Competitive Effects of Japanese Brome (Bromus Japonicus Thunb.) on Native Perennial Grasses

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COMPETITIVE EFFECTS OF JAPANESE BROME (<u>BROMUS JAPONICUS</u> THUNB.) ON NATIVE PERENNIAL GRASSES

being

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by

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THESIS ABSTRACT

Wolters, Gale L. 1962. Competitive effects of Japanese brome (Bromus japonicus Thunb.) on native perennial grasses.

A portion of the mixed prairie was studied in an attempt to measure the effects of Japanese brome on production of native perennial grass. Vegetation was analyzed by paired foot-square quadrats. Japanese brome was removed from treated plots and control plots were left as they naturally occur. Microclimate study consisted of soil temperature and soil moisture under both treatments. Germination tests on Japanese brome were conducted in a Mangelsdorf germinator and early growth and development was studied with the use of phytometers in the greenhouse.

Averages for a six-week period showed 20.90 and 18.18 percent soil moisture for treated and control plots, respectively, representing a statistically significant difference in soil moisture content. Highly significant differences in soil temperature existed between treated and control plots with averages of 22.4 and 20.7° C., respectively.

Production of Japanese brome averaged 1,774 pounds per acre on March 1 but production decreased to an average of 957 pounds per acre by maturity (June 30).

No statistical difference was found between the yield of perennial grasses from treated and control plots at

maturity of Japanese brome (June 30) when the annual was removed from the treated plots on March 16. Production of perennial grasses at the end of the growing season (September 19) was significantly greater on the control plots than on treated plots with averages of 2,394 and 2,214 pounds per acre, respectively, when Japanese brome was removed from the treated plots on March 16. Removal of Japanese brome at maturity (June 30) had no effect on production of perennial grasses which averaged 2,385 and 2,394 pounds per acre for treated and control plots, respectively. Total yearly production on control plots (perennial grass plus Japanese brome) averaged 2,877 pounds per acre.

Germination of Japanese brome caryopses averaged 94 percent. Freezing Japanese brome caryopses before germination had no effect on percentage germination, but non-frozen caryopses germinated approximately four hours sooner than frozen caryopses.

Early growth and development of Japanese brome was observed from the simple one-leaf two-root stage after four days of growth to the highly complex growth development 49 days after germination. The primary root penetrated to a depth of 81.0 cm. and the maximum depth of penetration of the 11 secondary roots was 77.5 cm. with a lateral spread of 15.0 cm. after seven weeks of growth. An average of 14 leaves per plant were found after seven weeks of growth.

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INTRODUCTION

Annual grasses grow among the dominant perennials in native prairies of western Kansas in seasons of abundant moisture. Caryopses of annuals may be present in a prairie soil for many years and not be apparent until a wet season promotes extensive germination and growth.

Japanese brome (Bromus japonicus Thunb.) is the principal annual occurring in the mixed prairie near Hays, Kansas, and its effect on the yield of perennial grasses is a topic of frequent discussion. Japanese brome is a winter annual that germinates in the fall, beginning in August, and makes rapid growth until the first killing frost. Not all Japanese brome caryopses germinate in the fall, some germinate early in the spring when the fall-germinated annuals are breaking dormancy. Spring growth is normally initiated during the month of March, although varying with the season. Plants mature in June and July, usually about 14 to 16 weeks after spring growth begins.

The study reported here was initiated in an attempt to measure effects of Japanese brome on production of perennial grasses. The study was started soon after winter dormancy of Japanese brome was broken and continued until the first killing frost in the fall. Additional studies concerning root and shoot growth were conducted in the greenhouse and caryopses germination trials were conducted in the laboratory during fall and winter months.

RELATED LITERATURE

Many studies have been conducted to measure the competitive effect of annual vegetation upon perennial vegetation. Talbot, Biswell, and Hormay (1939) described the annual vegetation types of California. Although annual vegetation comprises about 98 percent of the plant cover in California (Biswell, 1956) very few studies have been conducted to determine the competitive relationship existing between annual and perennial vegetation.

Biswell and Graham (1956) worked with seed production and plant counts on California annual-type ranges. Plant densities of over 20,000 per square foot were found at germination with a 93 percent reduction in number by maturity. Seed production in the annual vegetation type was found to be high under normal conditions of weather and grazing. An abundance of seed was found to be produced nearly every year.

Rummell (1946) conducted a greenhouse experiment in Iowa which was designed to measure the effects of competition from cheatgrass brome (<u>Bromus tectorum</u> L.) at two moisture levels on the establishment and growth of crested wheatgrass (<u>Agropyron cristatum</u> (L.) Gaertn.) and bluestem wheatgrass (<u>Agropyron smithii</u> Rydb.) seedlings. Results indicated cheatgrass brome deferred establishment of the perennial grasses. A highly significant reduction in number of seedlings, number of tillers, weight of tops, and weight of roots of both perennial species resulted from cheatgrass brome competition. The cool season perennial grasses were better able to compete with cheatgrass brome under limited moisture conditions than where moisture was adequate.

Stewart and Hull (1949) studied cheatgrass brome in southern Idaho and found the density of stands to vary from 100 to 1,400 plants per square foot. The seven-year average production was 1,230 pounds per acre and ranged from about 500 to nearly 3,500 pounds per acre. A large seed crop and rapid germination of the annual provided a strong advantage over associated perennials, especially when drought or heavy grazing had weakened the perennials.

In the winter game ranges of Idaho, Holmgren (1956) studied the influence of annual weeds on establishment, growth rate, and survival of artificially seeded bitterbrush (*Purshia tridentata* (Pursh) DC.). Fall-germinating cheatgrass brome, because of its advanced development at the time of bitterbrush germination, is a more severe competitor than spring-germinating cheatgrass brome and broad-leaved weeds.

