Growth and Tillering of Sand Bluestem as Affected by Exogenous Growth Regulators

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Highlight: Two plant growth regulators that were reported to inhibit auxin transport were exogenously applied to sand bluestem seedlings. DPX-1840 and Ethrel were shown to change tillering patterns, dry matter production, and plant form. When applied at relatively low concentrations, tillering was accelerated. Larger numbers of tillers developed on plants treated at the three-leaf stage as compared with those treated at the six-leaf stage. Exogenously applied plant growth regulators often reduced tiller length, plant height, and dry matter production. DPX-1840 caused plants to have an open or spreading appearance. In addition, laminas often remained rolled and were chlorotic.

Establishment is the most critical period in the life cycle of seeded range grasses. Environmental conditions favorable for seedling establishment may be present for only a limited time. If tillering was stimulated during favorable environmental conditions, the total number of established seedlings could be increased. No current agronomic practices exist which will satisfactorily increase tillering of grass seedlings.

In recent years, the chemical control of crop growth and development has been researched and many chemicals have been screened for possible effects on plant growth and development. However, little attention has been given to the physiological effects of these chemicals on growth and tillering of range grasses. Some researchers theorized that auxins directly inhibit the growth of lateral buds, or indirectly inhibit the growth of lateral buds by the production of some inhibitory compound (Thimann and Skoog, 1933; Eliasson, 1961). The inhibitor of lateral bud elongation is considered to be an auxin (Audus, 1963).

It was the authors' opinion that the rate of tillering in range grasses could be increased if the auxin's action was destroyed, or its transport was inhibited. This would reduce the amount of time required for seedling establishment and increase the productivity. A pilot study had shown that DPX-1840 [3,3a-dihydro-2-(p-methoxyphenyl)-8H-pyrazolo-(5,1-a) isoindol-8-

one] and Ethrel (technical product consists of 47% 2-chloroethane phosphonic acid, 13% 2-chloroethane phosphonic acid anhydride, and 37% mono-2-chloroethyl ester of 2-chloroethane phosphonic acid) increased the rate of tillering of sand bluestem seedlings. Both DPX-1840 and Ethrel are considered to be auxin transport inhibitors (Anonymous, 1971; Beyer, 1972; Morgan and Durham, 1972; Morgan, 1972). Ethrel has been applied to corn to successfully increase tillering (Earley and Slife, 1969). DPX-1840 is a newer chemical, and its effect on tillering of grasses had not been determined. The purpose of this study was to determine the effects of exogenously applied DPX-1840 and Ethrel on the growth and development of sand bluestem [*Andropogon hallii* (Hack.) Hack. ex Vasey] seedlings.

Materials and Methods

Four hundred and eighty plastic pots 12 cm square were filled with a mixture of Axtell sandy loam and washed sand. Ten caryopses of G-1773¹ sand bluestem were planted at a depth of 1 cm in each pot in a greenhouse. Temperatures varied from 30 to 36°C, and the photoperiod was maintained at 13 hours. After 2 weeks, the seedlings were thinned to three in each pot. Fifteen-day-old seedlings (three-leaf stage) were divided into two groups. Each group of 240 pots was randomly separated into four treatment replications of 60 pots and arranged in a randomized complete block design. The initial group was treated with growth regulators, and a second group was treated at the six-leaf stage, 30 days after planting.

Each chemical was applied at 0.010, 0.025, 0.050, 0.100, and 0.150 M concentrations in a solution of distilled water, with 0.5% Tween 20 (polyoxyethylene sorbitan monodaurate) added as a surfactant. A 0.1-ml volume was applied to each plant using an artist's brush. The control plants received an application of distilled water and 0.5% Tween 20.

Measurements were started 30 days after treatment and were made at 15-day intervals. Measurements included numbers of living plants, plant height, numbers of tillers, and tiller length. The plants were washed from the soil 75 days after planting. Roots and shoots were separated, oven dried, and weighed.

In a separate experiment, different sets of sand bluestem plants were treated at the early heading stage with several concentrations of Ethrel or DPX-1840. These plants were not harvested, but changes in plant form were observed and photographically recorded for 60 days.

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Table 1. Average number of tillers per sand bluestem seedling after treatment at the three and six-leaf stages with several concentration of Ethrel or DPX-1840.

