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PAM Spray Effects on Sugarbeet Emergence

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Polyacrylamide (PAM) is a term used to identify a class of water soluble, high molecular weight, synthetic organic polymers. All PAM molecules have a backbone structure comprised of acrylamide compounds, C_3H_5NO, modified via the loss of a C to C double bond, that are linked together into long chains. The term PAM is generic, describing a group of compounds, each different in its chemical and physical properties due to different chain lengths and minor alterations in some of the acrylamide subunits *(Lentz and Sojka, 1994)*. Water-soluble PAMs are effective flocculants, used as settling agents in food processing, water treatment, mineral processing and paper production *(Barvenik, 1994)*.

PAM is essentially non-toxic to organisms, though one impurity present in very low concentrations is a known human neurotoxin *(Seybold, 1994)*. In the environment, the carbon backbone of PAM is resistant to microbial attack but susceptible to physical breakage and chemical degradation from either free radicals or ultraviolet radiation. Seybold (1994) concluded that PAM posed no environmental threat and that it could be used to reduce irrigation-induced erosion and improve soil physical properties. Characteristics of PAM and several of its promising applications in agriculture have been reviewed recently by Lentz and Sojka (1994) and Seybold (1994).

PAMs have been used in agriculture for nearly 50 years, primarily to minimize soil structural deterioration *(Ben-Hur and Letey, 1989; Shainberg et al., 1992)*. PAM's greatest benefit, however, may be to control erosion under furrow irrigation. High molecular weight, moderately anionic PAMs added to irrigation water nearly eliminate irrigation-induced erosion, maintain infiltration rates, and strengthen soil structure *(Lentz and Sojka, 1994)*.

The emergence of row crops has often increased where PAM has been applied. Sweet corn (*Zea mays L.*) emerged better where 22 kg PAM ha^{-1} (in solution) were applied to field plots *(Cook and Nelson, 1986)*. In a greenhouse study under crusted conditions, sugarbeet emergence exceeded 80% where 70 mg PAM L^{-1} were applied in 30 ml to 8.6-cm-diameter pots, but was only 56% in untreated soil *(Ahmad, 1991)*. PAM sprayed onto newly planted rows, in combination with droplet energy minimization, may also increase seedling emergence.

Sugarbeet, a small-seeded species, emerges very poorly through crusted soils. If PAM or some other chemical amendment and/or droplet energy reduction would consistently enable 65% (or more) of seedlings from sown seeds to emerge, growers would experience substantial economic benefits. If replanting was not needed because an adequate stand had been established, the grower would have saved $370 ha^{-1} (including costs for seed, operation of the planting equipment, and reduced yields due to an estimated three-week delay in stand establishment). Due to soil crusting in southcentral Idaho alone, more than 3600 ha are replanted annually *(L. Kerbs, 1996, personal communication)*. Thus, soil crusting that requires replanting costs producers more than $1.3M in lost income.

This study was only a part of a research project seeking to increase sugarbeet emergence via

1) the cost-effective application of an appropriate chemical anti-crusting agent,

2) manipulation of the soil surface above planted rows of sugarbeet, and/or

3) reduction of sprinkler droplet energy. Our objective in this field study was to determine the effects of spray-applied PAM and sprinkler droplet energy on sugarbeet emergence.

Methods and Materials

Supplies and Site Characteristics

We used the polyacrylamide Superfloc1 836A (CYTEC Industries, Wayne, NJ) that has a high molecular weight of 12-15 Mg mol^{-1} and moderate (18%) anionic charge-density. Our soil was a Portneuf silt loam (Durixerollic Calciorthid), very unstable *(Lehrsch et al., 1991)* and quite susceptible to furrow erosion *(Lentz et al., 1996)*. A representative Portneuf Ap horizon commonly contains 660 g silt kg^{-1} and 200 of clay, has a pH of 7.7 in a saturated paste, and an organic C content of ca. 9.3 g kg^{-1}. Its aggregate stability at the soil surface in late July 1995 was ca. 89%.

