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Stabilization of Great Lakes Sand Dunes: Effect of Planting Time, Mulches and Fertilizer on Seedling Establishment

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ABSTRACT

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Studies were conducted to test the effect of planting time, mulches and fertilizer on seed germination and seedling establishment of *Calamovilfa longifolia* (Hook.) Scribn. and *Ammophila breviligulata* Fern. in a blowout along Lake Huron shoreline. Seeds were planted in June or October 1982 and covered with various mulches (sodium silicate, asphalt emulsion, wood chips, peat moss, straw, jute mesh, hydro mulch plus erosion blanket and control). Two other treatments (fertilizer and weekly watering) were also tested. Planting of grass seeds in October was more appropriate than the June planting because the seeds did not have to be artificially stratified and watering was not essential for seed germination and seedling emergence in spring. In 1982, about 2 to 26% of *Ammophila breviligulata* seedlings established in different treatments probably owing to shading by the sides of wooden frames and well distributed precipitation during summer. However, in summer 1983 with normal precipitation and natural dune environment, none of the seedlings survived in any of the treatments. It is suggested that *A. breviligulata* should not be planted from seed. In contrast, the seedling establishment of *C. longifolia* was rather high (7 to 96%) in different treatments in all three years. After 63 or 67 weeks of sowing, none of the mulch treatments was significantly better than control except jute mesh and erosion blanket for *C. longifolia.* The application of fertilizer resulted in larger seedlings than control at the end of one year.

ADDITIONAL INDEX WORDS: *Dune stabilization, mulches, Ammophila breviligulata, Calamovilfa longifolia, seedling establishment, fertilizer.*

INTRODUCTION

In North America, *Ammophila breviligulata* and *A. arenaria* are used extensively to repair or prevent erosion of natural and artificial dune systems (WOODHOUSE, 1986). The planting technique and fertilization regimes have been well established (JAGSCHITZ and BELL, 1966; HOBBS *et al.,* 1983). Vegetative segments are planted manually at 20 cm within the row and 30 cm between rows. Although the technique is expensive the transplants are effective in completely stablizing a wandering sand dune within about 2-3 years (WOODHOUSE, 1986). Nevertheless, problems arise about 5-10 years after the initial planting. The plants start to deteriorate in vigour naturally (MARSHALL, 1965; ELDRED and MAUN, 1982) and the density of shoots decreases thus exposing the bare sand surface to the force of wind once again (WOODHOUSE *et al.,* 1977). This deterioration is well known and the cause has been speculated upon for more than 100 years (MAUN and BAYE, 1989) in both *A. breviligulata* and *A. arenaria.* Thus, these measures are temporary unless they are followed by the introduction of other native species.

After artificial stabilization some dune species will naturally colonize the plantations but the process is rather slow (HEWETT, 1970). A method is therefore needed for permanent stabilization with a minimum of expenditure. A native grass of considerable importance on the dune systems of Lake Huron and Lake Michigan is *Calamovilfa longifolia.* It is a C_4 species which establishes from seeds and naturally follows *A. breviligulata* in succession. Direct seeding of grasses for sand dune stabilization has been utilized along the mid-Atlantic (ZAK, 1977) and in Europe (SHELDON and BRADSHAW, 1977). Generally, mulches of different types must be used for arresting sand move-

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ment and conservation of moisture. Effectiveness of mulches varies. For example, ECK *et al.* (1968) found that hay mulch was the most effective in sand stilling, holding moisture and generally improving conditions for the establishment of perennial sand binding grasses. MITCHELL (1974) showed that straw mulch disked in or used in conjunction with a bitumen emulsion (as an adhesive), was the most promising and least costly for temporary stabilization of sand dunes during the establishment of *A. arenaria*. In Israel, TSURIELL (1974) found that seeds of *A. arenaria* sown directly in sand and then the surface sprayed with bitumous emulsions to form a crust resulted in a high percent of germination. In Australia, BARR and MCKENZIE (1976) found that brush matting provided the best ground cover of grasses and was most effective in resisting the wind erosion of sand.