Growth regulator concentration	Molar	Days after treatment					
		Three-leaf stage			Six-leaf stage		
		30	45	60	30	45	
Control	0.000	0.00 d ¹	0.50 bc	2.54 bcd	0.78 d	2.63 ab	
Ethrel	0.010	0.03 d	0.30 c	1.26 cde	2.58 a	3.07 ab	
Ethrel	0.025	0.25 cd	0.24 c	2.28 bcde	2.28 ab	2.98 ab	
Ethrel	0.050	0.28 cd	0.39 c	2.20 bcde	2.23 ab	3.07 ab	
Ethrel	0.100	0.36 c	0.22 c	0.94 de	1.55 bc	2.32 b	
Ethrel	0.150	0.33 c	0.25 c	0.35 e	1.45 cd	3.24 ab	
DPX-1840	0.010	0.80 b	1.08 a	2.70 bcd	2.25 ab	3.40 a	
DPX-1840	0.025	1.11 a	1.05 a	5.15 a	1.33 cd	3.79 a	
DPX-1840	0.050	0.83 ab	0.85 ab	3.17 b	1.40 cd	3.36 a	
DPX-1840	0.100	0.94 ab	0.74 ab	2.79 bcd	1.65 bc	3.38 a	
DPX-1840	0.150	0.86 ab	0.77 ab	2.87 bcd	1.60 bc	3.85 a	

¹ Means in individual columns followed by different letters are significantly different at the 0.05 level of probability.

Results and Discussion

Numbers of Tillers

Average numbers of tillers per sand bluestem plant treated at the three-leaf stage and evaluated 30 days later were significantly increased by the two highest rates of Ethrel (Table 1). At that time no tillers were present on control plants. Tillers were found on all Ethrel-treated plants. Most concentrations of Ethrel inhibited tillering 45 and 60 days after treatment at the three-leaf stage. The 0.025 and 0.050 concentrations produced the largest numbers of tillers after 60 days from plants treated with Ethrel.

Tillering response to Ethrel differed when plants were treated at the six-leaf stage (Table 1). After 30 days, all except those plants treated with 0.150 M Ethrel produced significantly greater numbers of tillers than the control. However, 45 days following treatment at the six-leaf stage, none of the Ethrel treatments produced greater numbers of tillers than the control.

All concentrations of DPX-1840 significantly increased number of tillers on sand bluestem plants 30 days after treatment at the three-leaf stage (Table 1). Greatest increases in tiller numbers were obtained from the 0.025 M concentration. Forty-five days after treatment at the three-leaf stage, average numbers of tillers were greatest on plants treated with 0.010 and 0.025 M DPX-1840. The 0.050, 0.100, and 0.150 M concentrations of DPX-1840 did not produce higher numbers of tillers than the control, but tiller numbers were greater than those of any Ethrel treatment. Sixty days after treatment at the three-leaf stage, average numbers of tillers on plants treated with 0.025 M DPX-1840 were greater than under other treatments (Table 1 and Fig. 1).

Tillering response to DPX-1840 also differed when plants were treated at the six-leaf stage (Table 1). After 30 days, treatments with 0.025 and 0.050 M DPX-1840 inhibited tiller production. Forty-five days following treatment at the six-leaf stage, no DPX-1840 treatments produced greater numbers of tillers than the control. Numbers of tillers in DPX-1840 treatments were generally higher than in Ethrel treatments. This was the reverse of the relationship existing 15 days earlier.

Tiller Length

Average tiller length of control plants was highest 60 days after treatment at the three-leaf stage. Both growth regulators

Fig. 1. Comparison of a G-1773 sand bluestem control plant and one treated with 0.025 M DPX-1840 at the three-leaf stage.

decreased tiller length (Table 2). Average tiller length on control plants was longest 30 days after treatment at the six-leaf stage. These tillers remained the longest for an additional 15 days, although these lengths were not significantly different from the plants treated with 0.025 and 0.100 M DPX-1840. Shortest tillers occurred on plants treated with highest concentrations of Ethrel.

Table 2. Average length (cm) of tillers per sand bluestem seedling after treatment at the three and six-leaf stages with several concentrations of Ethrel or DPX-1840.

Growth regulator concentration	Molar	Days after treatment					
		Three-leaf stage			Six-leaf stage		
		30	45	60	30	45	
Control	0.000	0.00 c ¹	8.12 ab	17.83 a	7.85 a	12.30 a	
Ethrel	0.010	4.25 abc	9.75 a	13.35 ab	5.68 ab	8.93 b	
Ethrel	0.025	7.25 a	4.17 ab	11.05 bc	4.50 b	8.20 bc	
Ethrel	0.050	3.38 abc	7.10 ab	8.97 bcd	4.05 b	5.66 c	
Ethrel	0.100	2.21 bc	2.42 b	5.91 cd	3.43 b	4.37 c	
Ethrel	0.150	1.75 bc	2.34 b	3.28 d	5.65 ab	4.25 c	
DPX-1840	0.010	6.30 ab	7.20 ab	11.02 bc	4.55 b	8.63 bc	
DPX-1840	0.025	7.27 a	5.72 ab	9.55 bcd	5.18 ab	9.93 ab	
DPX-1840	0.050	5.64 ab	3.29 ab	8.21 bcd	4.60 b	7.86 bc	
DPX-1840	0.100	5.21 ab	4.26 ab	8.38 bcd	4.33 b	9.62 ab	
DPX-1840	0.150	4.65 abc	5.40 ab	7.41 bcd	4.00 b	8.65 bc	

¹ Means in individual columns followed by different letters are significantly different at the 0.05 level of probability.