Tillage and Planting

The experiment was performed 2.1 km southwest of Kimberly, ID, in 1995, on a field cropped the year before to spring wheat, *Triticum aestivum L.* On 10 April 1995, the field plots were fertilized with 11.2 kg Zn ha^{-1} and, one day later, with 18.5 kg N ha^{-1} and 38.2 kg P ha^{-1}.

After being moldboard plowed on 11 April, the site was roller-harrowed to a depth of 80 mm, once on 17 April and 16 May. On 18 May, a pre-emergence grass and broadleaf herbicide (s-ethyl cyclohexylethylthiocarbamate) was applied, then incorporated with a roller-harrow. On 24 July, the site was roller-harrowed twice in preparation for planting. On 25 July, a four-row Milton[1] planter, equipped with double-disk openers and rubber press wheels, was used to plant sugarbeet (cv. HM1 WSPM9, Large Pellet, 91% germination) at a depth of 20 mm every 0.13 m into rows spaced 0.56 m apart. Eight rows were planted. Precipitation was monitored on-site.

Experimental Design and PAM Treatments

The experiment was conducted as a split-plot with main plots arranged in randomized complete blocks. The main plots were two droplet energies, 5 and 15 J kg^{-1} of water reaching the soil surface. Droplet energies were randomly assigned to each 19.8-m half span of a lateral-move irrigation system (described below).

The subplots (PAM treatments, Table 1) were randomly assigned to

Table 1. PAM treatments

Treatment ID	PAM applied to sprayed area Nominal —kg ha⁻¹—	Actual	PAM Conc. mg L⁻¹	Tap water applied	Liquid applied L ha⁻¹
Control	0	0	0	No	0
Water	0	0	0	Yes	404
10 kg PAM ha^{-1}	10	9.9	1200	Yes	404
25 kg PAM ha^{-1}	25	26.7	3000	Yes	404

plots under each half span. To all plots but the control, we applied a similar volume, equivalent to a depth of ca. 0.84 mm, of either tap water or a PAM solution. Tap water, used for the water treatment and to make up the two PAM solutions, had an electrical conductivity (EC) of 0.9 dS m-1 and SAR of 1.5.

Operational characteristics of the equipment used to spray the PAM solutions or water on the soil surface are given by Lehrsch et al. (1996). Each spray solution flowed from a 19-L tank pressurized with regulated air through approximately 2.3 m of 6-mm (I.D.) rubber hose to a nozzle fitting. Each Teejet[1] nozzle (Spraying Systems Co., Wheaton, IL) was positioned immediately behind the rubber press wheels of a randomly selected planter unit. As a tractor pulled the planter at 4.12 km h^{-1} across the plots, the spray equipment applied each solution in a 25-mm-wide band to the soil surface directly above a planted sugarbeet row. Each planted row was an experimental unit, that is, a plot 25 mm wide by 13.7 m long, with the long axis perpendicular to the direction of travel of the irrigation system. The flow rates for all sprayed treatments were within 5.5% of the mean, 88.3 L h^{-1}. These application rates (on a total-volume-sprayed per unit-planted-area basis) were appropriate for producer use, with only 404 L ha^{-1} of solution being sprayed as planting occurred.

Droplet Energy Treatments and Irrigations

A lateral-move irrigation system was modified to deliver water to the soil surface at droplet energies of either 5 or 15 J kg^{-1}. In southern Idaho, droplet energies of at least 10 J kg^{-1} are common for center pivots with impact-type or high pressure spray heads.

Our lateral used two types of heads: a typical smooth-plate head operating at 138 kPa nozzle pressure for the low energy spray and a rotating four-groove plate operating at 103 kPa for the high. The lateral discharge rate was about 14 L $(min\ m)^{-1}$, common for pivots in the area.