The objectives of this study were (a) to determine the seedling establishment of two native dune building grasses; sand reed (*Calamovilfa longifolia*) and American beach grass (*Ammophila breviligulata*), in directly seeded plots and (b) to examine the effects of various mulches and fertilizer on the emergence and establishment of seedlings of the two grasses.

MATERIALS AND METHODS

Experiment 1

The experiment was laid out on the windward side of a blowout in the second dune ridge adjacent to Lake Huron shoreline at Picnic Area 9 in the northeastern section of Pinery Provincial Park (43°15 N latitude, 81°51'W longitude) Ontario. The study area had a slope of about 10° and was fenced to avoid vandalism. In the study area 3 rows, 11 m in length and 0.5 m in width and one row 6 m in length and 1 m in width were levelled. There was a distance of 2 m between rows. In each of four rows 22 wooden frames (0.5 × 0.5 × 0.21 m) were placed side by side. Each row served as one replication. The experiment consisted of comparison between two grass species; *Ammophila breviligulata* and *Calamovilfa longifolia,* and eleven treatments; (1) *water*—once a week the plot was sprayed with water until the top 8 cm was saturated, (2) *sodium silicate*—a 2½% solution of sodium silicate was sprayed on sand surface until it formed a 0.5 cm thick crust, (3) *asphalt emulsion*—emulsion of asphalt was sprayed on the sand until the layer was 0.5 cm thick, (4) *wood chips*—a 1-2 cm thick layer of shredded wood was placed on the sand, (5) *peat moss*—sphagnum peat was placed on the sand to a depth of 3-6 cm, (6) *straw*—straw was placed on the sand to a depth of 3-6 cm, (7) *jute mesh*—Burlap bags with 0.4 cm openings were spread over the sand, (8) *hydro mulch*—wood cellulose fiber was mixed with the seeds and water, and applied as a slurry on the sand to a depth of 4-5 cm, (9) *erosion blanket*—a 2-4 cm thick layer of excelsior with plastic netting was spread over sand and was held in place with metal staples, (10) *hydro mulch with erosion blanket*—hydro mulch as in treatment 8 was covered with erosion blanket as in treatment 9 and (11) control.

Seeds of *A. breviligulata* and *C. longifolia* for this experiment were collected from the first dune ridge in the fall of 1981, and stratified in sand for 25 and 33 days, respectively. Forty four samples of equal weight for each of *A. breviligulata* (about 250 seeds per sample) and *C. longifolia* (about 800 seeds per sample) were prepared. One seed sample of each species was then planted in monocultures in each frame at a depth of about 3 cm before the mulch was applied except for the hydro mulch treatments in which the seeds were mixed with hydro mulch and water and then spread on the sand surface. Treatments were watered once after the application of mulches except hydro mulch and the asphalt treatments. For the asphalt treatment the plots were watered prior to the application of emulsion. Thus, there were 11 treatments, two grass species (*A. breviligulata* and *C. longifolia*) and four replications. Within each replication, 11 × 2 treatments were randomly assigned to the 22 frames. The plantings of seeds was done from June 9-11, 1982. Starting two weeks after planting seedling counts were recorded in each frame once a week until the end of August (11 weeks). The counting of seedlings was resumed again in the end of May 1983 and continued until the end of August 1983 (63 weeks).

