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Title: Inhibitional Effects of the Four Dominant Tall Grass Prairie Species on Themselves and Associated Species

Abstract approved: John Kanson for R. L.

Inhibitory studies were made on the four dominant species of the Tall Grass Prairie. They were big bluestem, little bluestem, switch grass and Indian grass. Experiments were conducted on seed germination and seedling growth and development of their own kind and on plants associated with them.

Results from all data indicated that the four dominant grass extracts did inhibit or stimulate seed germination within the first 24 hours of most species tested. Differences in germination results occurred between June and July. This may be due to reduced rainfall during this time, or a change in the phenolic quantity of the test plants because of their growth and maturation. Fungi were found in all test plates after 48 hours of the germination experiment. These fungi might interfere with or reduce the inhibitional effects of the test extracts.

The four grass extracts inhibited seedling growth and development of some species including their own kind, but not in all species tested throughout the Summer.

INHIBITIONAL EFFECTS OF THE FOUR DOMINANT TALL GRASS PRAIRIE SPECIES ON THEMSELVES AND ASSOCIATED PLANTS

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INTRODUCTION

Rarely does a plant live in isolation. More commonly, it grows in association with many other plants. An individual plant affects another and is in turn affected by the interaction. The simplest interaction between individual plants of the same or different species in a community is that of competition for some essential growth requirement such as water, light, or mineral nutrients. It has been shown that certain plants can obtain a competitive advantage over others by producing chemical substances that inhibit the growth of other species (Bonner and Galston, 1952; Croak, 1969; Vuturo, 1971).

Most chemical inhibitors are compounds that have been termed secondary substances by Fraenkel (1959) and Whittaker and Feeny (1971) because they are of sporadic occurrence and thus do not appear to play a role in the basic metabolism of organisms. There are many thousands of such compounds; but, only a limited number of them have been identified as toxins involved in allelopathy (Rice, 1974).

Gray and Bonner (1948) found that leaves of Encelia farinosa produce 3-acetyl-6-methoxybenzaldehyde which causes severe retardation in the growth of other plants but does not retard its own kind. Parenti and Rice (1969) showed that substances were produced by crabgrass, Digitaria sanguinalis, an early invader in old field succession, which inhibited not only the germination and growth of associated species but also inhibited the growth and development of crabgrass seedlings. The substances serve as built-in population

control mechanisms. Three inhibitors were identified as chlorogenic acid, isochlorogenic acid and sulfosalicylic acid.

Since its discovery in 1837, chlorogenic acid has been the subject of much investigation. Qualitative reports of the detectable presence and isolation of chlorogenic acid from a variety of plants are available. Quantitative analyses of chlorogenic acid concentrations are now possible with the use of spectrophotometric equipment (Koeppe and Rohrbaugh, 1968).

Chlorogenic acid has been found to have a synergistic effect on indole-acetic-acid (IAA) action due to its competitive inhibition of IAA oxidase (Rabin and Klein, 1957). Chlorogenic acid has also been found to be an inhibitor of several enzyme systems (Sondheimer, 1964). Rice (1965) has postulated that inhibition of enzyme systems may be the chief mode of action of chlorogenic acid in inhibition of seed germination and growth of associated soil bacteria and fungi. Rice (1974) also found that Andropogon scoparius significantly inhibited growth of the algal genus, Anabaena. The inhibition of this nitrogen-fixing alga by the roots of A. scoparius was especially interesting, and may help explain in part why the bunch grass stage of old-field succession, dominated by A. scoparius, persists for such a long time.

Booth (1941) found that succession in abandoned fields in Central Oklahoma and Southeast Kansas included four stages: (1) pioneer weed, (2) annual grass, (3) perennial bunch grass, and (4) true prairie. The weed stage lasted only two to three years. The annual grass stage lasted from nine to 13 years and was dominated by triple awn grass, Aristida oligantha. The perennial bunch grass

stage was dominated by little bluestem, A. scoparius, and was still present 30 years after field abandonment. Booth was not able to ascertain how long a period is required for the return of the true prairie, which in Central Oklahoma and Southeast Kansas was dominated by little bluestem, Andropogon scoparius; big bluestem, Andropogon gerardii; switch grass, Panicum virgatum; and Indian grass, Sorghastrum mutans.