Cook (1943) conducted an investigation in Utah on root and top growth of selections of smooth brome grass (*Bromus inermis* Leyss.) which exhibited differences in ability to withstand controlled artificial drought tests in the seedling stage. The resistant selections were consistently higher in number of both "large" and "small" roots, and, in most cases, possessed greater average root depths than less resistant selections during the entire season. The resistant selections were found to posses greater root weights in proportion to top weights than non-resistant plants. It was concluded that total axial root length was one of the best single measurements for evaluating root systems of smooth brome.

Nutritive value of cheatgrass brome and crested wheatgrass on spring ranges of Utah were studied by Cook and Harris (1952). The nutritive value of crested wheatgrass was found to be good and relatively stabilized throughout the entire growing season whereas the value of cheatgrass brome decreased rather rapidly after the dough stage was reached.

Fleming, Shipley, and Miller (1942) investigated bronco grass (Bromus tectorum L.) on Nevada ranges. The maximum volume of bronco grass forage was produced by June 15 each year. Yearly forage production was found to be largely affected by spring moisture.

Hull and Stewart (1948) conducted research on reseeding perennial grasses on cheatgrass ranges in southern Idaho. Establishment of reseeded grasses increased as the density of cheatgrass decreased.

Robocker (1961) studied the influence of precipitation on occurrence of halogeton (Halogeton glomeratus C. A. Mey) and cheatgrass in arid and semi-arid regions of Nevada. A positive correlation of frequency of cheatgrass with precipitation was found for all periods and for individual and combined years. Correlations for halogeton were found to be both positive and negative and neither value approached the level of significance.

Kinsinger and Eckert (1961) investigated the emergence and growth of selected species of grasses and forbs in soils altered by halogeton leachate in Nevada. Cheatgrass and medusa-head wildrye (*Elymus caput-medusae* L.) appeared to favor soils partially altered by halogeton leachate, but under heavy treatment of the leachate emergence of all annual grasses was poor. Growth was reduced considerably, by the leachate, in all annual grasses.

Rate of root development of cheatgrass and medusa-head grass in Idaho was studied by Hironaka (1961). Prior to April, root systems of the two annual grasses penetrated to nearly equal depths (30 inches) and the roots consisted primarily of a single main root with short laterals. About the time the aerial portions of the plants began to add conspicuous growth, much ramification and lateral development of the root systems was observed. At maturity, cheatgrass had developed a more fragile and fibrous root system than medusa-head.

Hull and Pechanec (1947) investigated cheatgrass in Idaho. Density of cheatgrass was found to exceed 1,000 plants per square foot and yields ranged from 1,500 to 3,000 pounds per acre depending upon the amount of moisture. Seed production of 310 to 688 pounds per acre were harvested. Natural seed production of 1,646 seeds per square foot with over 99 percent germination was calculated. Production of seed and forage was greatly reduced by heavy grazing.

Evans (1961) worked on the competitive effect of downy brome (Bromus tectorum L.) on development of seeded crested wheatgrass (Agropyron desertorum (Fisch.) Schult.) in Nevada. Downy brome was planted at 4, 16, 64, and 256 plants per square foot and crested wheatgrass was seeded at the rate of 18 plants per square foot. At the end of the growing period, shoot and root weights of crested wheatgrass were decreased when grown with downy brome. Greater decreases were noted as the density of downy brome increased, especially when 64 and 256 downy brome plants per square foot were grown with crested wheatgrass. Shading of crested wheatgrass and depletion of soil moisture were the two main factors of plant competition that were observed.

Studies of Bromus tectorum and other annual bromegrasses were made in Washington, Oregon, Idaho, and Montana by Hulbert (1955). All bromegrasses studied produced roots that penetrated the soil to a depth of 150 cm. but Japanese brome had a greater proportion of roots at the 80 to 140 cm. depths than all others. Date of seeding was found to have a pronounced effect on seed production. Only one species, B. rubens, produced seed without going through a period of freezing temperature. Repeated clipping had little effect on seed production until the plants reached the dough stage, but if clipped during or after this stage, plants were killed.

DESCRIPTION AND LOCATION OF STUDY AREA

The general area of study was the mixed prairie which has been defined by Albertson (1937, 1938, 1939, 1941, 1942, 1943, and 1945), Weaver and Clements (1938), Tomanek and Albertson (1955 and 1957), and Weaver and Albertson (1956).

The specific location of the study was on a clay upland range site 2.5 miles southwest of Hays, Kansas. Albertson (1937) described the upland vegetation as a short grass community because of the continuous presence of blue grama (Bouteloua gracilis (H. B. K.) Lag. ex Steud.) or buffalo grass (Buchloe dactyloides (Nutt.) Engelm.) or a mixture of both. The study was conducted inside an exclosure erected in 1941 and grazed since that time only by rodents and small mammals.

Protection from grazing has increased the mulch, which in turn has decreased the basal cover of the short grasses in comparison to the cover under moderate grazing. The study was confined to plots supporting only short grasses to reduce the number of variables that might exist if other taller grasses were present.

Climatic conditions in the Hays area are often variable and quite extreme. The frost-free period extends from the latter part of April to the early part of October, providing a growing season of approximately 165 days. The long range average annual precipitation is nearly 23 inches, but extreme variations are from 43 inches in 1951 to 9 inches in 1956.