Experiment 2

This experiment was laid out on October 11, 1982 on the southeast slope of a blowout in Picnic Area 5 of the park. The seeds for this planting were collected from the 1982 crop of seeds of *A. breviligulata* and *C. longifolia*. The layout plan was similar to that of Expt. 1 but the plot size was increased to 1 × 1 m and wooden frames were not utilized to simulate more closely the natural conditions for seed germination, emergence and establishment of seedlings. The experimental area (11 × 16 m) was divided into nine 1-m wide rows with 1.5 m between rows. Within each row except the row at the bottom of the plot there were seven 1 × 1 m plots spaced 1 m apart. The bottom row contained eight 1 × 1 m plots. Out of the 11 mulch treatments in Expt. 1, water, sodium silicate, asphalt emulsion, and peat moss were deleted but a new treatment *i.e.* fertilizer (225 g of slow release 10-10-10 NPK per plot) was included. Thus, there were 8 treatments, 2 grass species (*A. breviligulata* and *C. longifolia*) and four replications. For the assignment of treatments, the bottom row (row 9) was assigned to the fertilizer treatment so that the seepage of fertilizer would not influence other treatments. From the other eight rows, rows one, three, five and seven were assigned to *A. breviligulata* while rows two, four, six and eight were assigned to *C. longifolia*. The seven mulch treatments were randomized within each row.

For planting of seeds, thirty two seed samples of equal weight for each of *A. breviligulata* (about 250 seeds per sample) and *C. longifolia* (about 300 seeds per sample) were prepared. The method of planting of seeds and the mode of application of mulch treatments was the same as in Expt. 1. The fertilizer was spread evenly over the sand surface after the planting of seeds and mixed with the top 2 cm of sand.

In this experiment, the seeds of *A. breviligulata* and *C. longifolia* underwent natural stratification during the winter of 1982-83. The seedling counts were initiated in each plot on May 15, 1983 and continued regularly on two week intervals until September 22, 1983. The counts were resumed again on May 16, 1984 and continued until August 21, 1984. For ease in seedling counts, a 1 × 1 m wooden frame divided into 100 grids was gently placed over each plot.

Statistical Analysis

Standardized survivorship curves of all treatments in both species were calculated and plotted on semilog paper for both experiments. For Expt. 1, the mean number of seedlings for both species were standardized to 1000 in the third or fourth week after planting depending on the date on which the plot contained the maximum number of seedlings. Similarly, for Expt. 2, the seedling numbers were standardized to 1,000 and 2,000 for *A. breviligulata* and *C. longifolia* respectively on the second recording date. Since few seedlings died during the initial stages of emergence, early seedling survivorship was not recorded. The mean proportion of surviving seedlings of *A. breviligulata* and *C. longifolia* for each mulch treatment was calculated at the end of 11 and 63 weeks in Expt. 1 and at the end of 19 and 67 weeks in Expt. 2. The mean proportion of surviving seedlings on the last recording date in 1982 (Expt. 1), 1983 (Expt. 2) and 1984 (Expt. 2) in different mulch treatments were analysed using Analysis of Variance (ANOVA) techniques. The proportions were transformed to Arc-sine values before the analysis of data. If ANOVA indicated significant differences, Duncan's multiple range test ($P < 0.05$) was used to determine differences between means.

RESULTS

Emergence of Seedlings

Seedlings from the June 9-11, 1982, (Expt. 1) planting began to emerge about 6 days after planting and emergence was maximum in most treatments about 19-21 days after planting. In the erosion blanket and erosion blanket plus hydro mulch treatments, germination continued for more than 2 months after planting. The number of seedlings per quadrat were the highest in control and watered plots for both grass species (Table 1).

The seeds planted in Oct. 1982 (Expt. 2) did not germinate in October or November 1982 primarily due to low soil temperatures and innate or enforced dormancy of seeds (MAUN 1981). The first seedlings started to emerge in the beginning of May and by about the end of May, peak emergence of seedlings had already occurred. The reduction of emergence by mulch treatments as seen in Expt. 1 was not recorded in this experiment (Table 1). Actually, several mulch treatments e.g. jute mesh, erosion blanket, and wood chips had more seedlings per quadrat than control.