The objective of this study was to collect data to support the hypothesis that the four species of grasses, big bluestem, little bluestem, switch grass and Indian grass, produce substances that have an inhibitory effect on germination and seedling growth of conspecific and certain other species found growing in association with the four test species.

MATERIALS AND METHODS

Entire plants, including roots, stems, and leaves of the four dominant tallgrass prairie species were collected at monthly intervals from June 1, 1977, to September 1, 1977. The collections were made on the Emporia State University Ross Natural History Reservation in Lyon County, Kansas.

Preparation of extracts.

Extracts of the test plants were prepared by grinding 10 g fresh weight of plant material in a Waring blender with 100 ml distilled water for ten minutes. The resulting extracts were then filtered through Whatman No. 1 paper in a Buchner funnel. If the volume of the filtrate was less than 100 ml, distilled water was added to maintain the 100 ml volume. Freshly prepared extract was used in all tests.

Assays of plant extract as an inhibitor of seed germination.

Extracts of the four grasses were tested on seeds of the following species:

Illinois bundleflower, *Desmanthus illinoensis*

Maximilian sunflower, *Helianthus maximiliani*

Roundhead lespedeza, *Lespedeza capitata*

Purple prairieclover, *Petalostemum purpureum*

Pitcher sage, *Salvia pitcheri*

Ironweed, *Vernonia baldwinii*

Big bluestem, *Andropogon gerardii*

Little bluestem, Andropogon scoparius

Switch grass, Panicum virgatum

Indian grass, Sorghastrum nutans

All seeds were soaked before planting in a 3 % clorox solution for two minutes to reduce fungal contamination.

Two hundred seeds of each of the ten species to be tested were placed on germination discs in petri plates containing extracts of each of the four grasses. The control groups were a duplication of the test set, except distilled water was used in place of the extracts. All were placed in an incubator at 27° C. After 24 hours of incubation, all petri plates were removed and seeds were checked and counted for germination. Subsequent counts of germinating seeds were made at 72 hours and 120 hours. The data were recorded for later statistical analysis.

Assays of the growth and development of seedlings affected by the test plant extractions.

Ten seedlings each of the following six species: L. capitata, S. pitcheri, A. gerardii, A. scoparius, P. virgatum and S. nutans were grown in quartz sand for two weeks in a complete nutrient solution (Hoagland and Arnon, 1950). They were then transferred to vials containing a 1:5 ratio of nutrient solution to plant extract and were allowed to grow for 12 days in a photoperiod of 16 hours at 27° C during the day and 18° C at night. Controls were run using a 1:5 ratio of nutrient solution to distilled water under the same conditions. Seedlings that showed injury or dried due to mechanical damage were replaced immediately. After 12 days, seedlings were

removed from the vials and dried for 48 hours in a plant drying oven. After removal from the oven, specimens were weighted and the data were recorded for later statistical analysis.

RESULTS AND DISCUSSION

Inhibitory effects on seed germination.

Results from seed germination tests indicated that all seeds tested had a low germination rate in both test and control groups. Each extract solution of little bluestem, big bluestem, switch grass and Indian grass affected the initial germination rates of most test species within the first 24 hours of the germination tests (Tables I through X).

Seeds of D. illinoensis, P. purpureum and P. virgatum were inhibited by the form test solutions in June. In July, there was less inhibition and, in some cases, a stimulatory effect was noted. Rainfall in June 1977 at the Ross Natural History Reservation was 2.6 inches but only 1.4 inches in July. This would suggest that increased rainfall contributed to a greater production of plant mass and, therefore, a higher metabolic activity. This, in turn, produced greater quantities of inhibitors. As temperatures became warmer and there was less rainfall, plant metabolism became less, reducing the production of inhibitors. Vuturo (1971) found that there is a tendency, as the growing season progresses, for plants to grow slower and to produce fewer inhibitory compounds and that the greatest chemically influence competition of plants appears to be in the earlier stages of plant growth and establishment. This study supports those conclusions.

TABLE I. Number of D. illinoensis seeds germinated in each month for both test and control per germination period and total percent germination effected by selected extracts.