We used the lateral-move system to irrigate the plots with water that commonly has an EC of 0.5 dS m^{-1} and SAR of 0.6 *(Lentz and Sojka, 1994)*. We applied 12 mm of water on 27 July, 21 mm on 1 August, 10 mm each on both 4 and 10 August, and 22 mm on 11 August. During the study, the plots received 0.25 mm of natural rainfall on four different days, on 29 and 31 July and on 3 and 14 August. Owing to low seedbed water contents, all plots were irrigated two days after planting. The water depth applied was measured using four catch cans at the soil surface under each 19.8-m-wide half span.

Emergence Evaluation and Statistical Analyses

We counted the emerged seedlings in the centermost 13.7-m of each row 24 days after planting. Emergence was reported as a percentage of the seeds sown. An analysis of variance identified significant effects (those with F-ratios significant at probability levels of 0.05 or less) of droplet energy and/or PAM on emergence. Once a significant source was found, means were separated using LSDs at a 0.05 probability level. Additional pre-planned single degree-of-freedom comparisons were also made.

Results and Discussion

Spray Patterns

Solution viscosity, that increased with PAM concentration, affected the treatment spray patterns *(Kincaid et al., 1996)*. The pattern of the 1200 mg L^{-1}-solution was fan-shaped about 35-40 mm below the nozzle but coalesced into a stream about 65 mm below the nozzle. Thus, to spray a 25-mm-wide band onto a plant row, we lowered the nozzle for this treatment only from 76 to 38 mm above the soil surface. The spray pattern of the 3000 mg L^{-1}-solution was never fan-shaped but resembled a dribbling stream. To apply this solution, we mounted two nozzles to the single supply line, with one nozzle offset about 12 mm from the other so that the combination of both streams wet the soil surface in a 20- to 30-mm-wide band.

Emergence

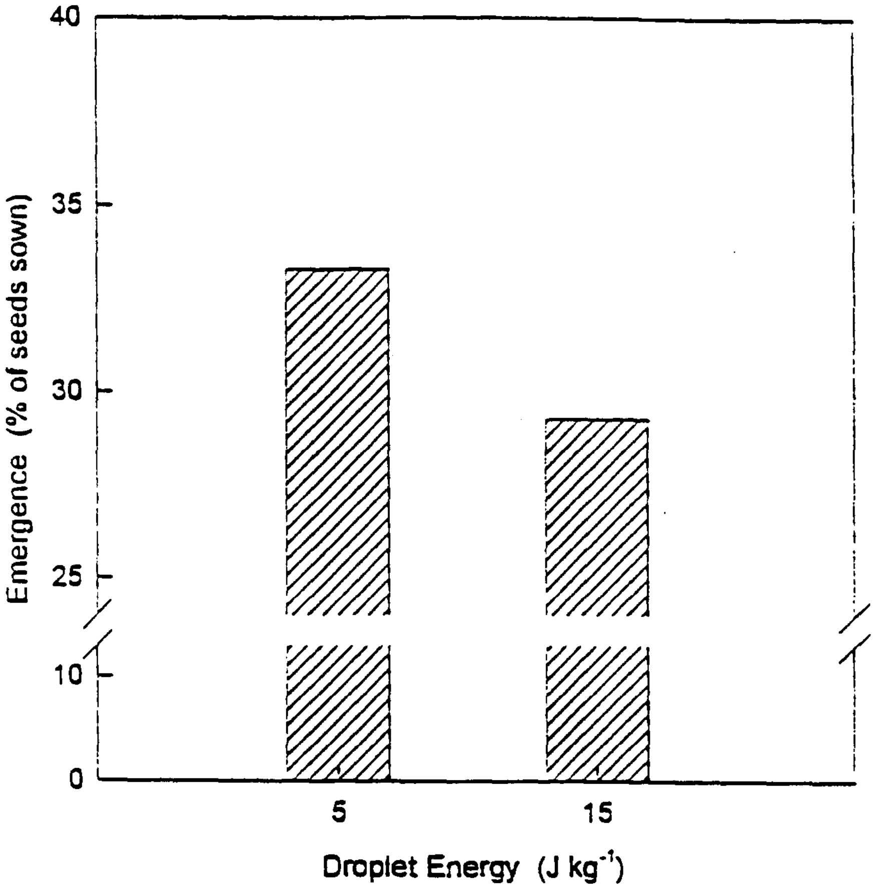
Since the variances of the emergence percentages from all treatments were homogeneous (Bartlett's test P =0.92) and the residuals from the fitted model were normally distributed (Shapiro-Wilk W =0.973, P =0.378), the emergence percentages were analyzed without transformation. The analysis of variance revealed that droplet energy was significant (P=0.055) and PAM was significant (P=0.022), but their interaction was not (P=0.405).

