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CHEATGRASS (*BROMUS TECTORUM* L.)—AN ECOLOGIC INTRUDER IN SOUTHERN IDAHO

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INTRODUCTION AND HISTORY

Cheatgrass brome[1] (*Bromus tectorum*) has proved to be a prolific immigrant. Arriving from Europe about 50 years ago, it has spread throughout practically all the arid West and has become a major member of the plant cover on vast areas.

Plant collections are first recorded for Pennsylvania in 1861, Washington in 1893, Utah in 1894, Colorado in 1895, and Wyoming in 1900 (Warg, '38). By 1914 it had appeared in practically every state in the Union (U. S. Forest Service, '14). Presumably collections were made soon after appearance, but unfortunately, collection notes generally give no clue as to abundance even at the point of collection.

Cheatgrass appeared in southern Idaho about 1900. Since then it has become a dominant species on approximately 4 million acres where it constitutes from 75 to 95 per cent of the herbage production. On another 2 million acres covered with sagebrush (*Artemisia tridentata* Nutt. and related species), cheatgrass is the principal herbaceous species and in large parts almost the only one. On another 10 to 15 millions acres it forms part of the cover, from a mere trace to 20 or 25 per cent of the herbaceous species. On these ranges, principally the vast expanses of the Snake River Plains, it merely awaits the opportunity to take possession. Almost every year recurrent fire and other forms of misuse destroy sagebrush and native grass and allow cheatgrass to add many thousands of acres to the area of almost complete occupation (Hull and Pechanec, '47).

The many gaps in our information concerning cheatgrass cause difficulty in preparing a comprehensive treatise about it. However, the widespread experience with cheatgrass, its challenging responses, and a considerable number of studies dealing with its ecological and economic behavior, when taken together, make it possible to present this fairly reliable over-all view of its status.

ADJUSTABILITY IN GROWTH HABITS

Cheatgrass is naturally a winter annual, but may act as a spring annual wherever too little fall moisture is available. In Idaho it ordinarily begins growth in late September or October and where the stands are thick, produces a basal rosette of leaves from 2 to 6 inches in diameter. In heavy stands with 500 or more plants per square foot, no rosettes are formed. When snow comes it merely stops growing and waits for warm spring weather; then it grows rapidly. In 5 or 6 weeks it produces luxuriant leafage and flower stalks with an abundant seed crop. It ripens seeds and dries from maturity or from early summer drought by June 5 at lower elevations (2,000–4,000 ft.) in southwestern Idaho, and by about June 30 in southeastern Idaho where the season is later because of higher elevation (4,500–6,000 ft.).

Whenever germination of cheatgrass is delayed until spring, both height growth and herbage yield are greatly reduced. When fall and spring moisture are both deficient, total height growth may be only 2 or 3 inches. On the other hand, when both fall and spring are warm and rainy the growth may reach 24 or more inches

[1] The most common name is merely "cheatgrass" by which name it is designated in this paper. Other names commonly used are broncograss, Junegrass, Mormon oats, and downy brome.

instead of the ordinary height of 12 to 20 inches. Sometimes in western Idaho when the winters are warm and rainy, growth continues most of the winter. Cheatgrass plants are highly adjustable and therefore well adapted to endure extreme drought. Under drought conditions the plants produce little herbage but mature a crop of seed great enough to provide for next year's plants. On occasions of a sharp drop in temperature or the rapid onset of a moisture shortage the foliage and inflorescences take on a distinctly purple color, which fades either with more favorable growing weather or with more distinct drying. This purple color develops under normal ripening but the change is not so rapid or the color so distinct as when brought on by sudden drought or a sudden drop in temperature.

Cheatgrass is a prolific seed producer, production commonly varying with the vigor of the vegetation. The caryopsis is about 1/4 to 3/8 inch in length with the lemma bearing an awn 1/4 to 1/2 inch long. The glumes are covered with short strong barbs that cause the spikelets to work into wool, hair, clothing, and probably through a litter cover (when disturbed) into the soil beneath. This same property makes hay with some mature cheatgrass in it miserable to handle. Occasionally the tender tissues of the face or mouth of colts, lambs, and calves may be penetrated by the barbed spikelets. A few cases of serious injury are known but they are not common.

After fall germination, the numerous roots grow rapidly and except where fall growth is poor they are well developed by the time spring growth begins. The roots quickly occupy the surface soil and therefore tend to crowd out species that develop more slowly. They do not, however, reach the great depth of perennial grasses nor produce as great a volume of growth. The rapid growth each fall and spring and the annual death of the roots, together with decaying top growth tend to make rapid additions to the organic matter in the surface soil. Being an annual, cheatgrass does not have the rhizomes of a true sod but grows in such dense stands as to form a temporary sod.

Invasion, Colonization, and Occupation of Range Lands

During the first few years after 1900 cheatgrass was observed (U. S. Forest Service, '14) to occur in Idaho on farm land left bare of cultivated crops, along the edges of dirt roads, and in orchards, berry patches, and in fields of alfalfa where the alfalfa stands were thin or otherwise weak. In dryland alfalfa fields the occupation was likely to be particularly complete especially when grazed heavily after a hay crop was removed. The most spectacular occupations were at first on farms abandoned to cultivation. Summer-fallow lands on dry farms were also fully infested unless great care was taken to make the tillage both thorough and timely.

Meanwhile, range lands where the native plant cover was broken or damaged were invaded. By 1915 to 1920, perhaps sooner in many areas (the time record is incomplete), range lands, wherever the perennial cover was seriously broken through, were rather thoroughly colonized and were beginning to be well occupied with cheatgrass.

After the price recession of 1920 the complete or partial abandonment of dry-farm wheatlands was common. Considerable areas of marginal irrigated land were also allowed to run wild. The abandoned land in southern Idaho is estimated to total 2 million acres. On such lands the driest areas were first occupied by Russianthistle (*Salsola kali-tenuifolia* (L.) Tausch) and later tumblemustard (*Sisymbrium altissimum* L.) with some cheatgrass which during the next few years increased in proportion and crowded out the weeds. In the areas with somewhat higher precipitation cheatgrass established island colonies and these took over rather promptly from the annual weeds and provided the major aspect to the vegetation.