Selected Extracts	Month	No. of Seeds Germinated/time in hrs. Hours of germination			Total Percent Germination
		24	72	120	
Little Bluestem	June	Test	8	-	-	4.0
		Control	16	3	-	9.5
	July	Test	17	-	1	9.0
		Control	13	1	-	7.0
	Aug.	Test	7	1	-	4.0
		Control	10	1	1	6.0
	Sep.	Test	40	13	1	27.0
		Control	31	10	1	21.0
Big Bluestem	June	Test	10	1	-	5.5
		Control	16	3	-	9.5
	July	Test	11	-	1	6.0
		Control	13	1	-	7.0
	Aug.	Test	6	5	1	6.0
		Control	10	1	1	6.0
	Sep.	Test	29	19	2	25.0
		Control	31	10	1	21.0
Switch Grass	June	Test	13	3	1	8.5
		Control	16	3	-	9.5
	July	Test	12	3	3	9.0
		Control	13	1	-	7.0
	Aug.	Test	10	1	-	5.5
		Control	10	1	1	6.0
	Sep.	Test	16	28	-	22.0
		Control	31	10	1	21.0
Indian Grass	June	Test	20	2	-	11.0
		Control	16	3	-	9.5
	July	Test	20	1	-	10.5
		Control	13	1	-	7.0
	Aug.	Test	12	2	-	7.0
		Control	10	1	1	6.0
	Sep.	Test	25	28	1	27.0
		Control	31	10	1	21.0

TABLE II. Number of H. maximiliani seeds germinated in each month for both test and control per germination period and total percent germination effected by selected extracts.

Selected Extracts	Month	No. of Seeds germinated/time in hrs. Hours of germination			Total Percent Germination
		24	72	120	
Little Bluestem	June	Test	2	11	9	11.0
		Control	-	23	7	15.0
	July	Test	-	14	10	12.0
		Control	-	18	20	19.0
	Aug.	Test	-	11	16	13.5
		Control	-	23	20	21.5
	Sep.	Test	-	12	24	18.0
		Control	-	18	26	22.0
Big Bluestem	June	Test	-	9	4	6.5
		Control	-	23	7	15.0
	July	Test	-	6	10	8.0
		Control	-	18	20	19.0
	Aug.	Test	-	16	11	13.5
		Control	-	23	20	21.5
	Sep.	Test	-	19	19	19.0
		Control	-	18	26	22.0
Switch Grass*	June	Test	11	9	5	12.5
		Control	-	23	7	15.0
	July	Test	-	14	11	12.5
		Control	-	18	20	19.0
	Aug.	Test	-	13	4	8.5
		Control	-	23	20	21.5
	Sep.	Test	-	8	11	9.5
		Control	-	18	26	22.0
Indian Grass	June	Test	-	13	7	10.0
		Control	-	23	7	15.0
	July	Test	-	17	24	20.5
		Control	-	18	20	19.0
	Aug.	Test	-	7	12	9.5
		Control	-	23	20	21.5
	Sep.	Test	-	16	16	16.0
		Control	-	18	26	22.0

*Test species significantly different at 0.05 level.

TABLE III. Number of L. capitata seeds germinated in each month for both test and control per germination period and total percent germination effected by selected extracts.

Selected Extracts	Month	No. of Seeds Germinated/time in hrs. Hours of Germination			Total Percent Germination
			24	72	120	
Little Bluestem	June	Test	1	117	16	67.0
		Control	3	118	6	63.5
	July	Test	-	150	3	76.5
		Control	-	169	3	86.0
	Aug.	Test	-	151	3	77.0
		Control	1	152	2	77.5
	Sep.	Test	-	135	2	68.5
		Control	-	154	1	77.5
Big Bluestem	June	Test	-	104	12	58.0
		Control	3	118	6	63.5
	July	Test	-	123	15	69.0
		Control	-	169	3	86.5
	Aug.	Test	1	142	4	73.5
		Control	1	152	2	77.5
	Sep.	Test	-	144	-	72.0
		Control	-	154	1	77.5
Switch Grass	June	Test	1	140	4	72.5
		Control	3	118	6	63.5
	July	Test	-	161	1	81.0
		Control	-	169	3	86.5
	Aug.	Test	5	122	-	63.5
		Control	1	152	2	77.5
	Sep.	Test	-	148	1	74.5
		Control	-	154	1	77.5
Indian Grass	June	Test	1	126	16	71.5
		Control	3	118	6	63.5
	July	Test	-	106	14	60.0
		Control	-	169	3	86.5
	Aug.	Test	3	138	2	71.5
		Control	1	152	2	77.5
	Sep.	Test	-	129	-	64.5
		Control	-	154	1	77.5

TABLE IV. Number of P. purpureum seeds germinated in each month for both test and control per germination period and total percent germination effected by selected extracts.