Precipitation was abundant throughout the period of study. Precipitation received during the study between March 1 and June 30 was over 112 percent of average normal rainfall for this period. Nearly 12 inches of precipitation was received between March 1 and June 30 in 35 measurable rainshowers. The average precipitation received from each shower was .34 inch but many showers of over .50 inch were recorded.

METHODS OF STUDY

A few days after Japanese brome broke winter dormancy (March 16), eighty (80) paired plots were selected for measuring vegetation and determining production. Each pair of plots was selected for uniformity of cover and composition as nearly as could be estimated. One of each pair of plots was denuded of all Japanese brome, forbs, and fresh mulch (treated) and the other plot was denuded of fresh mulch and forbs only (control) (Fig. 1). Japanese brome, forbs, and fresh mulch were also removed from around the outside of treated plots to reduce the "edge effect".

The perennial grasses from forty (40) paired plots were clipped when Japanese brome matured and the remaining forty (40) were clipped at the end of the growing season. This method was used to determine the difference, if any, in the production of perennial vegetation under control and treated circumstances at two different periods during the year.

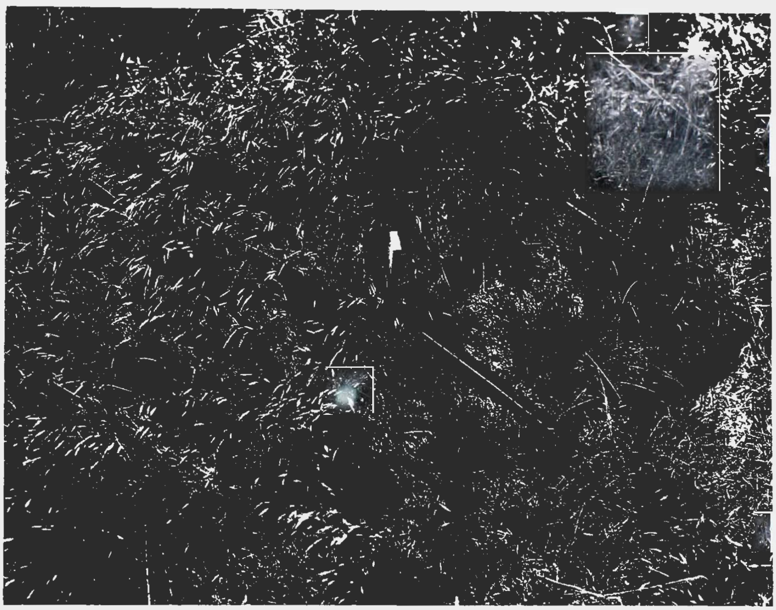

Fig. 1. Paired foot-square plots used in determining vegetational differences between control plots (left) from which mulch and forbs have been removed and treated plots (right) from which mulch, forbs, and Japanese brome have been removed.

Twenty (20) additional foot-square plots were selected after Japanese brome matured. All of the vegetation except perennial grass was removed from the series. The purpose of the series was to find the difference, if any, on production of perennial grass between control and treated plots from the time of maturity of Japanese brome to the end of the growing season. All yields were obtained by the air-dry forage method.

When discussing control and treated plots, treated plots will be referred to as D and M to indicate the time of Japanese brome removal. Japanese brome was removed from treated plots D immediately after winter dormancy was broken. The annual was removed immediately after maturity from treated plots M.

Seed stalk counts were made on blue grama at the end of the flowering season to determine if removal of annual grasses had any effect on seed production.

The density (number of plants) and yield of Japanese brome was determined at the end of winter dormancy, maturity of the annual, end of growing season, and after the first killing frost following fall germination.

Vegetation yields, blue grama seed stalk counts, and density of Japanese brome were determined by the average and range of 20 foot-square plots.

Water content of the soil in control and treated plots was determined by the use of the geotome as described by Weaver and Clements (1938). The percentage soil moisture was found at 0-6, 6-12, 12-24, 24-36, 36-48, and 48-60 inches of depth each week from the beginning of spring growth to maturity of Japanese brome in both the control and treated plots.

Soil temperatures were determined at two inches below the soil surface each time soil moistures were taken.

Germination tests were conducted on Japanese brome caryopses that had been subjected only to the normal summer temperatures; also tests were made on caryopses that had been subjected to a week of freezing temperature. The germination tests were run in a Mangelsdorf germinator at 25° Centigrade for one week.

Root development and growth measurements of Japanese brome were studied with the use of phytometers in the greenhouse (Fig. 2). Early growth and development studies were made by growing Japanese brome from caryopses and washing the roots out every four days from germination until the plants were three weeks old. The roots were removed only once a week from the three-week-old stage to the seven-week-old stage. Growth measurements were determined every time the roots were removed from soil. The following growth measurements were made: (1) depth of penetration of primary root, (2) lateral spread of primary root, (3) depth of penetration of secondary roots, (4) lateral spread of secondary roots, (5) number of secondary roots, (6) variation in length of secondary roots, (7) number of leaves, (8) length of longest leaf.