Experience soon demonstrated that cheatgrass burned more readily than the native species. Fires which began in cheatgrass spread to sagebrush stands already invaded by sparse amounts of cheatgrass. Cheatgrass had already become abundant enough to seed the range and nearly all the burned areas were well colonized by cheatgrass the first or second year following the fire. Cheatgrass was so aggressive as to start growth ahead of the native weeds and matchbrush shrubs (*Gutierrezia sarothrae* (Pursh), Britt. & Rusby), now known as snakeweed, that had formerly constituted one of the first steps in succession on burned areas. Cheatgrass fires often spread to and burned over good sagebrush-grass range where there was no cheatgrass. As severe grazing commonly followed burning, the vigor of the native grass was further reduced, and with sagebrush removed the way was prepared for mass cheatgrass invasion. With the aid of other fires at intervals of a year or two the native species were in many cases almost entirely eliminated. The forage cover by then consisted of 65 to 95 per cent or more of cheatgrass, and tended to remain in that proportion so long as regular grazing by cattle and promiscuous burning continued.

In the sagebrush-grass type, cheatgrass occurs either as an understory species or, where sagebrush has been removed by fire or farming, cheatgrass may be the dominant species over extensive areas (see figs. 1 and 2). Although it appears superficially to form pure stands it seldom occurs as a single species except on abandoned farm lands. Sandberg bluegrass (*Poa secunda* Presl.) is usually present. Other perennial grasses often present are bottlebrush squirreltail (*Sitanion hystrix* (Nutt.) J. G. Smith), bearded bluebunch and beardless bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith and *A. inerme* (Scribn. & Smith) Rydb.), streambank wheatgrass (*A. riparium* Scribn. & Smith), and giant wildrye (*Elymus condensatus* Presl.). Such annual weeds as Russianthistle, tumblemustard, sunflower (*Helianthus* spp.), curlycup gum weed (*Grindelia squarrosa* (Pursh) Dunal) and wild lettuce (*Lactuca* spp.) are often present, especially when heavy late spring rains occur.

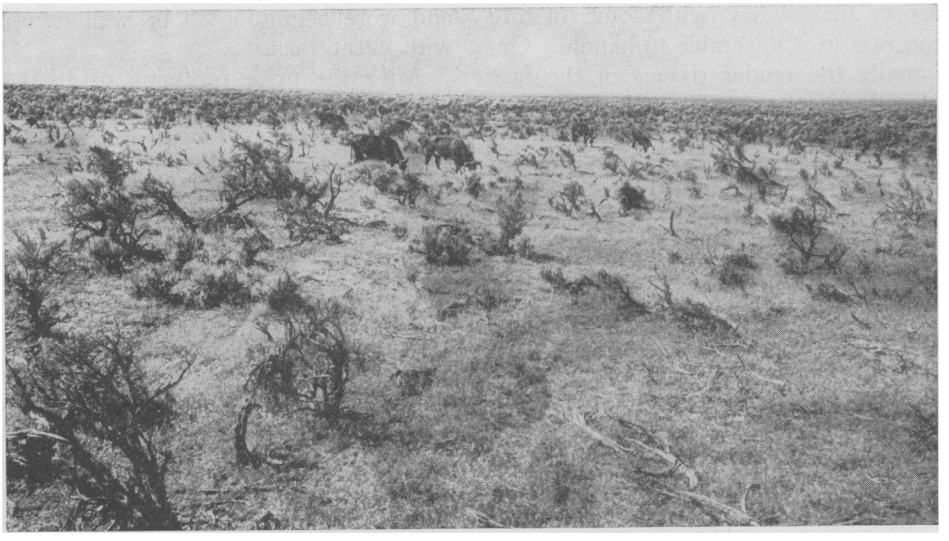

FIG. 1. Overgrazing on many sagebrush-grass ranges has killed the perennial grass and injured the sagebrush. Cheatgrass has largely replaced perennial grasses as the understory to sagebrush. Here, cattle are utilizing the cheatgrass for spring and summer grazing.

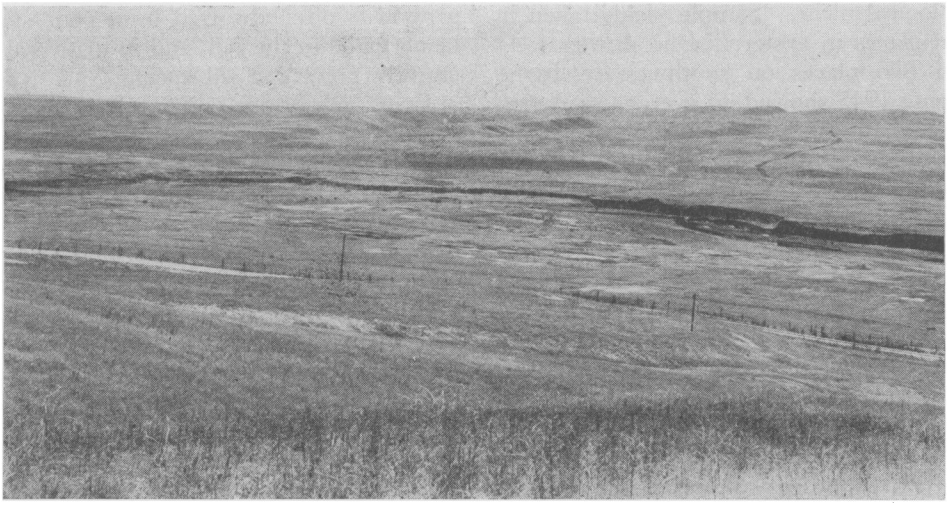

FIG. 2. Large areas in southwestern Idaho have been repeatedly burned and all sagebrush has been killed, allowing cheatgrass to occupy the whole area save for a scattering of perennial grasses. The cheatgrass area shown in the picture is divided into pastures and grazed yearlong. Parts of the area are being grazed too heavily, and are allowing accelerated runoff, as evidenced by the cutting of the main drainage channel. Losses of top soil on this area are heavy.

Surveys and studies between 1932 and 1947 showed that this process of occupation by cheatgrass after fires and other disturbances is continuing, principally in the elevational zone where sagebrush had originally occurred in large tracts (Piemeisel, '38). On its upper edges the sagebrush merges into mountain brush and timber vegetation. At these higher elevations cheatgrass occurs in scattered patches and is often locally abundant but it occurs in less and less exclusive proportions as the mountains are ascended. Widely scattered but locally abundant stands of cheatgrass occur up to 6,000 feet in southwestern Idaho and 7,000 feet in eastern Idaho on slopes that face south or southwest. Only occasionally is it abundant at these elevations. It is found on rare occasions at 8,000 feet in southwestern Idaho and 9,000 feet in eastern Idaho but it is not known that it will ever become abundant there.