Table 1. *Mean number ± S.D. of emerged seedlings per quadrat of* Ammophila breviligulata *and* Calamovilfa longifolia *planted in sand and covered with different types of mulches in 1982 and 1983.*[a]

Mulch Treatment	*Ammophila breviligulata* Quadrat Size 0.5 × 0.5 m 1982	*Ammophila breviligulata* Quadrat Size 1 × 1 m 1983	*Calamovilfa longifolia* Quadrat Size 0.5 × 0.5 m 1982	*Calamovilfa longifolia* Quadrat Size 1 × 1 m 1983
Control	185 ± 78	68 ± 53	610 ± 88	66 ± 39
Water	217 ± 42	–	581 ± 140	–
Jute Mesh	67 ± 37	181 ± 83	148 ± 72	192 ± 130
Hydro Mulch	17 ± 10	8 ± 5	43 ± 17	21 ± 4
Erosion blanket	30 ± 38	193 ± 45	82 ± 42	97 ± 67
Hydro Mulch + Erosion Blanket	13 ± 5	90 ± 40	76 ± 30	79 ± 75
Straw	47 ± 5	67 ± 32	42 ± 21	117 ± 78
Asphalt	33 ± 19	–	120 ± 107	–
Wood Chips	65 ± 16	92 ± 39	131 ± 37	127 ± 46
Sodium Silicate	61 ± 40	–	252 ± 109	–
Peat Moss	60 ± 11	–	143 ± 114	–
Fertilizer	–	114 ± 48	–	258 ± 143

[a]Each value is a mean of 4 replications. For *A. breviligulata* the number of planted seeds during 1982 and 1983 were 250 per quadrat. For *C. longifolia,* the number of planted seeds during 1982 and 1983 were about 800 and 300 per quadrat, respectively.

Survival of *Ammophila breviligulata*

Survival of seedlings (Expt. 1) in quadrats sprayed with water at weekly intervals was not significantly different from asphalt, hydromulch, control and wood chips treatments. Fewer seedlings survived in the jute mesh, straw and sodium silicate treatments than control but the differences in survival were not significant (Table 2, Figure 1). The least effective mulch treatment was peat moss in which all emerging seedlings exhibited drying of their tips. The drying progressed downwards to the base until they all died. The seedlings showed considerably higher mortality in the beginning than later in the summer season.

By the end of the second summer (63 weeks), the survival of seedlings in Expt. 1 had changed considerably (Table 2). In several treatments, new seedlings emerged from seeds that had remained dormant in the first summer but the mortality was rather high in all plots so that by the end of 63 weeks there was a substantial decrease in the proportion of established seedlings.

By the end of first summer (19 weeks) in 1983

Table 2. *The percent survival of seedlings of* Ammophila breviligulata *and* Calamovilfa longifolia *treated with different mulch treatments at the end of summer 1982 (11 weeks) and 1983 (63 weeks).*[a]

Treatments	*Ammophila breviligulata* 11 weeks	*Ammophila breviligulata* 63 weeks	*Calamovilfa longifolia* 11 weeks	*Calamovilfa longifolia* 63 weeks
Control	18 cd	9 abc	66 bc	45 c
Water	33 c	8 abc	75 abc	51 c
Jute Mesh	7 de	4 bc	95 ab	84 a
Hydro Mulch	17 cd	8 abc	81 abc	59 abc
Erosion Blanket	58 b	26 a	90 abc	83 ab
Hydro Mulch + Erosion Blanket	80 a	14 ab	90 abc	58 abc
Straw	4 de	2 bc	76 abc	60 abc
Asphalt	29 c	16 ab	61 c	48 c
Wood Chips	15 cd	2 bc	96 a	75 abc
Sodium silicate	10 de	4 bc	80 abc	47 c
Peat Moss	0 e	0 c	10 d	7 c

[a]Means in each column followed by the same letter are not significantly different at $P < 0.05$ according to Duncan's Multiple Range Test.