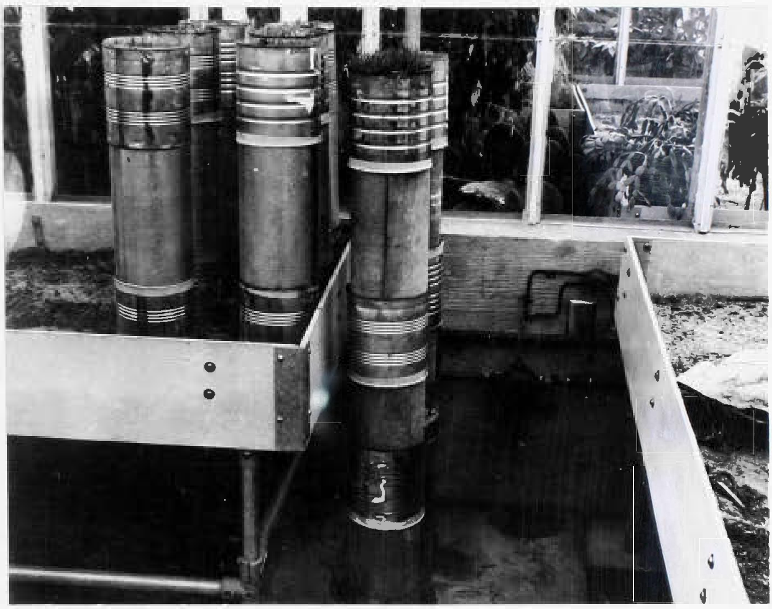

Fig. 2. Phytometers were used to study root growth and development of Japanese brome in the greenhouse.

Scientific names of grasses used in the study are those of Hitchcock and Chase (1950). Scientific names of forbs are from Rydberg (1932) and Harrington (1954).

Data that could be statistically analyzed were done so by the "T test" as described by Dixon and Massey (1957).

RESULTS

Soil moisture: Precipitation was abundant throughout the entire growing season and soil moisture content was nearly the same for the two treatments from beginning of spring growth (March 16) to the time when Japanese brome initiated elongation of its shoot (May 15). Soil moisture content from 0-2 feet in depth never dropped below the hygroscopic coefficient during the growing period of Japanese brome (Fig. 3). Soil moisture content for the 2-3 foot level was always above the hygroscopic coefficient in the treated plots but during one week (June 5 to June 12) the soil moisture content in the control plots dropped below the hygroscopic coefficient. Soil moisture content at the 3-4 foot level was above the hygroscopic coefficient all of the remaining period after June 5 in the treated plots but the moisture content of the control plots was above the hygroscopic coefficient only during the week of June 19. Soil moisture at the 4-5 foot level was generally below the hygroscopic coefficient. Control plots never did get above the hygroscopic coefficient at the 4 to 5 foot level and treated plots did so only during the weeks of June 5, June 19, and June 26.

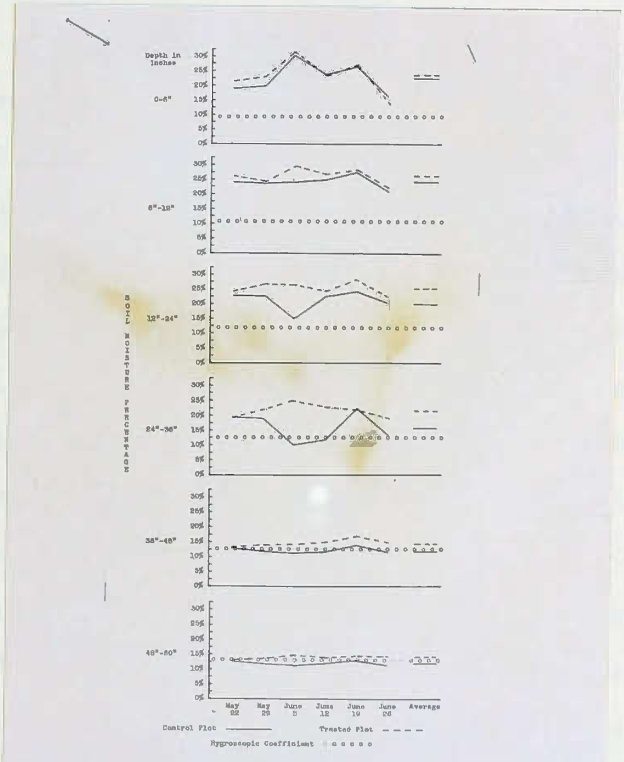

Fig. 3. Percentage soil moisture at 0-6, 6-12, 12-24, 24-36, 36-48, and 48-60 inches of depth in control and treated plot.

Averages for a six-week period at all depths showed 20.90 and 18.18 percent soil moisture for treated and control plots, respectively, and represented a statistically significant difference in soil moisture content between the two treatments.

Soil temperature: Highly significant differences in soil temperature existed between the two treatments (significant at .02 percent confidence level). Every time soil temperature readings were determined the treated plots had a reading that equalled or exceeded that of the control plots. Average soil temperatures were 22.4 and 20.7° C. for treated and control plots, respectively (Fig. 4).

Temperature, generally, increased from the last of April to the latter part of June under both treatments.

The significantly higher soil temperature on treated plots probably had a large influence on the significant reduction of soil moisture in the upper one-foot of soil in the treated plots. Soil temperature after June 5 ranged from 26 to 33° C. in the treated plots in the upper two inches. Soil temperature of control plots averaged nearly 3° C. lower than the treated plots from June 5 to June 30 and the maximum temperature of control plots reached only 28° C. which was 5° C. below the maximum of treated plots.