In the driest parts of broad Snake River Plains, sagebrush merges into the salt-desert shrub vegetation. Here cheatgrass has spread much more slowly than in the more moist upper edges of the plains and in the lower foothills. Apparently, the salt impregnated soils more strictly limit the spread than does the low precipitation, since cheatgrass already occurs on heavily grazed knolls in the salt desert area but not on the more saline bottomlands. Wherever the salt-desert shrub vegetation has been reduced or destroyed, cheatgrass has invaded and on many areas with good soil drainage is now being used for winter grazing on areas that were formerly covered with salt-desert shrubs.

ECOLOGICAL ADAPTATIONS AND RESPONSES

Unfortunately no great body of quantitative information has been built up regarding the plant development, ecological range, and growth requirements for cheatgrass. Concerning a few phases, however, definite data are now available, some of them of critical importance. Seed production of high viability, for example, is one of the qualities that counts for aggressiveness in colonizing any unoccupied

ecological niche. Sample yields taken in two places in eastern Idaho during 1944 and two places on southwestern Idaho during 1945 showed an average seed production of 478 pounds per acre. Average number of seeds is 150,000 to the pound. At 478 pounds of seed per acre the area is thus seeded at such a rate that each square foot receives 1,646 seeds. Seeds tested shortly after seed maturity germinated 99.75 per cent. Sprouting began within 1 day and was complete in some tests in 2 days and in all within 5 days (Warg, '38). This unusually prompt and complete germination, together with the high rate of natural seeding leaves little wanting in the way of seedling plants. Moreover there is no evidence of seed dormancy such as exists so markedly in grasses such as Indian ricegrass (*Oryzopsis hymenoides* (Roem. & Schult.) Ricker). It is little wonder therefore that cheatgrass tends both to invade new areas and to maintain its hold on an area once occupied.

Rapidity of germination is a real asset to a species in arid regions where late summer showers are infrequent and likely to be followed shortly by clear weather. Rains during September or October of 2 or 3 days duration germinate the seeds and start the seedlings well on their way to establishment. This immediate response sometimes results in death in the seedling stage because early rains (August for example) promote germination after which the surface desiccates in hot, dry weather and this prevents plant establishment (Piemeisel, '38).

Cheatgrass is an opportunist that is highly responsive to weather. Plants may start in the fall and in unfavorable weather make little growth. The September-October precipitation, or in lower elevations that of October-November, must total approximately 2 inches of well-concentrated rains to produce a vigorous fall growth. So much well-timed precipitation can be expected once in 3 years in southeastern Idaho but only once in 8 years in southwestern Idaho. Thus, growth is often dwarfed by a poor start being made in the fall, and in many cases entirely prevented till spring.

Even in periods unfavorable to seed production, the seed crop is ample and the conditions that help to establish stands are auspicious enough to insure good stands of cheatgrass. After the severe droughts of 1931 and 1934, and several less severe ones, cheatgrass responded with a good cover as soon as moisture and temperature again became favorable. On the other hand, native perennial species that previously were in a good state of vigor took 2 to 4 years to recover after 1934; native species that had been heavily grazed recovered even more slowly and in many cases succumbed (Pechanec, Pickford, and Stewart, '37). By using this opportunity, cheatgrass increased its relative abundance in the plant cover during the protracted period in which native perennials were recovering from the setback. Accidental fires, encouraged by the greater inflammability of the invading cheatgrass, permitted a still fuller occupation by this aggressive species.

Although the principal ecological situation in which cheatgrass thrives is one where the native plant cover has been killed or badly injured, it has appeared in sagebrush ranges where the herbaceous understory is still well preserved. In wet years, it temporarily produces considerable volume but with normal rainfall it again becomes small and inconspicuous. This species is found in small proportions in long-protected areas near Dubois and Pocatello.

Competitive Relationships

The heavy natural seeding provided by cheatgrass, the rapid germination of seeds when conditions are favorable, the rapid root and top growth made by the seedlings, and the high adjustability of the species to seasonal conditions all encourage thick stands that have great competitive power. Numerous counts all across southern Idaho, incidental to travel and made as opportunity afforded, showed

stands varying from 100 to 1,400 cheatgrass plants per square foot and averaging 572 plants. Such density of numbers leaves no doubt that the area is intensely occupied and makes clear why perennial species have difficulty in establishing stands unless they get artificial aid.

About 30 species, including all the ones well suited to range seeding, have been seeded several times on areas occupied by cheatgrass without obtaining successful stands. Crested wheatgrass has been repeatedly experimented with in this respect, always with such exceedingly poor or variable results as to be regarded as having failed. Only bulbous bluegrass (*Poa bulbosa* L.) has shown itself able to establish stands after the bulbils are broadcast in undisturbed cheatgrass. It is thought that the ability of bulbous bluegrass to colonize in cheatgrass results from its small heavy bulbil, sown in place of seed, which works through litter to the mineral soil and grows rapidly. In 27 of 28 plots where bulbous bluegrass was seeded into dense stands of cheatgrass without any seedbed preparation it produced a fair to good stand among the cheatgrass, and then began to reduce the cheatgrass. Unfortunately, bulbous bluegrass is valuable for forage in the Intermountain region only on a relatively small area in southwestern Idaho, where, because of mild winters and a long spring growing season, it makes an appreciable top growth.

Crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.), when sown by means of an ordinary grain drill into areas occupied by cheatgrass, germinates well, but most of the crested wheatgrass seedlings die during the first few weeks of warm weather, apparently from the rapid exhaustion of soil moisture. Crested wheatgrass sown in furrows 1-1/2 to 2 inches deep and covered lightly with soil,

FIG. 3. Lone plants of crested wheatgrass on land otherwise fully occupied by cheatgrass. When established, plants of crested wheatgrass crowd back the cheatgrass for a foot or more, as shown here. Apparently strong competition for soil moisture is the force that permits crested wheatgrass to oust cheatgrass.

produced good stands when the drilling was done after cheatgrass had germinated. Sometimes the deep furrow lister drill is used to open furrows 2 to 4 inches deep and 3 to 5 inches wide, in the bottom of which crested wheatgrass seed is covered lightly with soil (Hull and Stewart, '48). Where the soil sloughs readily or blows, however, sowing in this manner often fails because seeds become too deeply covered.