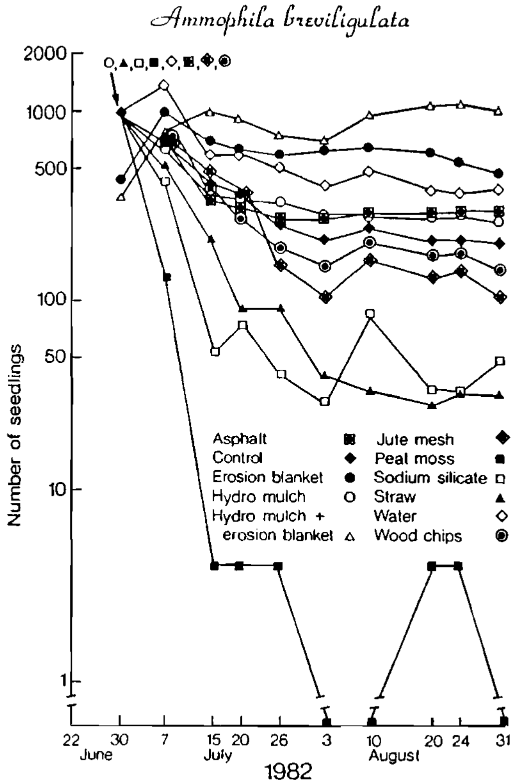

Figure 1. Survivorship (June 30 to August 31, 1982) of emerged seedlings of *Ammophila breviligulata* from seeds planted in wooden frames (0.5 × 0.5 × 0.21 m) and covered with different types of mulches.

(Expt. 2) all seedlings of *A. breviligulata* in all treatments had died (Table 3 and Figure 3). A small proportion of the seeds (10%) that had remained dormant in 1983 produced a cohort of new seedlings by the end of May 1984. These seedlings also died by the middle of July 1984 (Figure 3). Most of the mortality was observed during June and July of both summers.

Survival of *Calamovilfa longifolia*

Wood chips treatment resulted in highest value of survival for this species in Expt. 1 (Table 2 and Figure 2). The survival of seedlings (96%) was significantly higher in this treatment than control. However, many other mulch treatments e.g. jute mesh, erosion blanket, hydro mulch plus erosion blanket produced 90% or more survival of seedlings after 11 weeks and did not significantly differ from wood chips treatment. Spraying of asphalt decreased the survival of seedlings to 61%. The mulching treatment that was least effective was peat moss where only 10% and 7% of the seedlings were still surviving at the end of first (11 weeks) and second summer (63 weeks), respectively (Table 2).

The mortality during summer was the highest in the beginning of the summer (June and July) than later in the season (Figure 2). In two of the treatments, hydro mulch plus erosion blanket and erosion blanket alone, the number of seedlings per quadrat continued to increase until the end of July.

By the end of second summer (63 weeks), there was a decrease in seedling establishment in Expt. 1 especially in some treatments (Table 2). Most mortality occurred during winter months or during June and July (Figure 2). However, overall the establishment was rather

Table 3. *The percent survival of seedlings of* Ammophila breviligulata *and* Calamovilfa longifolia *treated with different mulch treatments at the end of summer 1983 (19 weeks) and 1984 (67 weeks).*[a]

Treatments	*Ammophila breviligulata* 19 weeks	*Ammophila breviligulata* 67 weeks	*Calamovilfa longifolia* 19 weeks	*Calamovilfa longifolia* 67 weeks
Control	0	0	33 ab	27 ab
Jute Mesh	0	0	47 a	24 ab
Hydro Mulch	0	0	42 ab	33 a
Erosion Blanket	0	0	25 b	18 ab
Hydro Mulch + Erosion Blanket	0	0	20 b	13 b
Straw	0	0	20 b	13 b
Wood Chips	0.03	0	31 ab	25 ab
Fertilizer	0	0	20 ab	13 ab

[a]Means in each column followed by the same letter are not significantly different at $P < 0.05$ according to Duncan's Multiple Range Test.