Yields: One to two weeks after Japanese brome broke winter dormancy (March 16) the average yield was 1,774 pounds per acre but varied from 595 to over 3,515 pounds

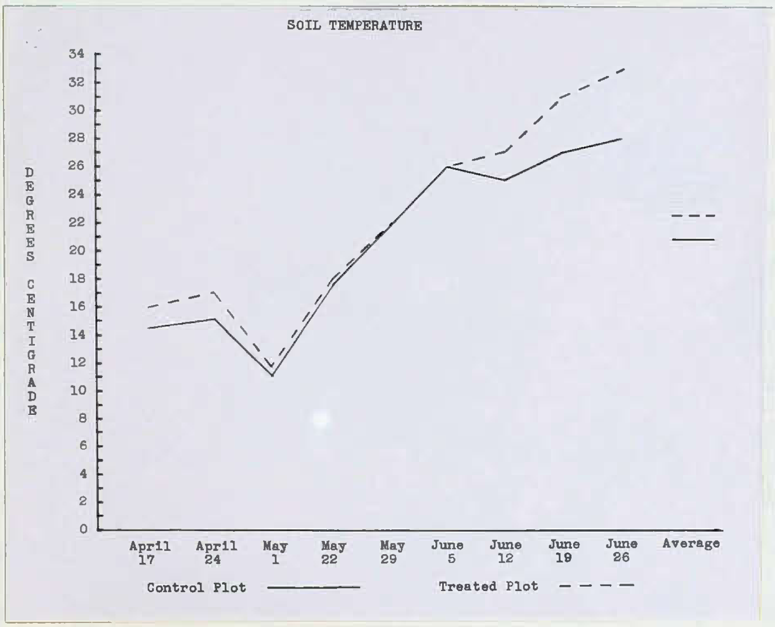

Fig. 4. Soil temperature in degrees centigrade for control and treated plot.

(Table I). On the same date Japanese brome formed a thick mat of vegetation between the clumps of perennial grasses (Fig. 5). Average density of the annual was 1,132 plants per square foot but ranged from 713 to 1,642 plants (Table II).

Table I. Production in pounds per acre of Japanese brome at the end of winter dormancy (March 16).

	POUNDS PER ACRE	
	Average	Range
Japanese brome	1,774	595-3,515

Production of Japanese brome decreased to an average of 957 pounds per acre by maturity (June 30) (Table III). Reduction in yield from the end of winter dormancy (March 16) to maturity of Japanese brome was 46 percent. Density of Japanese brome was reduced by 50 percent during the spring growing season leaving an average of only 568 live plants per square foot at maturity (Table II).

Yield of perennial grasses, at maturity of Japanese brome, was influenced very little by increased soil moisture on areas where the annual had been removed. Production averaged 1,701 and 1,657 pounds per acre for treated D and control plots, respectively (Table III). Variations in production of perennial grasses were slightly larger on the control plots than on the treated plots D but no statistical difference was found between the yield of perennial grasses from treated and control plots for this period. Total yield of control plots (perennial grass plus Japanese brome) was

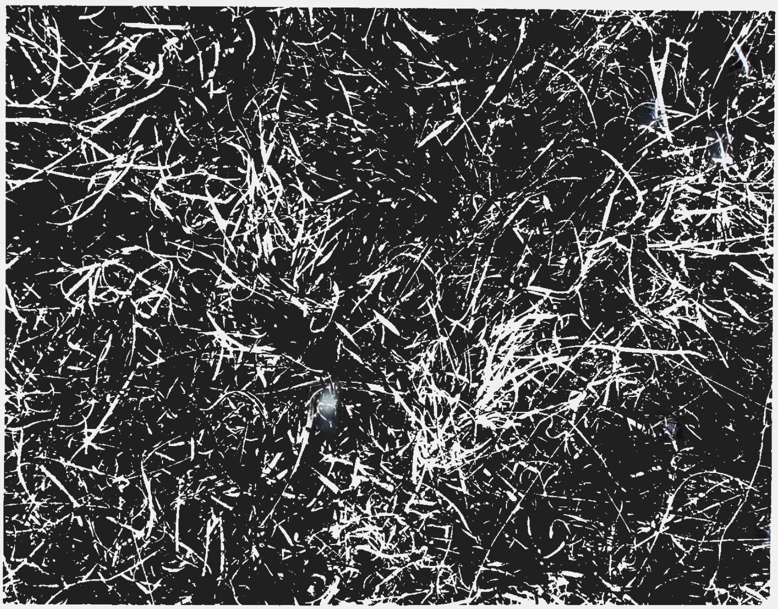

Fig. 5. Thick mat of Japanese brome occurring between clumps of perennial grasses on March 16. Light colored grasses are perennials.

Table II. Number of Japanese brome plants per square foot (density) at four phenological periods during the year.

	PLANTS PER SQUARE FOOT			
	End of winter dormancy (March 16)	Maturity of Japanese brome (June 30)	End of growing season (September 19)	Seedlings after fall germination (October 19)
Average	1,132	568	372	1,274
Range	713-1,642	319-935	109-570	540-2,196

35 percent greater than on the treated plots D. The former produced an average of 2,614 pounds while the latter produced 1,701 pounds per acre.

Table III. Production in pounds per acre at maturity (June 30) of Japanese brome from control and treated plots D.

		POUNDS PER ACRE	
		Average	Range
Treated	Perennials	1,701	903-2,689
	Perennials	1,657	951-2,862
Control	Annuals	957	643-1,469
	Total	2,614	1,796-3,793

Production of perennial grasses at the end of the growing season was significantly greater in the control plots than in treated plots D (Table IV). Average yields were 2,394 and 2,214 pounds per acre for control and treated plots D, respectively, when Japanese brome was removed from treated plots D early in the spring (Table IV).

Table IV. Production in pounds per acre at the end of the growing season (September 19) from control and treated plots D.

		POUNDS PER ACRE	
		Average	Range
Treated	Perennials	2,214	1,104-3,399
	Perennials	2,394*	1,210-3,323
Control	Annuals	483	96-825
	Total	2,877	1,613-3,736

*Significant at the .05 probability level.

Removal of Japanese brome might possibly have produced a more severe environmental condition which had a retarding effect on growth because of the higher temperature on the treated plots whereas the control plots had a more favorable temperature for growth. Soil moisture apparently was not a limiting factor under either condition.