As soon as crested wheatgrass plants are established, however, the process reverses itself and the cheatgrass is crowded out. Roots of crested wheatgrass by the third or fourth growing season occupy the soil very fully for 8 to 20 inches on all sides and either completely eliminate cheatgrass or suppress it almost to extinction (see fig. 3). Crested wheatgrass stands that are at all uniform keep out cheatgrass except in openings more than 2 feet across. At Arrowrock substation of the Intermountain Forest and Range Experiment Station, near Boise, Idaho, for example, a good stand of crested wheatgrass seeded in 1936 held cheatgrass to an average of 3.2 very dwarf plants per square foot up to 1947 as compared to 556 well-developed cheatgrass plants per square foot on an adjacent similar unseeded area. Only a small portion of the cheatgrass plants growing in thick crested wheatgrass produce seed and then only in small amounts. Openings in crested wheatgrass pasture stands from a few feet to a few yards across that are occupied by cheatgrass are gradually filled in with young plants of crested wheatgrass. With no pasturing as a possible means of burying the seeds, or with heavy pasturing that prevents seed production by crested wheatgrass, cheatgrass will remain in possession of the openings for a long time. Severe grazing is likely to weaken crested wheatgrass and allow cheatgrass to increase.

Cheatgrass is regarded to have become a small but consistent part of the vegetation of the northern desert shrub (sagebrush-grass) association (Robertson and Pearse, '45). It has also been regarded as part of the climax vegetation of the prairies and sagebrush-grass vegetation of Washington (Daubenmire, '42). In British Columbia it was found to increase rapidly on overgrazed sagebrush-wheatgrass range and to appear in climax areas but not to become a major constituent of the flora (Tisdale, '47). Piemeisel ('38) concluded from observations in southwestern Idaho during 1928 and 1935 that drought would not cause cheatgrass to fail as a dominant on areas that it now occupies. Successional studies on host plants of sugar beet leafhopper in southern Idaho show that cheatgrass is the intermediate successional stage and will replace Russianthistle, mustards, and other annual weeds in approximately 5 years (Piemeisel, '38–'45). Cheatgrass as an intermediate dominant is in turn replaced by perennial weeds and grasses. Thus cheatgrass is a dominant on large areas in the intermediate successional role and has also persisted for 30 to 40 years as a minor member of well-preserved native vegetation.

Economic Importance

Data which have been gathered show cheatgrass to have great economic importance for forage and to be fair protection to soil and watersheds. These advantages are partly offset, however, by its high fire hazard. These three factors of forage production, soil protection, and fire hazard are interrelated but must be considered and studied thoroughly before the full value of cheatgrass can be determined. Enough information is available, however, to permit setting forth these values in general terms.

Forage production

Cheatgrass makes great contributions to the total forage supply of Idaho and on many ranges it is the most important forage plant, especially for spring use. Its palatability is often lower than that of the associated perennial grasses and weeds but all classes of stock readily

graze the green herbage. Judged by the appearance of the animals and by the data on chemical composition, the green growth of cheatgrass has a satisfactory nutritive value (Fleming, Shipley, and Miller, '42; Warg, '39). The protein content of cheatgrass at seasonal intervals is highly similar to that of wheatgrass for the same developmental periods. The period during which the herbage is fresh and green is, however, several weeks shorter for cheatgrass. On reaching maturity the top growth turns straw colored and dries up rapidly. Since it is an annual the roots cease to function and the stems dry right down to the ground, whereas stem bases in perennial grasses retain some succulence for several weeks.

Dry cheatgrass is little used by sheep but cattle and horses graze the dry grass reasonably well (Hurtt, '39). The dry forage apparently does not have sufficient protein and phosphorus to meet the requirements of grazing animals and in Nevada and Oregon it has been recommended that cattle be marketed 6 to 8 weeks earlier in the fall to avoid loss in weight (Fleming, Shipley, and Miller, '42; Platt and Jackman, '46). Sheep make little use of cheatgrass in the fall except when there is enough growth of new plants to permit grazing. This is in contrast to the use of perennial grasses on sagebrush-perennial grass ranges where sheep often graze as long in the fall as they do in the spring.

In relatively snow-free areas livestock often graze all winter on dry cheatgrass forage. There is often a considerable loss in weight, especially with sheep, unless there is ample green grass from the preceding fall or unless protein supplements are fed. In some areas, cattle graze yearlong on cheatgrass ranges with what appears to be fairly satisfactory results to the livestock (see fig. 2).

Cheatgrass produces a relatively large amount of herbage. Yields have been taken in southern Idaho for 7 years on one area, 6 on another, 5 on another, and 4 on another. The average air-dry herbage yield for all years at all locations is 1,230 pounds per acre. At the same locations crested wheatgrass yielded 1,543 pounds of air-dry herbage per acre. Herbage production of cheatgrass fluctuates greatly from year to year, however, and variations in production caused by weather are greater than those of perennial grasses (Piemeisel, '45). For example, at Arrowrock, the yield of cheatgrass in 1943 was only one-tenth that of 1944, whereas that of crested wheatgrass was one-half (see fig. 4). According to unpublished data on file at the U. S. Forest Service Experiment Station, Ogden, Utah, the variations in cheatgrass yield that occurred during a 6-year period at Arrowrock are twice as great as any that occurred in perennial vegetation during a 17-year period at the U. S. Sheep Experiment Station at Dubois, a period which includes the 1943 drought. A Gem County study showed cheatgrass to have 11 times as much density in 1938 as in 1937 (Stewart and Young, '39). Oregon reports considerable fluctuation in cheatgrass yields (Platt and Jackman, '46). These fluctuations in cheatgrass production are important because the range stockman cannot readily adjust numbers of livestock to meet such great variations in seasonal forage production.

Data regarding seasonal production taken at Arrowrock—1943–47—show that perennial grasses excel cheatgrass in producing much needed early spring forage. Grasses such as crested, bluebunch, and streambank wheatgrass, Sandberg, and bulbous bluegrass started growth from 5 to 15 days earlier and were two to six times as tall and herbage production of crested wheatgrass was twice as great at the start of the spring grazing season as cheatgrass (table I).