Selected Extracts	Month	No. of Seeds Germinated/time in hrs. Hours of germination			Total Percent Germination
		24	72	120	
Little Bluestem	June	Test	104	96	1	80.5
		Control	131	28	1	80.0
	July	Test	92	57	2	75.5
		Control	92	40	4	68.0
	Aug.	Test	118	12	1	65.5
		Control	111	16	5	66.0
	Sep.	Test	5	122	1	64.0
		Control	10	113	4	63.5
Big Bluestem	June	Test	73	73	3	74.5
		Control	131	28	1	80.0
	July	Test	68	58	2	64.0
		Control	92	40	4	68.0
	Aug.	Test	101	31	6	69.0
		Control	111	16	5	66.0
	Sep.	Test	4	119	-	61.5
		Control	10	113	4	63.5
Switch Grass	June	Test	70	84	6	80.0
		Control	131	28	1	80.0
	July	Test	93	35	6	67.0
		Control	92	40	4	68.0
	Aug.	Test	60	65	1	63.0
		Control	111	16	5	66.0
	Sep.	Test	4	111	4	59.5
		Control	10	113	4	63.5
Indian Grass	June	Test	111	64	1	88.0
		Control	131	28	1	80.0
	July	Test	92	37	2	65.5
		Control	92	40	4	68.0
	Aug.	Test	99	43	2	72.0
		Control	111	16	5	66.0
	Sep.	Test	1	125	2	64.0
		Control	10	113	4	63.5

TABLE V. Number of S. pitcheri seeds germinated in each month for both test and control per germination period and total percent germination effected by selected extracts.

Selected Extracts	Month	No. of Seeds Germinated/time in hrs. Hours of Germination				Total Percent Germination
			24	72	120	
Little Bluestem	June	Test	4	4	1	4.5
		Control	1	6	2	4.5
	July	Test	10	25	-	17.5
		Control	3	6	-	4.5
	Aug.	Test	11	53	8	36.0
		Control	7	49	19	37.5
	Sep.	Test	-	71	11	41.0
		Control	-	76	6	41.0
Big Bluestem	June	Test	6	12	3	10.5
		Control	1	6	2	4.5
	July	Test	6	48	2	28.0
		Control	3	6	-	4.5
	Aug.	Test	10	48	7	32.5
		Control	7	49	19	37.5
	Sep.	Test	-	25	33	29.0
		Control	-	76	6	41.0
Switch Grass	June	Test	15	26	3	22.0
		Control	1	6	2	4.5
	July	Test	6	22	-	14.0
		Control	3	6	-	4.5
	Aug.	Test	7	40	6	31.0
		Control	7	49	19	37.5
	Sep.	Test	-	15	15	15.0
		Control	-	76	6	41.0
Indian Grass	June	Test	5	12	1	9.0
		Control	1	6	2	4.5
	July	Test	4	17	6	13.5
		Control	3	6	-	4.5
	Aug.	Test	9	70	7	43.0
		Control	7	49	19	37.5
	Sep.	Test	-	49	4	26.5
		Control	-	76	6	41.0

TABLE VI. Number of V. baldwinii seeds germinated in each month for both test and control per germination period and total percent germination effected by selected extracts.