Production of Japanese brome at the end of the growing season averaged only 483 pounds per acre and was 73 percent lower than yield at the beginning of the growing season when winter dormancy was broken.

Removal of Japanese brome when mature had no effect on the production of perennial grass at the end of the growing season. Production of perennial grass from maturity of Japanese brome to the end of growing season was increased by 684 pounds per acre in the treated plots M and 737 pounds per acre in control plots. Yearly production averaged 2,385 pounds per acre for treated plots M and 2,394 pounds per acre for control plots (Tables IV and V).

Table V. Production in pounds per acre of perennial grasses at the end of the growing season (September 19) from treated plots M.

		POUNDS PER ACRE	
		Average	Range
Treated	Perennials	2,385	1,590-3,335

Total yearly production on control plots (perennial grass plus Japanese brome) was 2,877 pounds per acre (Table IV) or 23 percent greater than the 2,385 pounds per acre yearly production on the treated plots M.

No data on soil moisture and soil temperature were collected after maturity of Japanese brome but observations indicated that soil temperature was rising and soil moisture was decreasing under both treatments and that the most rapid and pronounced changes were occurring in the treated plots. Insufficient data were available to make an absolute statement but observations indicated that the high soil temperature in treated plots influenced microclimate enough to cause a decrease in growth rate of perennial grasses but there is need for additional study.

Tremendous reduction of the stand of Japanese brome occurred naturally even though moisture was plentiful. The limiting factor must have been light which is in agreement with results reported by Evans (1961). Reduction from 1,132 plants per square foot at the beginning of the growing season to 568 plants at maturity to 372 plants at the end of the growing season (Table II) represents a total loss of 67 percent.

Fall germination of Japanese brome was observed during the middle of August and a total of 1,274 seedlings per square foot were recorded by the first killing frost on October 19. It is possible some may have germinated after the first killing frost. Field notes indicate some seedlings remained green all winter and possibly made growth during warm winter days.

<u>Blue grama seed stalk production</u>: Average number of seed stalks of blue grama on treated D and control plots was 39 and 35 per square foot (Table VI), respectively. This difference was not statistically significant.

Table VI. Number of blue grama seed stalks produced on treated D and control plots.

	SEED STALKS PER SQUARE FOOT	
	Average	Range
Treated	39	0-95
Control	35	0-74

<u>Japanese brome germination</u>: Germination was first observed in the non-frozen caryopses 42 hours after they were placed in the germinator but 54 hours were required before the first signs of germination were observed in caryopses exposed to freezing temperatures. Germination was complete after 66 and 70 hours for non-frozen and frozen caryopses, respectively, with 94 percent germination occurring under both treatments.

<u>Early growth and development</u>: Early growth and development of Japanese brome was studied by growing the plants from seed in the greenhouse.

Four days after germination the seedlings were in the one-leaf two-root stage (Fig. 6). Average height of the first leaf was 3.5 cm. and the primary root had penetrated through the soil to a depth of 3.5 cm. (Table VII). Lateral spread of the primary root was 0.5 cm. Recent protrubrance

Table VII. Growth and development of Japanese brome, in centimeters, taken periodically from 4 to 49 days after germination.

	Primary Root		Secondary Roots				Leaves	
Days after germination	Length in cm.	Spread in cm.	Length in cm.	Spread in cm.	Number of roots	Variation in length in cm.	Number of leaves	Length in cm.
4	3.5	0.5	1.0	0.5	1	0.0	1	3.5
8	11.0	1.5	3.5	1.0	1	0.0	2	7.0
11	16.0	2.5	5.0	5.0	4	2.0-5.0	3	7.5
16	26.0	4.0	12.0	9.5	4	5.5-9.5	5	10.0
20	37.0	4.0	12.5	12.0	9	1.0-12.5	9	10.0
23	43.0	4.0	20.0	13.5	9	3.0-20.0	9	12.0
28	48.0	5.0	17.0	14.0	8	2.0-17.0	13	13.0
35	62.0	5.0	57.0	15.0	10	2.5-57.0	15	15.0
42	68.0	5.0	65.5	15.0	11	3.0-65.5	15	18.5
49	81.0	5.5	77.5	15.0	11	4.0-77.5	14	21.5

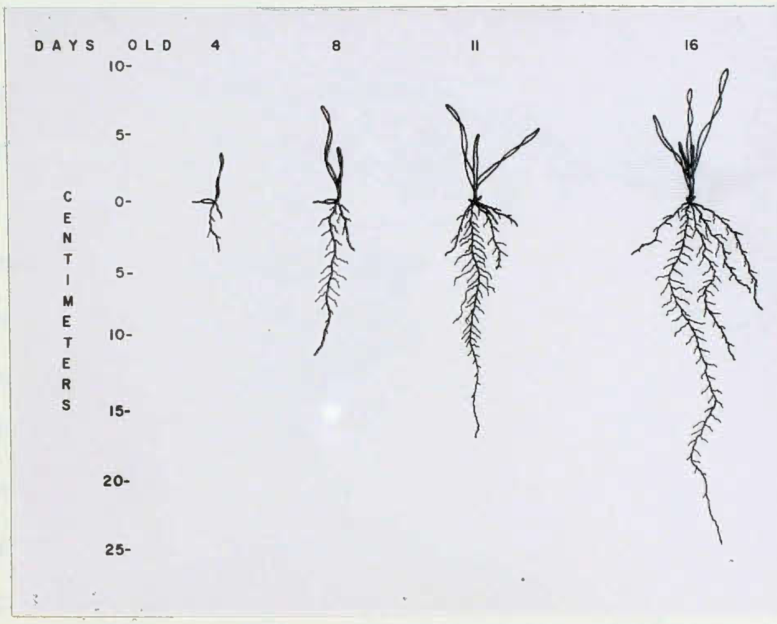

Fig. 6. Growth and development of Japanese brome at 4, 8, 11, and 16 days after germination.

of branch roots composed the greatest portion of lateral spread. One secondary root was observed with an average depth of penetration near 1.0 cm., however, no branch roots were observed, as yet, on secondary roots. The total lateral spread of primary and secondary roots was near 1.0 cm.