Droplet energy effects

The effects of droplet energy on emergence, averaged across PAM treatments, are shown in Fig. 1. In all our plots, emergence was low, averaging 31.3%. Overall poor emergence was the result of water stress caused by i) low initial water contents (mean of 0.10 kg kg^{-1}) in the seedbed at planting, ii) a relatively dry soil profile at and below the seeding depth, and iii) rapid drying of surface soil between irrigations. At the conclusion of the study, we uncovered numerous seeds that had not swollen sufficiently to crack their clay coating.

As droplet energy increased, emergence decreased, Fig. 1. Where droplet energies increased three-fold, emergence dropped by more than 12%. Droplet impact energies of 15 J kg^{-1} caused structural deterioration of the soil surface *(Lehrsch et al., 1996)* that led to crust formation. Our data in Fig. 1 show that more sugarbeet seedlings will emerge if sprinkler droplet energies can be kept low, as with smooth-plate sprinkler heads rather than single-nozzle impact-type heads *(Kincaid, 1996)*. If a sugarbeet grower were to modify his irrigation system to reduce droplet energy by two thirds, e.g., from 15 to 5 J kg^{-1}, our results indicate that his seedling emergence might increase by more than 13%. Since producers in a nine-county area in southcentral Idaho now harvest, on average, 90 plants / 30.5 m of row (90 plants / 100 ft of row) *(J. Gallian, 1996, personal communication)*, a 13% increase would be more than 10 plants / 30.5 m of row. A 10-plant-increase per 30.5 m of row increases a grower's net return by \$130 ha^{-1} *(J. Gallian, 1996, personal communication)*. In this region, where more than 56,600 ha of sugarbeet are grown annually, the potential exists for net income to increase by more than \$7.4M.

Fig. 1. **Droplet energy effects on sugarbeet emergence, averaged across PAM treatments. Means (n=32) were different at P=0.055.**



PAM effects

PAM sprayed on the soil surface at planting did not increase sugarbeet emergence, averaged across droplet energies, Fig. 2. In fact, the emergence of the 10 kg/ha^{-1} treatment was 16% less (significant at P=0.022) than that of the water treatment. An insufficient volume of PAM solution may have been applied to fully coat aggregate surfaces *(Malik and Letey, 1991; Roa, 1996)*. Alternatively, too little PAM may have been applied to enable aggregates to withstand subsequent droplet impact *(Shainberg et al., 1992)*. Emergence from our higher concentration (3000 mg L^{-1}, Table 1), 25 kg/ha^{-1} treatment was numerically greater than from the 10 kg/ha^{-1} treatment and statistically equal to the water treatment, Fig. 2. The emergence from either the 10- or 25-kg/PAM/ha^{-1} treatment was, however, statistically equivalent to the control. Single degree-of-freedom comparisons revealed that, when averaged across droplet energies, the average sugarbeet emergence of the two PAM treatments, 29.8%, was less ($P < 0.006$) than that of the water treatment and was less ($P < 0.016$) than the average of the two treatments without PAM, 32.8%. It may be, where the water treatment was applied and where the four naturally occurring rains fell, that clay platelets and silica came into suspension, along with Ca^{+2} into solution, and were transported via mass flow to particle-to-particle contact points above the seed, where they precipitated to strengthen aggregates as the soil later dried *(Lehrsch et al., 1996)*. In the treatments sprayed with PAM, on the other hand, clay platelets were immediately flocculated by PAM and did not likely enter suspension.