Selected Extracts	Month	No. of Seeds Germinated/time in hrs. Hours of germination			Total Percent Germination
		24	72	120	
Little Bluestem	June	Test	-	-	1	0.5
		Control	-	-	1	0.5
	July	Test	-	1	1	1.0
		Control	-	-	7	3.5
	Aug.	Test	-	-	4	2.0
		Control	-	-	-	0.0
	Sep.	Test	-	-	-	0.0
		Control	-	-	-	0.0
Big Bluestem	June	Test	-	-	2	1.0
		Control	-	-	1	0.5
	July	Test	-	-	-	0.0
		Control	-	-	7	3.5
	Aug.	Test	-	-	-	0.0
		Control	-	-	-	0.0
	Sep.	Test	-	-	-	0.0
		Control	-	-	-	0.0
Switch Grass	June	Test	-	-	1	0.5
		Control	-	-	1	0.5
	July	Test	-	-	4	2.0
		Control	-	-	7	3.5
	Aug.	Test	-	-	-	0.0
		Control	-	-	-	0.0
	Sep.	Test	-	-	-	0.0
		Control	-	-	-	0.0
Indian Grass	June	Test	-	-	-	0.0
		Control	-	-	1	0.5
	July	Test	-	-	4	2.0
		Control	-	-	7	3.5
	Aug.	Test	-	-	-	0.0
		Control	-	-	-	0.0
	Sep.	Test	-	-	-	0.0
		Control	-	-	-	0.0

TABLE VII. Number of A. scoparius seeds germinated in each month for both test and control per germination period and total percent germination effected by selected extracts.

Selected Extracts	Month		No. of Seeds Germinated/time in hrs. Hours of Germination 24	72	120	Total Percent Germination
Little Bluestem	June	Test	-	58	23	40.5
		Control	-	70	11	40.5
	July	Test	-	74	31	52.5
		Control	-	56	31	43.5
	Aug.	Test	-	41	5	23.0
		Control	-	51	16	33.5
	Sep.	Test	-	48	57	52.5
		Control	-	39	60	49.5
Big Bluestem	June	Test	-	58	21	39.5
		Control	-	70	11	40.0
	July	Test	-	53	41	47.0
		Control	-	56	31	43.5
	Aug.	Test	-	39	16	27.5
		Control	-	51	16	33.5
	Sep.	Test	-	81	34	57.5
		Control	-	39	60	49.5
Switch Grass	June	Test	-	39	17	28.0
		Control	-	70	11	40.0
	July	Test	-	49	28	38.5
		Control	-	56	31	43.5
	Aug.	Test	-	21	10	15.5
		Control	-	51	16	33.5
	Sep.	Test	-	26	34	30.0
		Control	-	39	60	49.5
Indian Grass	June	Test	-	53	11	32.0
		Control	-	70	11	40.0
	July	Test	-	59	27	43.0
		Control	-	56	31	43.5
	Aug.	Test	-	48	16	32.0
		Control	-	51	16	33.5
	Sep.	Test	-	74	22	48.0
		Control	-	39	60	49.5

TABLE VIII. Number of A. gerardii seeds germinated in each month for both test and control per germination period and total percent germination effected by selected extracts.

Selected Extracts	Month	No. of Seeds Germinated/time in hrs. Hours of Germination			Total Percent Germination
			24	72	120	
Little Bluestem	June	Test	-	26	16	21.0
		Control	-	30	18	24.0
	July	Test	-	9	8	8.5
		Control	-	22	12	17.0
	Aug.	Test	-	10	5	7.5
		Control	-	7	8	7.5
	Sep.	Test	-	15	23	19.0
		Control	-	16	25	20.5
Big Bluestem	June	Test	-	39	18	28.5
		Control	-	30	18	24.0
	July	Test	-	7	6	6.5
		Control	-	22	12	17.0
	Aug.	Test	-	6	4	5.0
		Control	-	7	8	7.5
	Sep.	Test	-	28	23	25.5
		Control	-	16	25	20.5
Switch Grass	June	Test	-	14	10	12.0
		Control	-	30	18	24.0
	July	Test	-	6	7	6.5
		Control	-	22	12	17.0
	Aug.	Test	-	7	4	5.5
		Control	-	7	8	7.5
	Sep.	Test	-	7	22	14.5
		Control	-	16	25	20.5
Indian Grass	June	Test	-	19	17	18.0
		Control	-	30	18	24.0
	July	Test	-	10	16	13.0
		Control	-	22	12	17.0
	Aug.	Test	-	8	14	11.0
		Control	-	7	8	7.5
	Sep.	Test	-	26	39	32.5
		Control	-	16	25	20.5

TABLE IX. Number of P. virgatum seeds germinated in each month for both test and control per germination period and total percent germination effected by selected extracts.