Japanese brome had become established and was growing rapidly sixteen days after germination. The seedlings had reached the five-root five-leaf stage. Leaf length ranged from 4.0 to 10.0 cm. with an average length of 6.5 cm. Primary root penetration had reached a depth of 26.0 cm. and extensive growth of branch roots on the primary root produced a lateral spread of 4.0 cm. for the primary root. Four secondary roots, which ranged from 5.5 to 9.5 cm. in length, were present. Branch roots had been initiated on only three of the four secondary roots but the total lateral spread of all roots was 9.5 cm.

Japanese brome began to tiller and produce large amounts of vegetative growth after sixteen days. Five weeks after germination each seedling had produced an average of 15 leaves but no signs of shoot elongation had been detected. Maximum height of leaves at five weeks after germination was 15.0 cm. and lateral spread of leaves was 14.0 cm. (Fig. 7). Figure 8 shows the dense foliage of Japanese brome after five weeks of growth. Primary root growth reached 62.0 cm. in depth five weeks after germination. Branch roots on the primary root averaged 2.5 cm. long and were present throughout

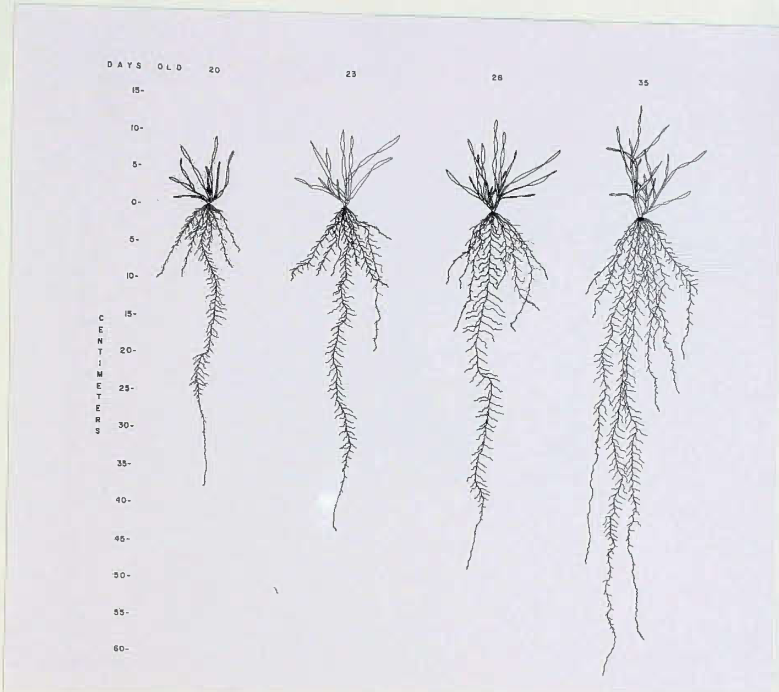

Fig. 7. Growth and development of Japanese brome at 20, 23, 28, and 35 days after germination.

Fig. 8. Dense foliage of Japanese brome after five weeks of growth.

the entire length of the root except for 3 to 4 cm. next to the root tip. An average of ten secondary roots were present after five weeks of growth. Penetration of secondary roots ranged from 2.0 to 57.0 cm. with six secondary roots penetrating to over 17.0 cm. in depth. Numerous root hairs were present on all secondary roots except one which was only 2.0 cm. long. Lateral spread of roots was 15.0 cm. but growth may have been restricted by the walls of phytometers. Much ramification and development of roots was observed at all depths after five weeks of growth.

Seven weeks after germination of Japanese brome, leaf tips began to turn brown and dry. Vegetative development of the shoot had stopped but root growth was still occurring at a rapid rate. Development of leaves was nearly the same at the seven-week stage as at the five-week stage except that elongation of the leaves had continued. After seven weeks of growth, Japanese brome leaves had grown to a length of 21.5 cm. (Fig. 9). Root development was extensive with much branching of all roots. Primary root penetration averaged 81.0 cm. in depth while six secondary roots had penetrated to a depth of over 49.0 cm. and four secondary roots had grown to a depth of over 72.0 cm. Branch roots were so numerous, especially in the upper 15.0 cm., that the soil seemed to be completely filled.