Cheatgrass supports heavy grazing use for a time but continued overgrazing reduces the number and height of plants. Counts at 10 places in southern Idaho showed numbers of plants on overgrazed ranges to be only one-tenth to one-fiftieth as great as those on adjacent,

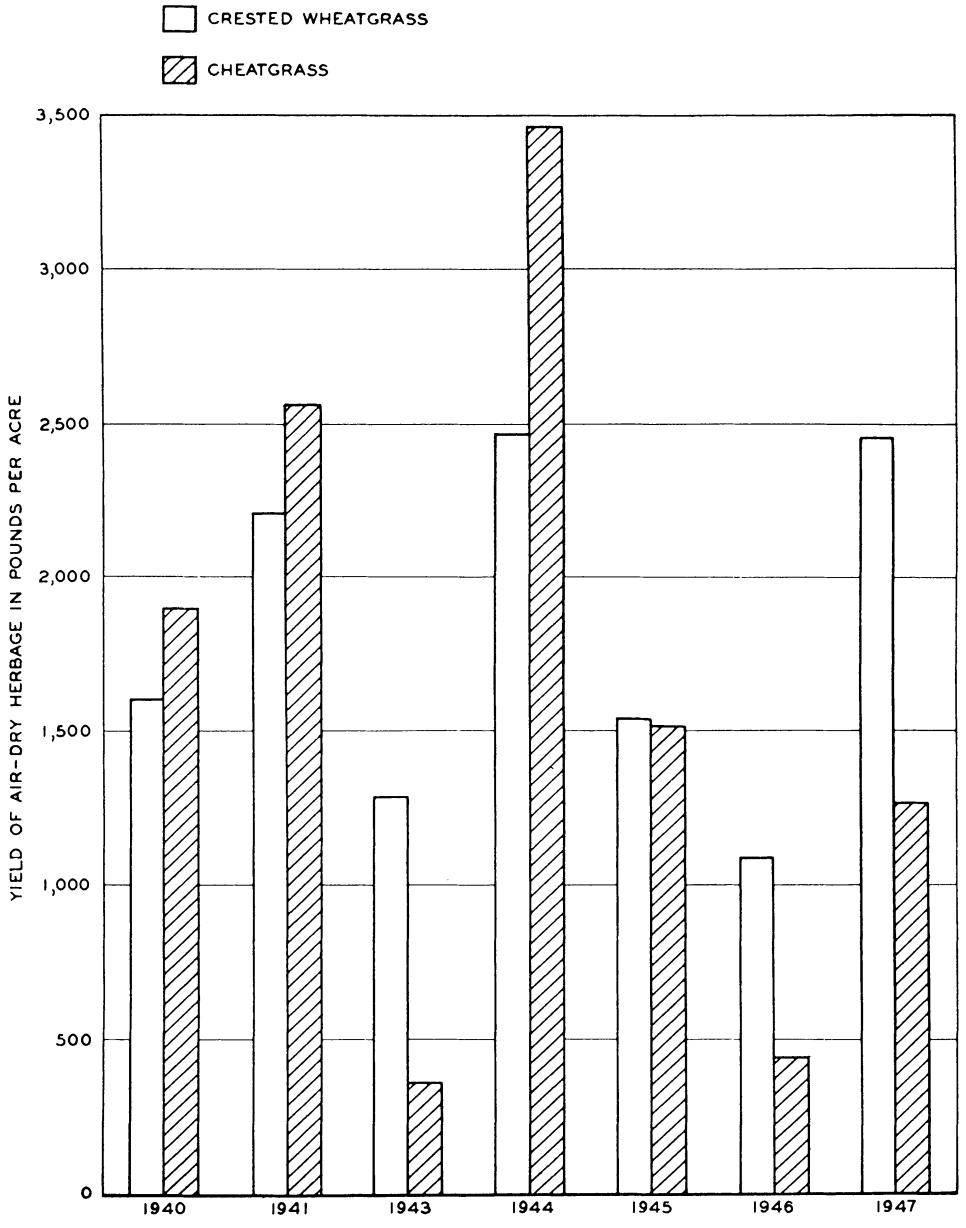

FIG. 4. Cheatgrass yields an abundance of herbage but production fluctuates greatly from year to year. Data from Arrowrock, near Boise, show that cheatgrass fluctuates twice as much in herbage production as does crested wheatgrass at the same location. Although average production of the two grasses is similar, the lowest production of crested wheatgrass is almost three times greater than the lowest production of cheatgrass. (No data for 1942.)

TABLE I. *Average height and herbage production of cheatgrass and crested wheatgrass clipped at ground level at Arrowrock during the first 2 months of the grazing season in 1945, 1946 and 1947*

Date	Herbage production		Average height	
	Crested wheatgrass	Cheatgrass	Crested wheatgrass	Cheatgrass
	Pounds per acre		*Inches*	
May 1	515	297	7.3	1.8
May 15	828	509	8.2	3.7
June 1	1,232	659	11.9	7.0
June 15	1,345	706	16.5	9.6

lightly used ranges. Spring height growth on heavily grazed areas was slower and averaged only three-fifths as tall. Piemeisel ('38, '45) in southern Idaho and Daubenmire ('40) in Washington noted that excessive spring grazing by sheep may practically destroy a cheatgrass cover or prevent its dominance. Although few and shorter plants are readily noted on overgrazed ranges, lower yields are authenticated only by comparisons with less heavily grazed ranges. Common indicators of erosion from heavy grazing such as small gullies and pedestaled plants which are found on perennial grass ranges are not suitable indicators for cheatgrass ranges, on account of its being an annual (Hormay, '44). A sparse stand of plants and absence of enough old stems to form sufficient cover of litter for soil protection are important signs of overgrazing on cheatgrass range.

Grazing capacity of cheatgrass ranges is high. Many cheatgrass pastures on favorable sites show capacities to be 2 to 3 acres per cow-month. This is fully as high as good native sagebrush-grass pastures in the same locality. No signs of deterioration are yet evident from this degree of utilization.

Cheatgrass aids in soil protection

Cheatgrass, ungrazed and unburned, helps protect the soil and control erosion (Leopold, '41; Piemeisel, '45), by providing cover on poor soils and on other areas where perennials are not present, or where they can be restored only slowly. It has a fibrous root system which occupies the upper 12 inches of soil (Piemeisel, '38; Spence, '37). In studies of infiltration and runoff, cheatgrass cover was found to be less effective than wheatgrass, and superior to perennial lupine-needlegrass and annual weed types in promoting water absorption and preventing erosion on the granitic slopes of southwestern Idaho (Craddock and Pearse, '38). Cheatgrass, where neither burned nor heavily grazed for several years, consecutively builds up a considerable litter accumulation which helps to add organic matter to the surface soil. The litter itself helps materially to increase infiltration on many denuded areas.