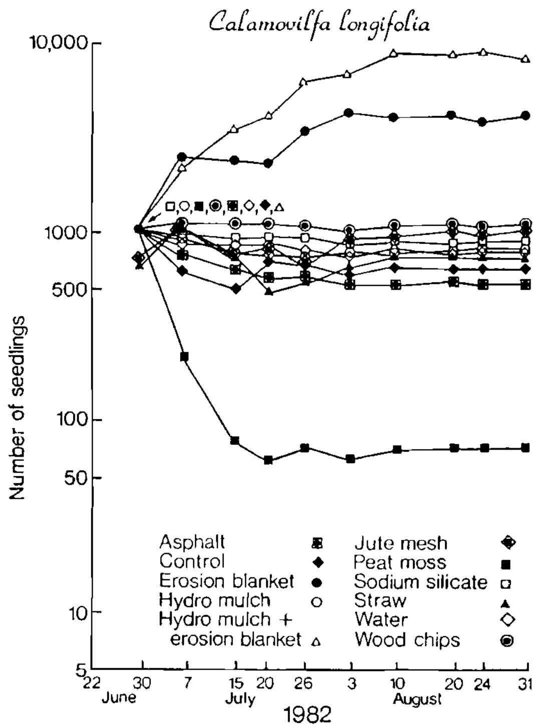

Figure 2. Survivorship (June 30 to August 31, 1982) of emerged seedlings of *Calamovilfa longifolia* from seeds planted in wooden frames (0.5 x 0.5 x 0.21 m) and covered with different types of mulches.

high (45–84%) in this species in control and all other treatments except peat moss.

At the end of first summer (19 weeks), the highest seedling establishment of *C. longifolia* in Expt. 2 was observed in the jute mesh treatment; however, none of the treatments were significantly different than control (Table 3, Figure 4). After 67 weeks of sowing there was a further decrease in establishment of seedlings (Table 3, Figure 4); however, about 13 to 33% of the seedlings survived. The addition of fertilizer showed low seedling establishment at the end of first and second summers but the seedlings were larger than other treatments.

A comparison between the two grass species showed that the survival of *C. longifolia* seedlings was much higher than *A. breviligulata* in all mulching treatments during all three summers.

DISCUSSION

Under natural sand dune conditions, the seedling establishment of *A. breviligulata* occurs only in years of well distributed summer rainfall (MAUN, 1985) while that of *C. longifolia* occurs every year but the rate of establishment seldom exceeds 20% (MAUN, 1981). The major limiting factors are trampling (PAYNE and MAUN, 1981) soil temperature, percent moisture, nutrient status and sand accretion or erosion (PAYNE and MAUN, 1984; MCLEOD and MURPHY, 1977; MAUN and BAYE, 1989; ROSS and HARPER, 1972). Generally, surface sand temperatures may exceed 50°C in June or July and the 5-10 cm layer of sand may contain little or no moisture (BALDWIN and MAUN, 1983).

The time of seedling emergence may act as a deciding factor for seedling establishment. Under natural conditions, seedling emergence is complete by the end of May before the onset of warm dry conditions. In Expt. 1, planting was done in early June but the seeds not only had to be stratified but also artificially watered once at considerable expense. Natural field conditions in Expt. 2 proved to be more satisfactory because the following winter not only fulfilled the chilling requirements of seeds but provided sufficient soil moisture for germination and emergence of seedlings in spring.

The use of mulches prolongs the growing season by acting as an insulator, extends period of moisture availability, prevents water loss, lowers soil temperature, controls soil erosion, eliminates undercutting and increases infiltration of water (SHELDON and BRADSHAW, 1977; SWANSON *et al.*, 1967; MCGINNIES, 1987; GROSSNICKLE and REID, 1984; ZAK, 1977; BUTTON and POTHARST, 1962). DUDECK *et al.* (1967) concluded that favourable grass growth in sand was associated with high soil moisture and low soil temperatures. Seedling establishment in Expt. 1 was not, however, limited to a great extent by soil moisture since the summer of 1982 had above average precipitation. The two weeks immediately following the planting of seeds of *A. breviligulata* and *C. longifolia* were particularly wet. The "control" and "water" treatments had more grass seedlings emerge than any of the mulch treatments. The lowered emergence in mulch treatments may