Selected Extracts	Month		No. of Seeds Germinated/time in hrs. Hours of germination 24	72	120	Total Percent Germination
Little Bluestem	June	Test	19	99	6	62.0
		Control	73	85	5	81.5
	July	Test	-	184	1	92.5
		Control	-	150	6	78.0
	Aug.	Test	34	122	10	83.0
		Control	59	108	5	86.0
	Sep.	Test	-	110	47	78.5
		Control	-	133	37	85.0
Big Bluestem	June	Test	51	108	9	84.0
		Control	73	85	5	81.5
	July	Test	-	181	2	91.5
		Control	-	150	6	78.0
	Aug.	Test	39	109	4	76.0
		Control	59	108	5	86.0
	Sep.	Test	-	132	26	79.0
		Control	-	133	37	85.0
Switch Grass	June	Test	33	128	4	82.5
		Control	73	85	5	81.5
	July	Test	-	168	4	86.0
		Control	-	150	6	78.0
	Aug.	Test	22	118	14	77.0
		Control	59	108	5	86.0
	Sep.	Test	-	129	36	82.5
		Control	-	133	37	85.0
Indian Grass	June	Test	66	122	8	98.0
		Control	73	85	5	81.5
	July	Test	-	171	5	88.0
		Control	-	150	6	78.0
	Aug.	Test	30	138	10	89.0
		Control	59	108	5	86.0
	Sep.	Test	-	91	62	76.5
		Control	-	133	37	85.0

TABLE X. Number of S. nutans seeds germinated in each month for both test and control per germination period and total percent germination effected by selected extracts.

Selected Extracts	Month	No. of Seeds Germinated/time in hrs. Hours of Germination			Total Percent Germination
		24	72	120	
Little Bluestem	June Test	-	10	2	6.0
	Control	-	6	4	5.0
	July Test	1	9	3	6.5
	Control	-	7	11	9.0
	Aug. Test	-	1	-	0.5
	Control	-	7	1	4.0
	Sep. Test	-	2	5	3.5
	Control	-	4	-	2.0
Big Bluestem	June Test	-	4	4	4.0
	Control	-	6	4	5.0
	July Test	1	4	6	5.5
	Control	-	7	11	9.0
	Aug. Test	-	-	-	0.0
	Control	-	7	1	4.0
	Sep. Test	-	6	-	3.0
	Control	-	4	-	2.0
Switch Grass	June Test	-	-	1	0.5
	Control	-	6	4	5.0
	July Test	-	2	14	8.0
	Control	-	7	11	9.0
	Aug. Test	-	-	-	0.0
	Control	-	7	1	4.0
	Sep. Test	-	1	2	1.5
	Control	-	4	-	2.0
Indian Grass	June Test	-	2	2	2.0
	Control	-	6	4	5.0
	July Test	-	1	3	2.0
	Control	-	7	11	9.0
	Aug. Test	-	1	2	1.5
	Control	-	7	1	4.0
	Sep. Test	-	4	2	3.0
	Control	-	4	-	2.0

Test seeds were infected by fungi two days after the germination experiment was begun. There were no fungi infected germination plates within the first 48 hours of the germination experiment. It was possible that the fungi noted above was responsible in part for much of the final germination inhibition and that would agree with Croak (1969). Patrick (Parenti, Emporia State University) suggested phenola often cause secondary infections such as the fungi which might contribute to the inhibition of germination. Fungi which occurred in the plates after two days might interfere with and reduce the inhibitional effects of the extracts, thereby affecting the final germination percentages.

From the results of the germination experiments the following conclusions could be made: When no fungi were involved, it appeared that an inhibitional effect might be due to the extracts of the dominant tallgrass prairie grasses on themselves and the six associated plants used in this experiment.

Extract effects on the growth and development of selected seedlings.

Results of studies done over the four month period showed that extracts of little bluestem, big bluestem, switch grass and Indian grass were inhibitory to the seedling growth and development of some species but not significantly inhibitory toward other species (Tables XI, XII, XIII and XIV).

For example, little bluestem extracts used to treat seedling of L. capitata showed significant inhibitory effects in every four-month study period. S. pitcheri seedlings were inhibited by little

TABLE XI. Weights with Standard Deviation of 12-day old seedling treated with an aqueous extract of A. scoparius at monthly intervals.