Table 3. Average extended leaf height (cm) of sand bluestem seedlings after treatment at the three and six-leaf stages with several concentrations of Ethrel or DPX-1840.

Growth regulator	Molar concentration	Days after treatment				
		Three-leaf stage			Six-leaf stage	
		30	45	60	30	45
Control	0.000	13.48 a ¹	25.33 a	38.34 a	30.40 a	44.74 a
Ethrel	0.010	12.35 a	15.55 b	38.63 a	29.32 a	29.74 c
Ethrel	0.025	7.73 b	10.10 c	27.45 abc	30.88 a	29.00 c
Ethrel	0.050	6.30 bc	7.90 cd	24.40 abcd	27.15 ab	29.50 c
Ethrel	0.100	4.00 c	2.83 e	29.38 ab	23.53 b	29.82 c
Ethrel	0.150	4.18 c	2.85 e	9.50 d	23.88 b	33.41 bc
DPX-1840	0.010	9.15 b	8.93 cd	19.80 bcd	31.18 a	34.42 bc
DPX-1840	0.025	8.73 b	7.73 cd	16.32 bcd	28.40 ab	37.26 b
DPX-1840	0.050	6.98 bc	6.38 d	14.33 bcd	32.43 a	30.79 bc
DPX-1840	0.100	6.85 bc	5.88 de	12.35 cd	30.03 a	31.29 bc
DPX-1840	0.150	6.63 bc	6.23 d	14.08 bcd	28.08 ab	33.48 bc

¹Means in individual columns followed by different letters are significantly different at the 0.05 level of probability.

Plant Height

Control plants and those treated with the lowest concentration of Ethrel, at the three-leaf stage, were taller than other plants 30 days after treatment (Table 3). Plants treated with 0.100 and 0.150 M Ethrel were shortest, and no differences occurred among other treatments. After 45 days, control plants were taller than plants treated with Ethrel. Sixty days after treatment at the three-leaf stage, no differences in plant height occurred between control plants and those treated with the four lowest rates of Ethrel. Shortest plants were those treated with 0.150 M Ethrel.

Thirty days after treatment at the 6-leaf stage, plants with the two highest concentrations of Ethrel were shorter than the control plants (Table 3). Relatively small increases in plant height were recorded for most Ethrel-treated plants after an additional 15 days; however, the height of control plants continued to increase. The control plants were taller, after 45 days, than plants treated with Ethrel at the six-leaf stage.

Height increases were inhibited in plants treated with DPX-1840 at the three-leaf stage (Table 3 and Fig. 1). After 30, 45, and 60 days, control plants were taller than plants treated with concentrations of DPX-1840. Thirty days after treatment at the six-leaf stage, no differences in plant height occurred between control plants and those treated with DPX-1840. After 45 days, height inhibition among DPX-1840-treated plants was evident.

Stage of development at the time of treatment had an effect on the response of sand bluestem plants. Generally, plants treated with DPX-1840 at the six-leaf stage were taller than those treated with Ethrel (Table 3). This was the reverse of the response obtained by treating plants at the three-leaf stage.

To overcome apical dominance, plant growth regulators must inactivate auxin or interrupt auxin transport (Audus, 1963; Holden, 1969). Inhibition of plant height may result. The quantity of photosynthates produced in young plants is often limiting (Salisbury and Ross, 1969). It may be postulated that photosynthates were being used for production of additional tillers on treated plants rather than for the elongation of existing tillers.

Plant Production

Plants treated at the three-leaf stage were harvested 60 days after treatment, or 75 days after planting. Dry matter

Table 4. Average total production (mg/plant) of sand bluestem seedlings 60 days after treatment at the three-leaf stage with the growth regulators Ethrel or DPX-1840.

Growth regulator	Molar concentration	Roots	Shoots	Total
Control	0.000	73 ab ¹	87 a	160 ab
Ethrel	0.010	83 a	110 a	193 a
Ethrel	0.025	52 b	76 ab	128 abc
Ethrel	0.050	52 b	70 ab	122 abc
Ethrel	0.100	18 c	35 bc	53 bc
Ethrel	0.150	9 c	20 c	29 c
DPX-1840	0.010	9 c	65 abc	74 abc
DPX-1840	0.025	15 c	74 ab	89 abc
DPX-1840	0.050	8 c	28 bc	36 c
DPX-1840	0.100	5 c	29 bc	34 c
DPX-1840	0.150	7 c	31 bc	38 c

¹Means in each column followed by different letters were significantly different at the 0.05 level of probability.

production was variable. Root production was significantly higher for plants treated with 0.010 M Ethrel than for any other chemical treatment, although it was not significantly different than the control (Table 4). Plants treated with Ethrel at 0.025 and 0.050 M concentrations produced roots that were heavier than those treated with 0.100 and 0.150 M Ethrel.