In many cases cheatgrass develops a litter cover that varies from a little straw on the surface to a mat a half inch thick or thicker. Such a mat is highly effective in protecting the soil against the direct impact of rain on the mineral soil. It also prevents rain from accumulating in rills and aids immeasurably in promoting percolation and thus retards runoff.

In 1945, Salt Lake City suffered a flood, the waters of which accumulated on a 620-acre tract which the year before had been burned over, removing not only the ripe cheatgrass but also a good mat of straw litter. The fire also greatly weakened perennial grasses and herbs that were intermixed with the cheatgrass (Craddock, '45). Gullies from a few inches to several feet in depth led off the burned area but none at all from similar surrounding unburned areas that still bore a substantial mat of cheatgrass litter. Since this condition has occurred more than once in Idaho, the results from Salt Lake City are fully apropos.

Cheatgrass greatly increases fire hazard

The hazard of fire is greatly increased by the presence of cheatgrass whether as a major species or as a species interspersed with other vegetation. The ex-

tremely high inflammability of dry cheatgrass permits fires to kindle with great readiness and to spread with unusual rapidity. It thus increases both the number and size of fires and increases fire suppression costs. In Oregon it was found that a cheatgrass range was 500 times more likely to burn than a non-cheatgrass range (Platt and Jackman, '46). The Forest Service estimates that five times more men and equipment are needed for standby crews on cheatgrass ranges than if these same ranges were in perennial grasses (U. S. Forest Service, '47). The Cow Creek burn near Boise defied control for 5 days and burned 16,000 acres of mixed sagebrush and cheatgrass range. Cheatgrass was responsible for most of the runs made by this fire.

Adjacent areas which are normally not so inflammable are also endangered by a fire that starts in cheatgrass, spreads rapidly, and runs into the native vegetation. Fires starting in inflammable cheatgrass spread to brush and timbered lands where watershed values are higher and fire control is more difficult. For example, the Second Fork fire near the Boise National Forest made an initial spread of 3,500 acres in the cheatgrass understory of a ponderosa pine type, thus rendering it practically impossible to get either early or low-cost control before the fire burned up into the more valuable timbered areas. Such fires in many cases kill reproduction of ponderosa pine and limit the areas occupied by this timber species to higher elevations than formerly (U. S. Forest Service, '47).

Cheatgrass fires may produce almost revolutionary changes in plant cover type. In 1947, Idaho suffered 307 fires, many of them of unusual size, in the sagebrush zone in which cheatgrass had invaded the sagebrush or replaced it, burning over more than 200,000 acres of sagebrush and more than 300,000 acres of cheatgrass. Hereafter, for many years at least, these areas will bear little or no sagebrush and become or remain predominantly in cheatgrass. Since cheatgrass follows most of these fires, the acreage of cheatgrass is increasing with great strides. Perennial grasses are injured by fires, most species temporarily. The presence of cheatgrass in great areas, however, helps other fires to burn over the same and adjacent areas and these fires again set back the perennials, frequently before they recover from the last fire. Eventually, the perennials are killed by repeated burning at short intervals. Grazing animals also congregate on burned-over areas as soon as they become green. This accentuates and sharpens the acute stress to which perennial grasses are put on burned-over cheatgrass ranges. The final result is the disappearance of perennial vegetation and a badly exposed soil, which because of destruction of litter and loss of perennials is less permeable and highly susceptible to erosion.

The high inflammability of dry cheatgrass is now fully recognized but its cause is only partly known. The high hazard results partly from the fact that cheatgrass dries with approaching maturity and becomes inflammable 4 to 6 weeks earlier in summer than do perennials and remains susceptible to fall fires for 1 to 2 months later (Platt and Jackman, '46). Seasonal maturity, markedly different as it is, however, is not the whole story of increased fire hazard. Cheatgrass actually burns more readily than other species that are dry. It is likely that internally cheatgrass is really drier than other species, partly as a result of much more slender stems and pedicels, but possibly also because of having a softer, less fibrous tissue. Differences in tissue drying are at present merely postulated and not proved, but the assumption is probably correct.

Forage for the current year is destroyed by being burned and forage for future years is often reduced. Sometimes a private individual thus loses most of the forage he expected to use for the coming fall and winter.

Stockmen are affected not only by the loss of current forage but by the sharp

reduction in early spring forage which is caused by early summer cheatgrass fires the preceding year. In some places, such fires have reduced early spring height growth of cheatgrass by at least 50 per cent according to unpublished data on file at the U. S. Forest Service Experiment Station, Ogden, Utah. Forage available at the time sheep go on a burned range is often less than one-tenth of that present on adjacent unburned ranges (Pechanec and Hull, '45). Although early production, however, is lessened by fire, the fewer and later starting plants on the burned ranges stool out very markedly and so speed up in height