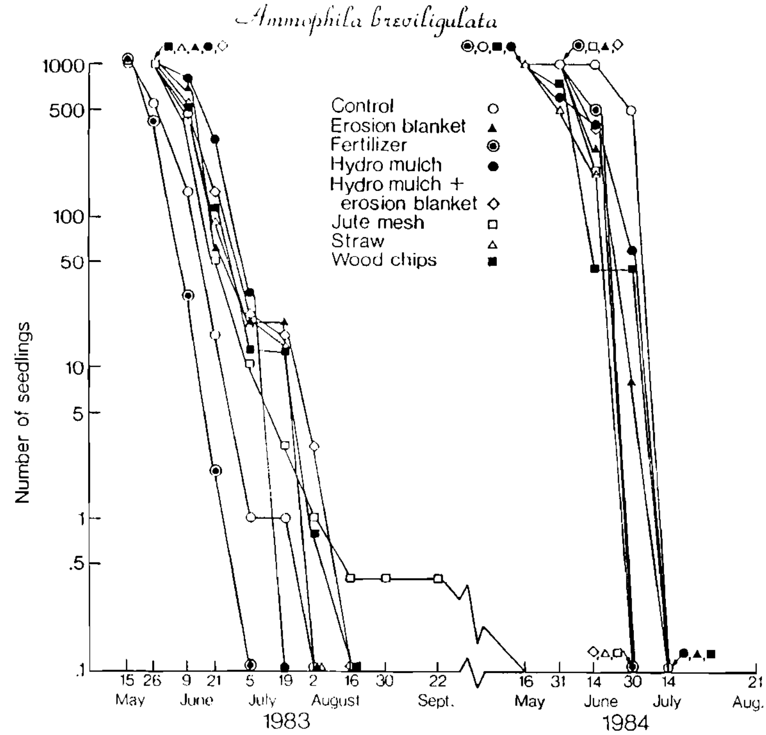

Figure 3. Survivorship (May 15, 1983 to July 14, 1984) of emerged seedlings of *Ammophila breviligulata* from seeds planted in 1 m² plots on the southwest slope of a blowout and covered with different types of mulches.

have been caused by induction of enforced dormancy, or more likely the inability of seeds to emerge from layers of material and possibly seed exposure especially in the hydro mulch treatment. In 1983, however, the same effect was not experienced except in the hydro mulch treatment (Table 1). The exposure of mulches to freezing and thawing, decomposition, rearrangement and breakdown of material and settling down of organic material may have reduced the adverse effects on emergence. The proportion of establishing seedlings is dependent on microenvironmental conditions and physiological requirements of seedlings.

Ammophila breviligulata

In Expt. 1 there was a substantial establishment of seedlings during both summers in all treatments except peat moss. Erosion blanket and hydro mulch plus erosion blanket, produced the highest rate of establishment. Even in control, 18 and 9% of the seedlings established after 11 and 63 weeks, respectively (Table 2). In Expt. 2 all seedlings of *A. breviligulata* died by the middle of August 1983 and July 1984 (Figure 3). The discrepancy between the two experiments is primarily caused by the wooden frames. The sides of wooden frames used in Expt. 1 shaded the seedlings on the north and west sides of the plot thus protecting them from desiccation and extreme fluctuations of soil moisture and temperature. Several studies (MCLEOD and MURPHY, 1983; MAUN, 1981) have shown that shaded habitats and nurse plants increase seedling establishment by lowering evaporative demands from the leaf surface.