No sign of shoot elongation of Japanese brome was observed during the first seven weeks of growth after germi-

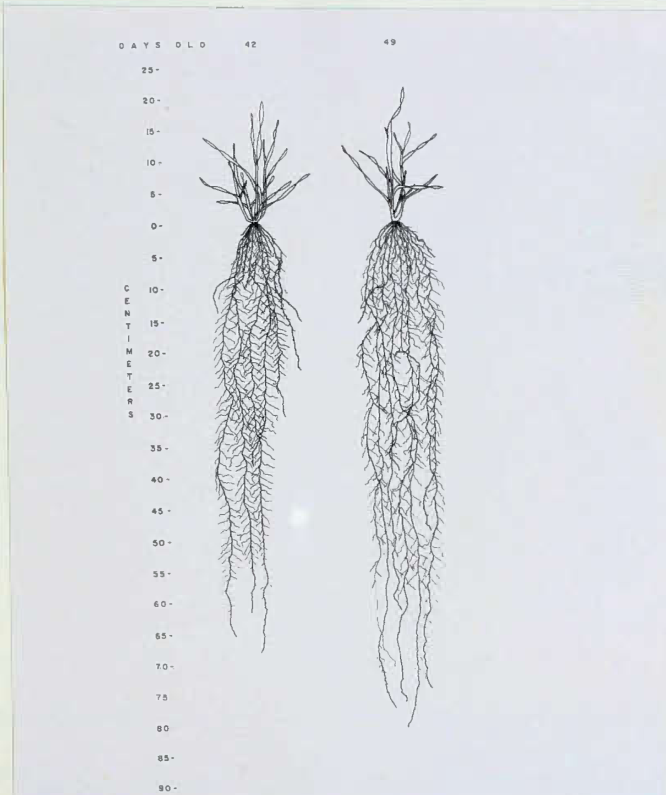

Fig. 9. Growth and development of Japanese brome at 42 and 49 days after germination.

nation. Day-length was increased to 14 hours per day in an attempt to stimulate flowering. Increased day-length was continued for 15 days with no apparent results. Japanese brome plants were subjected to a period of cool temperature (14 days at a constant 7° C.) and a period of low soil moisture (plants were kept in a wilted condition for 8 days) but neither treatment influenced shoot elongation. One hundred and twenty one days after germination Japanese brome plants were still in a vegetative stage but growth had ceased, although plants were still living. Hulbert (1955) found that Japanese brome would not produce seed unless the plants first passed through a period of freezing temperature.

SUMMARY

Caryopses of the winter annual, Japanese brome, may be present in the prairie soil of western Kansas for many years and not be apparent until a wet season promotes extensive germination and growth. Effects of Japanese brome upon production of perennial grasses is a question of growing concern.

In order to determine competitive effects of brome on perennial grasses production of vegetation was determined from paired foot-square quadrats. Fresh mulch and forbs were removed from control plots, and fresh mulch, forbs, and Japanese brome were removed from treated plots at the end of winter dormancy (D plots) and at maturity of Japanese brome (M plots). Yields of perennial grasses were determined at maturity of Japanese brome and at the end of the growing season.

Moisture content of the soil was determined periodically from soil surface to a depth of five feet on treated and control plots. Soil temperature was measured at a depth of two inches below the soil surface for both treatments on the same day soil moistures were taken.

The density of Japanese brome was determined at the end of winter dormancy, maturity of the annual, end of growing season, and after the first killing frost following fall

germination. Density of blue grama seed stalks was determined at the end of the growing season.

Germination tests were conducted on Japanese brome caryopses that had been subjected to two temperature treatments before being placed in a Mangelsdorf germinator.

Root development and growth measurements of Japanese brome were studied with the use of phytometers in the greenhouse. Periodically, roots were washed free of soil, measurements were taken and plants were drawn to scale.

Precipitation was abundant throughout the entire study period and soil moisture was always above the hygroscopic coefficient during the growing period of Japanese brome under both treatments. Averages of 20.90 and 18.18 percent soil moisture for treated and control plots, respectively, represents a statistically significant difference in soil moisture.

A highly significant difference in soil temperature was found between treated and control plots which averaged 22.4 and 20.7^{o} C., respectively.

At the end of winter dormancy production of Japanese brome averaged 1,774 pounds per acre with an average density of 1,132 plants per square foot.

Yield of perennial grasses, at maturity of Japanese brome, were influenced very little by removal of the annual in March. Production averaged 1,657 and 1,701 pounds per acre on control and treated plots D (Japanese brome was removed at the end of winter dormancy), respectively. By maturity, average production of the annual had decreased to 957 pounds per acre.

By the end of the growing season production of perennial grasses averaged 2,394 and 2,214 pounds per acre for control and treated plots D, respectively, which represents a significant difference between the two treatments.

Removal of Japanese brome at maturity had no beneficial effect on the yield of perennial grasses at the end of the growing season. Yearly production averaged 2,385 per acre on treated plots M (Japanese brome was removed at maturity) and 2,394 pounds per acre for control plots. Total production of control plots (perennial grass plus Japanese brome) averaged 2,877 pounds per acre at the end of the growing season which represents a 17 percent greater production than treated plots M and 23 percent greater production than treated plots D.

Insufficient data were available to make an absolute statement but observations indicated that the high soil temperature in treated plots influenced microclimate enough to cause a decrease in growth rate of perennial grasses.

The number of Japanese brome plants were reduced from 1,132 plants per square foot at the beginning of the growing season to 568 plants at maturity to 372 plants at the end of the growing season.

No statistical difference was found between the two treatments on the number of blue grama seed stalks produced per square foot.

Germination of Japanese brome caryopses occurred more rapidly when caryopses had not been frozen than if caryopses were frozen for a period before germination. Percentage germination was 94 for both treatments.

Early growth and development of Japanese brome was studied periodically from germination to the 49 day-old-stage. Only one primary root per plant was detected but it remained in a growing condition throughout the study period. Plants began to tiller after 16 days of growth and yielded an average of 15 leaves per plant after 35 days of growth. Elongation of primary and secondary roots averaged 1.65 and 1.58 cm. per day, respectively. Total depth of penetration of primary root averaged 81.0 cm. and secondary roots penetrated to a depth of 77.5 cm. in 49 days. Lateral spread of roots was 15.0 cm. and maximum elongation of the 14 average leaves per plant was 21.5 cm. after 49 days of growth.

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