Test Species	Month	Mean Oven-Dry Weight, mg. with Standard Deviation: Test	Control
Lespedeza capitata	June	1.6±0.51	3.0±0.00
	July	1.1±0.31	2.2±0.42
	Aug.	1.2±0.42	2.9±0.31
	Sep.	2.1±0.31	2.9±0.31
Salvia pitcheri	June	2.3±0.67	4.6±0.51
	July	3.0±0.47+	4.1±2.02
	Aug.	3.0±0.47	4.6±0.69
	Sep.	3.6±0.69	7.2±0.91
Andropogon scoparius	June	1.5±0.52	3.5±0.52
	July	1.2±0.42	2.8±0.91
	Aug.	1.3±0.48	3.2±0.78
	Sep.	2.5±1.35+	2.9±0.56
Andropogon gerardii	June	2.5±0.52	5.8±0.63
	July	2.0±0.66	5.7±0.67
	Aug.	2.6±0.51	5.8±0.78
	Sep.	3.8±1.61+	5.1±1.10
Panicum virgatum	June	1.8±0.42+	1.8±0.42
	July	1.1±0.31	1.8±0.42
	Aug.	1.2±0.42	1.7±0.48
	Sep.	2.0±0.00	2.7±0.48
Sorghastrum nutans	June	2.0±0.00	2.5±0.52
	July	1.8±0.42+	2.3±0.67
	Aug.	1.7±0.48	2.5±0.52
	Sep.	6.5±2.41	10.5±1.43

Test weights significantly different at the 0.05 level.
+No significant differences.

TABLE XII. Weights with Standard Deviation of 12-day old seedlings treated with an aqueous extract of A. gerardii at monthly intervals.

		Mean Oven-Dry Weight, mg. with Standard Deviation	
Test Species	Month	Test	Control
Lespedeza capitata	June	1.6±0.51	3.0±0.00
	July	1.2±0.42	2.2±0.42
	Aug.	1.5±0.52	2.9±0.31
	Sep.	2.6±0.51+	2.0±0.31
Salvia pitcheri	June	2.1±0.31	4.6±0.51
	July	3.5±1.08+	4.1±2.02
	Aug.	2.2±0.63	4.6±0.69
	Sep.	4.4-1.26	7.2-0.91
Andropogon scoparius	June	1.5±0.52	3.5±0.52
	July	1.2±0.42	2.8±0.91
	Aug.	1.4±0.51	3.2±0.78
	Sep.	2.1±0.56	2.9±0.56
Andropogon gerardii	June	3.0±0.12	5.8±0.63
	July	2.6±0.69	5.7±0.67
	Aug.	2.8±0.42	5.8±0.78
	Sep.	3.3±0.94	5.1±1.10
Panicum virgatum	June	1.9±0.99+	1.8±0.42
	July	1.3±0.48	1.8±0.42
	Aug.	1.3±0.48+	1.7±0.48
	Sep.	2.0±0.66	2.7±0.48
Sorghastrum nutans	June	1.7±0.48	2.5±0.52
	July	1.2±0.42	2.3±0.67
	Aug.	1.2±0.42	2.5±0.52
	Sep.	8.2±1.61	10.5±1.43

Test weights significantly different at the 0.05 level.
+No significant differences.

TABLE XIII. Weights with Standard Deviation of 12-day old seedlings treated with an aqueous extract of P. virgatum at monthly intervals.

		Mean Oven-Dry Weight, mg. with Standard Deviation	
Test Species	Month	Test	Control
Lespedeza capitata	June	1.9±0.31	3.0±0.00
	July	1.3±0.48	2.2±0.42
	Aug.	1.4±0.51	2.9±0.31
	Sep.	2.7±0.94+	2.9±0.31
Salvia pitcheri	June	2.2±0.42	4.6±0.51
	July	3.0±1.05+	4.1±2.02
	Aug.	2.8±0.42	4.6±0.69
	Sep.	3.8±1.31	7.2±0.91
Andropogon scoparius	June	1.8±0.42	3.5±0.52
	July	1.3±0.48	2.8±0.91
	Aug.	1.7±0.48	3.2±0.78
	Sep.	1.5±1.52	2.9±0.56
Andropogon gerardii	June	3.5±1.35	5.8±0.63
	July	2.8±1.03	5.7±0.67
	Aug.	2.6±0.51	5.8±0.78
	Sep.	2.5±0.70	5.1±1.10
Panicum virgatum	June	1.1±0.31	1.8±0.42
	July	1.0±0.00	1.8±0.42
	Aug.	1.1±0.31	1.7±0.48
	Sep.	1.5±0.52	2.7±0.48
Sorghastrum nutans	June	1.3±0.48	2.5±0.52
	July	1.7±0.48	2.3±0.67
	Aug.	1.2±0.42	2.5±0.52
	Sep.	8.6±0.96	10.5±1.43

Test weights significantly different at the 0.05 level.
+No significant differences.