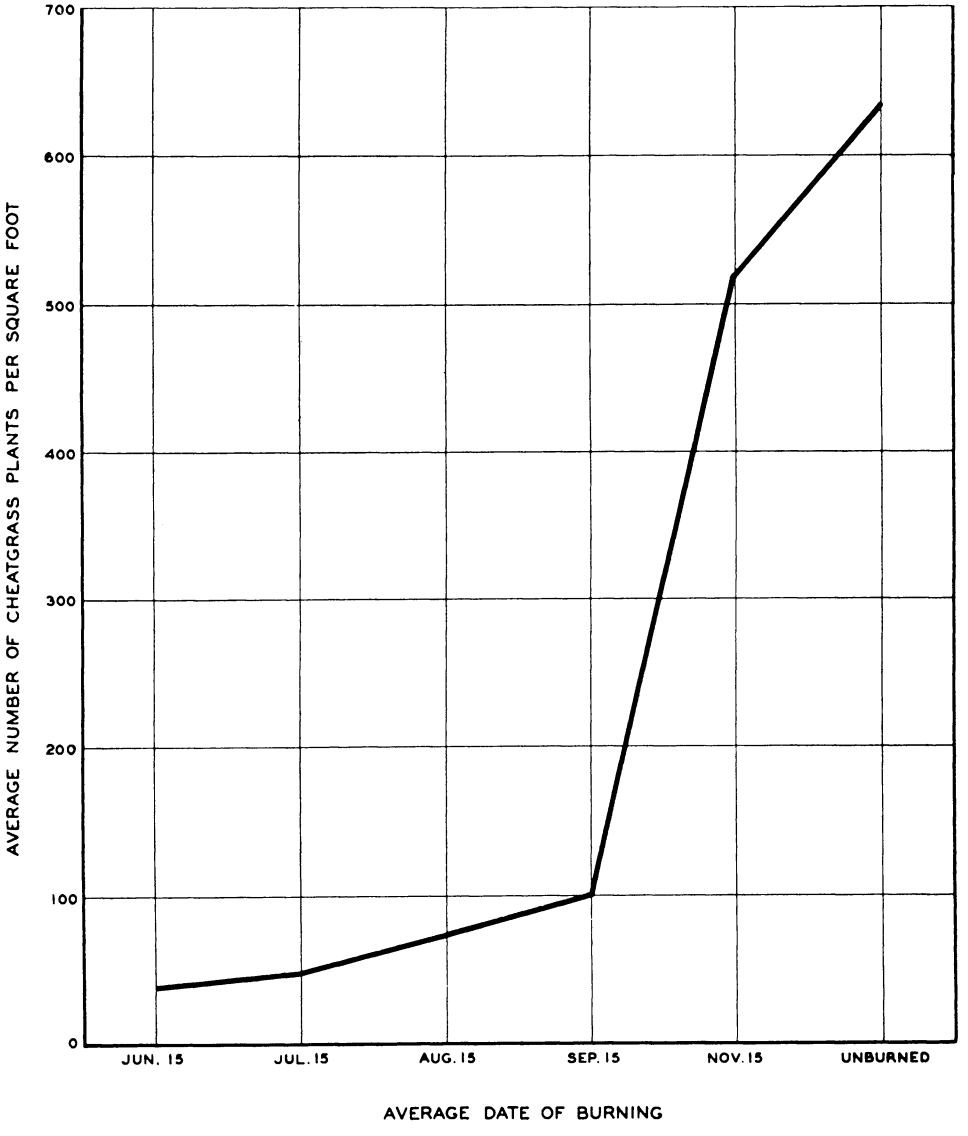

FIG. 5. Average number of cheatgrass plants per square foot one year after burning at five dates for four years (near Boise, 1943–1946.) Burning in early summer greatly reduces the number of cheatgrass plants the following year.

growth that by the end of the growing season, total herbage production on most burned ranges equals or exceeds that on unburned ranges.

Burning in early summer reduces the numbers of cheatgrass plants the next year. The reduction in numbers is related to the dates of burning the previous year. The earlier the fire, the more serious the thinning (Pechanec and Hull, '45). In a burning study near Boise in 1943, 1944, 1945 and 1946, early summer burns reduced plant numbers to an average of one-fourteenth that of fall burns and unburned areas. Effects of later burning were less marked (fig. 5).

Plots of cheatgrass near Riggins, Idaho, burned the first of each month during the summer of 1945 showed the same trend. During 1946 the following average plants were counted from the different dates of burning: July, 89; August, 38; September, 114; October, 274; and unburned, 707.

Miscellaneous Biological Relationships

No ecological study is complete without recognition that miscellaneous relations to other living organisms may have fairly far reaching effects. Although it seems unlikely at the present juncture that all of these are known for cheatgrass, such relations have been sufficiently observed to permit a statement about predatory insects, smut, rodents, and sugarbeet leafhopper.

Cheatgrass has been so far unusually free from injuries by predatory insects that attack it specifically. Grasshoppers and Mormon crickets feed on it but much less voraciously than on young perennial grasses. Several cases have occurred in test plots where perennial seedlings have been taken to the ground, while cheatgrass with some flower stalks was barely nibbled. In one case good seedling stands of crested wheatgrass, smooth brome (*Bromus inermis* Leyss.), tall oatgrass (*Arrhenatherum elatius* (L.) Mert. & Koch), and orchardgrass (*Dactylis glomerata* L.) were practically destroyed in June without injury to cheatgrass, then well headed.

Smut of bromes (*Ustilago bromivora*) attacks cheatgrass more or less regularly and rather vigorously. The caryopses are filled with fungous growth and later by black spores. In some years only a small percentage of the seeds are so replaced, but at intervals the disease reaches epidemic proportions and greatly reduces the seed crop. Since in most cases this happens only in single seasons several years apart, cheatgrass is usually able to maintain its stand. In the general vicinity of the Arrowrock substation near Boise, however, an epidemic occurred 3 years in succession (1935–37) and largely destroyed the stand which took several years to reestablish itself. In epidemic years clouds of smut spores have been observed to drift before a gentle breeze like a heavy dust cloud. Epidemics have also occurred on mountain brome (*Bromus carinatus* Hook. & Arn.) but it is not known whether the same biologic race of smut is involved in both cases.

It has been established that jackrabbits and field mice (Piemeisel, '45) strongly influence the development and maintenance of a cheatgrass cover. Studies around Burley and Castleford showed that jackrabbits prolonged the period which was required by a cheatgrass stand to replace Russianthistle and mustards on abandoned land from a 5-year period to one of 10 to 12 years. Rabbits also tended to prevent perennial grasses from increasing in cheatgrass stands as much as they might otherwise have done. Rodent damage to reseeded grass is especially severe in August and September when native grasses and cheatgrass are dry. In several cases rabbits have reduced and sometimes destroyed reseeded grass without eating cheatgrass. Field mice did not become numerous until the cheatgrass stand developed. Mice thereafter fed largely on cheatgrass and on as much as 10 per cent of the area reduced cheatgrass until the area was again sup-

porting principally Russianthistle or mustards, or both. Piemeisel's ('45) charts, however, show that as a whole cheatgrass increased rapidly between 1933 and 1944. On areas closed to livestock and rabbits, perennial grasses increased about as rapidly as cheatgrass but tended to disappear where grazed by both livestock and rabbits.

These findings came from a much more comprehensive study of host plants of the leafhopper (*Eutettix tenellus*) carrier of the curly top disease of sugar beets, and of brown blights of beans and tomatoes. Other crop and decorative plants are also seriously injured by the virus carried by leafhopper. The native mustards and saltbushes were original host plants, but on abandoned lands and on range land with the plant cover damaged by overgrazing the exotic Russianthistle and mustards produced much greater populations of leafhoppers. When cheatgrass, a non-host plant for leafhoppers, became dominant on an area, leafhopper populations decreased. Drought and field mice, however, set back the cheatgrass and allowed Russianthistle and mustards to come in. Altogether there still remains ample host vegetation to maintain abundant leafhopper populations.