Shoot production was also highest on plants treated with 0.010 M Ethrel at the three-leaf stage (Table 4). No differences in shoot production occurred between control plants and those treated with the three lowest concentrations of Ethrel. The concentration of Ethrel applied was inversely related to shoot production.

Plants treated at the six-leaf stage were harvested 45 days after treatment, which also was 75 days after planting. Not as much variation existed among the six-leaf as in the three-leaf treatments. Root production was higher for the control than for any of the chemical treatments (Table 5). Highest shoot production was from plants treated with 0.010 M Ethrel. Due mainly to greater root production, total production from control plants was highest, although it was not different from plants treated with the two lowest concentrations of Ethrel. The two highest concentrations of Ethrel produced the smallest amounts of total dry matter.

Root production decreased after DPX-1840 was applied at either the three or six-leaf stage (Table 4 and 5). Root production was reduced more than shoot production. The lowest concentrations of DPX-1840 applied at the three-leaf stage did not reduce shoot production. None of the

Table 5. Average total production (mg/plant) of sand bluestem seedlings 45 days after treatment at the six-leaf stage with the growth regulators Ethrel or DPX-1840.

Growth regulator	Molar concentration	Roots	Shoots	Total
Control	0.000	74 a ¹	106 ab	180 a
Ethrel	0.010	35 b	133 a	168 a
Ethrel	0.025	39 b	107 ab	146 abcd
Ethrel	0.050	32 b	98 ab	130 bcde
Ethrel	0.100	23 b	93 ab	116 de
Ethrel	0.150	30 b	78 b	108 e
DPX-1840	0.010	39 b	108 ab	147 abcd
DPX-1840	0.025	42 b	134 a	176 a
DPX-1840	0.050	34 b	121 ab	155 abc
DPX-1840	0.100	25 b	100 ab	125 cde
DPX-1840	0.150	26 b	100 ab	126 cde

¹Means in each column followed by different letters were significantly different at the 0.05 level of probability.

concentrations reduced shoot production when applied at the six-leaf stage. The lowest concentrations of DPX-1840 applied at the three-leaf stage and the lowest concentrations applied at the six-leaf stage did not significantly reduce total production.

Plant Form

Plant form was affected by treatment with growth regulators. Tillers formed on plants treated with Ethrel grew nearly vertically, much like tillers on control plants. Laminas quickly unrolled upon exposure to light and had a natural green color. Tillers were often uniform in length.

This was contrasted by the form of those plants treated with DPX-1840. Tillers often grew at 45° to 60° angle from the soil surface. This accentuated the opposite leaf arrangement and gave plants an open or spread appearance (Fig. 1). Leaves of tillers on plants treated with DPX-1840 often did not unroll. These tillers were stiff to the touch and generally had a chlorotic appearance. Chlorosis was most evident toward the leaf tips of these tillers.

Plants treated with 0.100 and 0.150 M concentrations of DPX-1840 often exhibited other unusual features. Leaves on the main shoot and on tillers were commonly curled. In some cases, early internode elongation was associated with these two treatments.

In a separate experiment, a few sand bluestem plants were treated at the early heading stage of development. The 0.100 and 0.150 M concentrations of Ethrel caused roots to be formed at nodes of the elongated culm. High concentrations, 0.100 and 0.150 M, of DPX-1840 caused both branching and root initiation at nodes of elongated culms (Fig. 2). It is evident that this chemical is affecting biological processes other than auxin inactivation or transport.

Not only were rates of tillering affected, but also type of tiller produced. Desirability of altered tiller form would have to be determined over one or more complete growing seasons.

Conclusions

Range seeding failures are common. The lack of favorable environmental conditions of sufficient length is most frequently cited as the cause of failure of establishment. Many of the agronomic practices, other than proper seedbed preparation, designed to extend the period of favorable environmental conditions are not practical or economically feasible for range seedings.

The data from this experiment show that this problem can be approached from a different angle. Rather than trying to physically extend the period of favorable environmental conditions, grass seedlings could be physiologically stimulated by growth regulators, applied at an early stage of growth, to efficiently use this period of time to maximize establishment. The results from this experiment show that the use of plant growth regulators has the potential to stimulate tillering, which could increase the rate of establishment of range grasses. The effects of DPX-1840, Ethrel, and other growth regulators should be thoroughly tested on other range grass species.

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Fig. 2. Branches and roots formed at the nodes of an elongated culm of a G-1773 sand bluestem plant 60 days after application of 0.100 M DPX-1840 at the early heading stage.

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