence of PAM. During the 6th, 8th and 10th week no meaningful conclusions were drawn. Twelve weeks after sowing, the tallest plants were found in the control and fertilizer treated pots, but the differences are not significant.

8. *Length of leaves no. 2, 3 and 4*

No clear differences in rate of development of the leaves could be recorded.

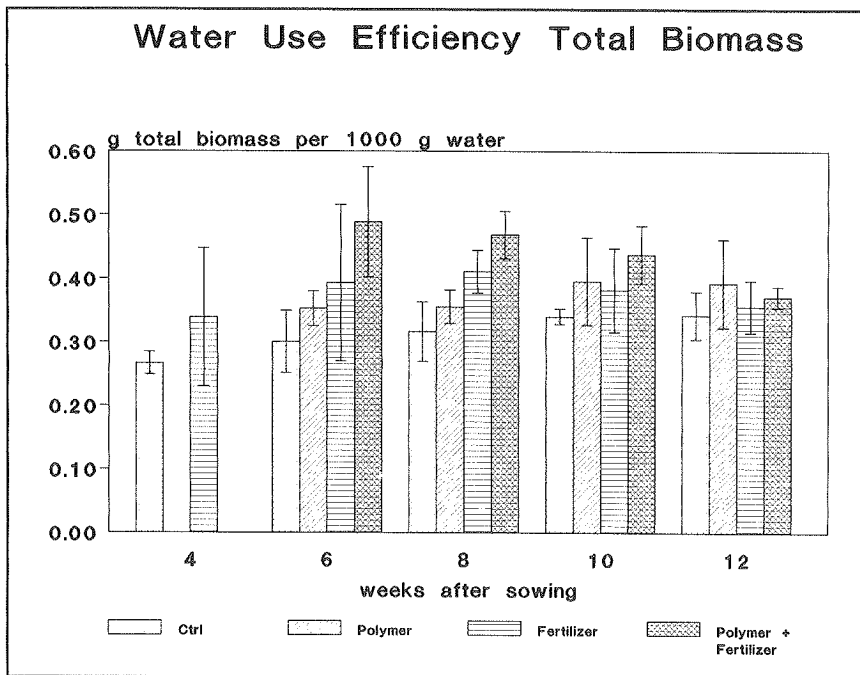


FIG. 7. — Water use efficiency for the total biomass production (in grams of dry matter per 1000 gram water, vertical lines indicate Standard Deviation).

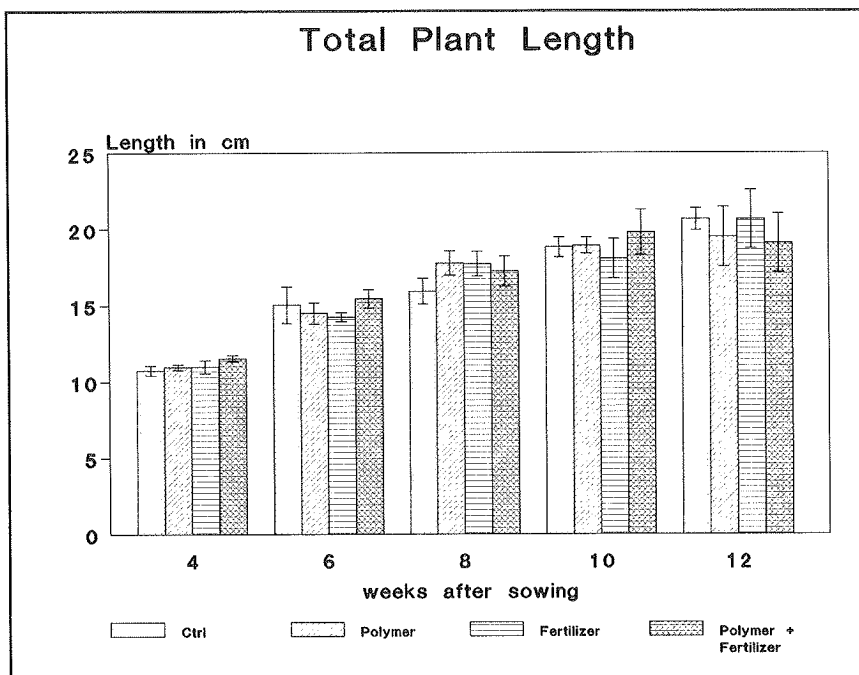


FIG. 8. — Total shoot length in cm (vertical lines indicate Standard Deviation).

DISCUSSION

Beneficial effects of PAM on germination and seedling emergence are reported by DE VLEESCHAUWER & GABRIELS 1975, AZZAM 1985, WALLACE & WALLACE 1986a, 1986b, WALLACE 1987 and DANNEELS *et al.* 1987. Our results confirm those findings. In the presence of PAM, the first germination stadia occurred earlier although the differences after stabilization of the seedling number are not significant ($P < 0.05$, Fig. 2).

Interesting to note are the differences of the effect of PAM and/or fertilizer on shoot and root biomass. Shoot biomass is hardly influenced by the treatments during the first 10 weeks. As for the root growth, an increasing effect of PAM, fertilizer and the combination was recorded during the first 8 weeks (Fig. 5). After 12 weeks shoot biomass was negatively influenced in the presence of PAM and the combination, while root biomass is positively influenced by those treatments (Fig. 4 and 5). The increase of root biomass in presence of polymers has also

been observed in other experiments (DANNEELS *et al.* 1992a, 1992b). The somewhat higher soil moisture content in the presence of PAM could also form a partial explanation for this. HURD (1968) found that root length in wet soil conditions was significantly higher than in dry conditions. The cumulation of these two effects leads to minute differences in total biomass production between the different soil treatments. Total biomass production is slightly higher in presence of PAM, but the differences are not significant ($P < 0.05$, Fig. 6).

The presence of PAM and/or fertilizer decreases the water use. With fertilizer, this decrease is probably caused by crust formation of the upper sand particles, which slightly decreases evaporation. Pots treated with the combination consumed 128.2 g less water in respect to the control, or only 94.2% of the total water consumption of the control.

As the differences in water consumption and biomass production are minute, the differences in water use efficiency after 12 weeks are consequently very small. Much greater differences are seen 6 and 8 weeks after sowing.

The influences of the two products on shoot length are also small. After 4 weeks the effect of a somewhat quicker germination in presence of the combination was seen: the plants were small but their differences in length were significant. That effect disappears during the following weeks. After 12 weeks the results for shoot length and shoot biomass are quite similar (correlation 95.84%, $P < 0.001$). No differences in development of the leaves could be recorded.

A soil moisture content of 5% (w/w) causes a moderate to strong drought stress. At the end of every irrigation period, the permanent wilting percentage (3% soil moisture content (w/w) for dune sand) is surpassed. In this circumstance, the effects of low rates of PAM and/or fertilizer are limited. Moreover, *Ammophila* is a stress-tolerant species (HUISKES 1979 : 364), in which the effects of the products are supplementarily masked. Nevertheless, the additional positive effects of PAM upon root growth and of fertilizer upon shoot growth are remarkable.

The same experiment has also been executed at soil moisture content levels of 10% and 20%. The entire results thereof will be published elsewhere, but it can already be mentioned here that the positive effects of both products are even more pronounced under these wetter conditions.

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