Influence of Controlled Use on Ecological Responses

In consideration of the great area of range land occupied by cheatgrass and the information available as to the ecological requirements of cheatgrass and its responses to grazing use, what can and should be done in the way of managing cheatgrass ranges? The answer falls inevitably into four phases, as follows: (1) The immediate use of all cheatgrass ranges while they are awaiting the initiation of a program of natural revegetation or artificial reseeding; (2) the ranges to be grazed on the basis of perpetuating the present stands of cheatgrass; (3) the ranges to be grazed in such manner as to restore perennial vegetation; and (4) the ranges to be restored by artificial reseeding.

Until much more experience and research information are available, it is not possible to determine, except in general terms, the most desirable long-time management of cheatgrass ranges. Although it will be many years before comprehensive and detailed information can be gathered, there are still some guiding principles on which to base general procedures.

Revegetation through grazing control

During the immediate future, before long-time procedures can be determined and initiated, cheatgrass ranges will be grazed. It is almost obligatory during this period so to manage all cheatgrass ranges that soil losses by wind and water erosion do not lessen the soil productivity. This means a degree of utilization that leaves enough ungrazed herbage and litter at all seasons to protect the soil from accelerated erosion. Protection against haphazard burning to prevent undue exposure to erosion and also to prevent loss of forage by fire must be provided for. This much management seems the absolute minimum that should be required by society for its own protection.

Areas of cheatgrass range that are to be restored to perennial plant cover by natural revegetation must receive enough protective management to permit desirable perennials to maintain their vigor. Since most high-value perennials are more palatable to livestock than is cheatgrass, the utilization of cheatgrass that may be permitted is likely to be less than 50 per cent and may prove to be as low as 35 or 40 per cent. Because cheatgrass dries earlier than perennials, grazing animals will pick out the perennials and leave the dry cheatgrass. Just what is proper intensity of use, however, is one of the major ecological questions that only research and experience can answer.

Revegetation by range reseeding

Since competition between reseeded species and cheatgrass is severe, dense

stands of cheatgrass need to be thinned to permit establishment of reseeded species (Hull and Pearse, '43; Platt and Jackman, '46; Robertson and Pearse, '45; Warg, '38). If cheatgrass can be reduced during the first growing season of the perennial grass the perennials compete with it successfully from then on.

Reduction of competition from cheatgrass in some places has commonly been accomplished by moldboard plowing, though at a high cost. In an attempt to circumvent the high cost, studies in Montana where summer rainfall prevails, have shown that land might be plowed and a crop of spring rye taken before seeding crested wheatgrass in the rye stubble (Friedrich, '45).

Wheatland plowing, heavy disking, or some type of thorough cultivation in late spring before seed is formed or after fall germination are all feasible for cheatgrass eradication. Contour plow furrowing in the fall has not been as successful as was formerly hoped (Hull and Pearse, '43; Platt and Jackman, '46; U. S. Forest Service data, Ogden; and Warg, '38). When used after fall germination, both ordinary disk and lister type drills eliminate considerable cheatgrass. Seedlings of perennials growing in a deep furrow are more protected and better able to compete with the cheatgrass than if they were in shallow, narrow furrows (Hull and Pearse, '43; U. S. Forest Service data, Ogden). Five years' observations show that burning early in the summer may be a successful low cost method of thinning cheatgrass (see fig. 5). Platt and Jackman ('46) recommended this method of preparing land for seeding cheatgrass areas in Oregon. Crested wheatgrass is the most universally adapted species for seeding lands covered by cheatgrass but some newly introduced species are promising.

Summary

Cheatgrass, a native of Europe, appeared in western United States in the 1890's and has since spread throughout the arid region. Approximately 4 million acres in Idaho are now occupied by cheatgrass as the major species; 2 million acres by damaged sagebrush where cheatgrass is the principal herbaceous species; and 10 to 15 million acres of the sagebrush plains which bears cheatgrass in minor proportions.

Cheatgrass is naturally a fall annual, but if fall weather is unusually dry it does not germinate till spring. It ordinarily makes a growth of 12 to 20 inches in height, although height may vary from 24 or 30 inches to as little as 3 or 4 inches. However, plants generally produce enough seeds to provide a full stand the next year.

At first, cheatgrass took hold along roadsides, in cultivated land left bare, in orchards, and in fields with thin stands of alfalfa. Then it spread to range lands wherever the plant cover was badly injured. Where range fires burned off sagebrush, cheatgrass filled in rapidly. It is most abundant at elevations of 2,000 to 6,000 feet, but is found up to 8,000 feet.

Cheatgrass not only has occupied farm lands and range wherever the soil is not fully used by other plants, but also has made its way into natural plant cover that has not deteriorated greatly. Some ecologists think the species has established itself in places as part of the climax vegetation, although others doubt that its foothold is as yet so assured. At any rate, it is present on ranges with well-preserved plant cover and is ready to spread rapidly should the cover be injured by drought, fire, or overgrazing in such a way as to leave ecological space, even for a short time.

In this study, stands of plants were found to vary from 100 to 1,400 plants per square foot and averaged 572. Its large seed crop and rapid germination give it a strong advantage over perennials, especially when drought or heavy grazing has weakened the perennials.

It is very difficult for perennials to start in undisturbed stands of cheatgrass, except in the case of bulbous bluegrass.

Crested wheatgrass requires help to get started, but once good stands are established it crowds out cheatgrass. Mixed stands of crested wheatgrass and cheatgrass soon become nearly pure crested wheatgrass if grazing on the area is well managed.

Cheatgrass produces, on poor range, 75 to 85 per cent as much forage as crested wheatgrass. In years of drought, its yield of forage dropped to less than 20 per cent of its average, whereas crested wheatgrass in the poorest year produced 58 per cent as much as in its average year. Cheatgrass is valuable for soil protection and helps the infiltration of storm waters greatly as compared with weeds.

Cheatgrass is highly inflammable and allows fire to spread rapidly. Its presence greatly increases the danger of fire and the costs of presuppression and control. Burning in early summer, however, offers a means of reducing the stands of cheatgrass to such a level as to allow the reseeding of perennial grasses without other treatment.

The welfare of society in the West demands that the grazing management of cheatgrass be such that enough herbage is left ungrazed to provide top growth and litter to prevent rapid soil losses by wind or water erosion. This probably means only 50 per cent utilization of cheatgrass. It is likely that only 35 to 40 per cent utilization can be permitted on lands that are to be restored to perennial grasses without reseeding. Range reseeding requires the reduction of cheatgrass competition by the use of fire or mechanical methods to enable the perennials to develop a stand. Thereafter grazing must remain at such a conservative level as to preserve the more palatable perennials.

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