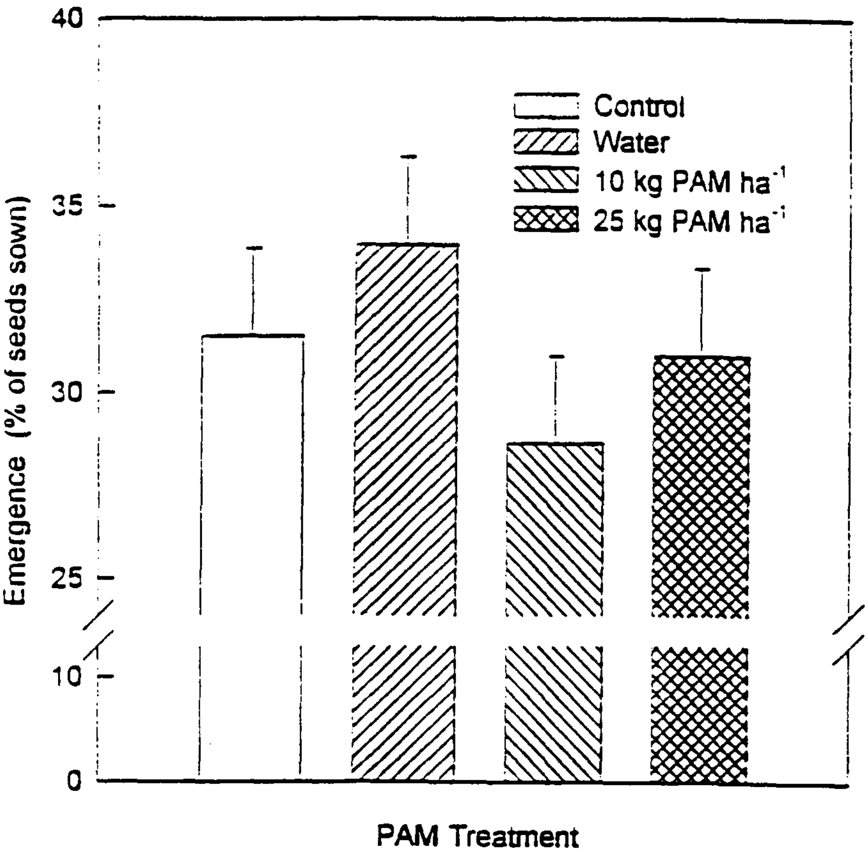
In our experiment, seedling emergence did not increase where either a 1200- or 3000-ppm PAM solution was sprayed onto newly planted sugarbeet rows. Other polyacrylamides, anti-crusting polymers, or application techniques may prove effective, however. Roa (1996) has shown that soil surface applications of high volumes of 10-ppm PAM solutions can stabilize soil against rain drop-induced erosion. Ahmad (1991) reported that polymers other than polyacrylamides increased sugarbeet emergence.

Summary and Conclusions

Two rates (10 and 25 kg ha^{-1}) of a moderate charge-density, anionic PAM were sprayed in 404 L of solution ha^{-1} in 25-mm-wide bands onto newly planted rows of sugarbeet. Neither rate increased field emergence more than the control. Where 25 kg PAM ha^{-1} were applied, emergence was statistically equal to the treatment with the best emergence, one in which tap water alone was sprayed onto the rows.

Where droplet energy was reduced from 15 to 5 J kg^{-1}, emergence increased by 13%. In a nine-county

Fig. 2. PAM treatment effects on sugarbeet emergence, averaged across droplet energies. Each bar is the mean + 0.5 L.S.D. (n=16).



area in southcentral ID, a 13% increase in emergence would increase growers' net returns by more than $7M. To increase field emergence, producers should reduce sprinkler droplet energy striking the soil surface after planting.

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[1] Trade names are necessary to report experimental details. These names are included for the reader's benefit and do not imply endorsement of the product by the USDA.