Calamovilfa longifolia

Rate of establishment of seedlings was high in all treatments in both experiments except when using peat moss mulch (Table 2). In con-

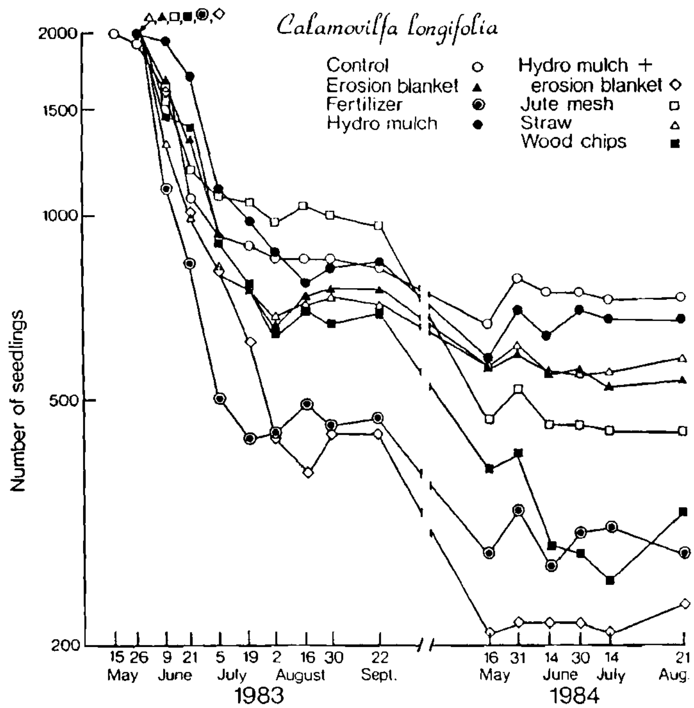

Figure 4. Survivorship (May 15, 1983 to August 21, 1984) of emerged seedlings of *Calamovilfa longifolia* from seeds planted in 1 m^2 plots on the southwest slope of a blowout and covered with different types of mulches.

trast, SHELDON and BRADSHAW (1977) reported that peat moss increased establishment more than the application of most chemical stabilizers. The rest of the treatments were not substantially different from control plots. Even in control, the establishment in Expt. 1 was 66 and 45% after 11 and 63 weeks, respectively. In Expt. 2, the values were 33 and 27% after 19 and 67 weeks of planting, respectively.

Plots treated with fertilizer exhibited a high percent of seedling emergence but the rate of establishment decreased to 20% after 19 weeks and 13% after 67 weeks of sowing the seeds. After 67 weeks, these plots were completely covered with foliage and had vigorous seedlings with several tillers each. Seedlings were also acting as centres of sand accumulation.

In earlier studies, the establishment of *A. breviligulata* seedlings has been shown to be rare occurring only in certain years under specific conditions (MAUN, 1985). This conclusion is borne out by the data presented in this study. The seedling survival was rather low in Expt. 1 and occurred only in wooden frames under rather artificial conditions. In larger plots (1 × 1 m quadrats) under natural growth conditions no *A. breviligulata* seedlings survived the summer. Thus, it will be inadvisable to establish *A. breviligulata* populations from seed. Planting of vegetative tillers has been shown to be an effective planting technique for *A. breviligulata* to restabilize the blowouts (WOODHOUSE, 1986). However, since the plants deteriorate within a few years and start to die out, interplanting of *C. longifolia* will be highly effective for long-term stabilization. Data clearly showed that *C. longifolia* shows good establishment from planted seeds in control as well as mulched plots. Certain general recommendations for restabilization of deteriorated sand dunes along Lake Michigan and Lake Huron are listed below.

(1) Plant *Ammophila breviligulata* from vegetative shoots according to the methods outlined by JAGSCHITZ and BELL (1966).

(2) Interplant *C. longifolia* seeds during the period most suitable for natural establishment. Along Lake Michigan and Lake Huron dune system, the fall would be the most appropriate season because stratification of seeds would occur naturally during winter and moisture levels in the spring would ensure good germination, emergence and establishment.

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