TABLE XIV. Weights with Standard Deviation of 12-day old seedlings treated with an aqueous extract of S. nutans at monthly intervals.

Test Species	Month	Mean Oven-Dry Weight, mg. with Standard Deviation: Test	Control
Lespedeza capitata	June	1.2±0.42	3.0±0.00
	July	1.1±0.31	2.2±0.42
	Aug.	1.2±0.42	2.9±0.31
	Sep.	2.7±0.48+	2.9±0.31
Salvia pitcheri	June	2.2±0.42	4.6±0.51
	July	3.2±1.03+	4.1±2.02
	Aug.	2.9±0.56	4.6±0.69
	Sep.	4.9±1.28	7.2±0.91
Andropogon scoparius	June	1.8±0.42	3.5±0.52
	July	1.3±0.48	2.8±0.91
	Aug.	1.7±0.48	3.2±0.78
	Sep.	1.8±0.42	2.9±0.56
Andropogon gerardii	June	3.0±0.94	5.8±0.63
	July	2.9±0.99	5.7±0.67
	Aug.	2.9±0.56	5.8±0.78
	Sep.	3.5±1.43	5.1±1.10
Panicum virgatum	June	1.4±0.51	1.8±0.42
	July	1.1±0.31	1.8±0.42
	Aug.	1.2±0.42	1.7±0.48
	Sep.	2.0±0.66	2.7±0.48
Sorghastrum nutans	June	2.0±0.00	2.5±0.52
	July	1.5±0.52	2.3±0.67
	Aug.	1.5±0.52	2.5±0.52
	Sep.	8.7±1.05	10.5±1.43

Test weights significantly different at the 0.05 level.
+No significant differences.

bluestem extracts in June but not in July. This might be due to the decrease in the amount of rainfall during the summer, as discussed earlier. Another reason might also be due to the maturing of the four grasses in July, causing the change of phenolic content in these grasses.

The inhibitory effects of big bluestem were shown on seedlings of little bluestem, Indian grass and their own seedlings in all seasons (Table XII). S. pitcheri seedlings were also inhibited by big bluestem in June but not in July. Switch grass extracts inhibited the growth and development of L. capitata, little bluestem, big bluestem, Indian grass seedlings and also their own seedlings. Switch grass extracts inhibited S. pitcheri seedlings in June but not in July (Table XIII). The inhibitional effects of Indian grass on seedlings were noted in Table XIV: seedlings of L. capitata, little bluestem, big bluestem, switch grass and Indian grass were significantly different. There was also the inhibitory effects on S. pitcheri seedlings in June but not in July.

SUMMARY

Inhibitory studies were made on the four dominant species of the Tall Grass Prairie. They were big bluestem, little bluestem, switch grass and Indian grass. Experiments were conducted on seed germination and seedling growth and development of their own kind and on plants associated with them.

Results from all data indicated that the four dominant grass extracts did inhibit or stimulate seed germination within the first 24 hours of most species tested. Differences in germination results occurred between June and July. This may be due to reduced rainfall during this time, or a change in the phenolic quantity of the test plants because of their growth and maturation. Fungi were found in all test plates after 48 hours of the germination experiment. These fungi might interfere with or reduce the inhibitional effects of the test extracts.

The four grass extracts inhibited seedling growth and development of some species including their own kind, but not in all species tested throughout the Summer.

Three suggestions are made for the improvement of an investigation of this type:

1. An identification of the inhibiting compounds found in the four grasses studied should be made.

2. Several seeds should be studied as to their hardness, viability and need for pre-germination treatment.

3. Fungi contamination should be eliminated as much as possible to avoid errors in quantitative results of seed germination.

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