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Abstract

Medusahead (*Taeniatherum asperum* Nevski), a winter annual native to the Mediterranean region of Eurasia, has infested several million acres of rangeland in the northwestern United States. It has been estimated carrying capacity for domestic livestock on infested ranges has been reduced 75 percent.

The review is a condensed summarization of the literature pertaining to medusahead. Four tables contain the types and effectiveness of various controls applied to medusahead. The bibliography is the result of an extensive literature review on this species.

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Medusahead (*Taeniatherum asperum* Nevski): A Review and Annotated Bibliography

Thomas O. Hilken and Richard F. Miller

Medusahead, a winter annual native to the Mediterranean region of Eurasia, is one of the primary range weeds in the western United States. It is a serious threat to rangelands with sparse native plant communities, and more complex communities degraded to a low seral state (71). An aggressive competitor with other plants, medusahead is a low-value forage species for livestock and wildlife. It has been estimated that the carrying capacity of rangeland for domestic livestock has been reduced by 75 percent after medusahead invasion (36).

To decrease the negative effects of medusahead, wildland managers need to know the general ecology of the plant and practical control methods. The objective of this paper is to present a brief review of the literature pertaining to (1) origin and distribution, (2) environmental factors, (3) growth and nutritional characteristics, and (4) control methods of medusahead.

Medusahead (*Taeniatherum asperum* Nevski) was classified in the United States as *Elymus caput-medusae* L. because of a mistake (16). Earlier, Nevski, a Russian taxonomist, had classified the plant found on our range as *Taeniatherum asperum* Nevski. The mistake was discovered by Major (35) when he visited Europe. Major published the correct name, *Taeniatherum asperum* Nevski, in the United States, where it is now generally accepted (16). McKell et al. (39), studying the ecotypic variation in medusahead, concluded that the best name for our plant seems to be *Taeniatherum asperum* (Simonkai) Nevski.

Medusahead was introduced into the United States from the Mediterranean region of Eurasia, where it consists of three geographically and morphologically distinct taxa (39). The original *Elymus caput-medusae* grows on the Siberian peninsula (35). Another species, *Taeniatherum crinitum*, grows in North Africa and in the southern Balkans through the Middle East to Soviet Central Asia. The third, *Taeniatherum asperum*, our western American weed, originally was found from Hungary through Ukraine to Tadzhikistan.

The late 1800s is believed to be the approximate time of introduction of medusahead into the United States (48). The plant probably was brought to North America through dispersal of seed by imported animals. The first known specimen submitted to the University of California herbarium was collected near Roseburg, Oregon, in 1887 (11). In 1901, it was recorded from Steptoe Butte in eastern Washington by Vasey (55), and in 1908, near Los Gatos, California, by Hitchcock (39).

After the initial introduction period, literature citations increased with the rapid spread of medusahead throughout the western rangelands. An estimated 2.5 million acres were included within the periphery of known medusahead infestations in Oregon (61). In Idaho, the weed spread from a few isolated patches to more than 750,000 acres in 15 years (23). A total of 100,000 acres of rangeland were affected in the North Coast region of California. Medusahead has infested 120,000 to 150,000 acres in eastern Washington, and the potential area is much greater (12). Medusahead also has successfully invaded seral plant communities on the edge of the interior basin of northeastern California, northern Nevada, and western Utah (71).

Medusahead probably has not reached its ecological limits (39). The plant successfully competes and overlaps both in area and in local habitat ecology with two other exotic, annual range invaders, *Bromus mollis* L. in California and southern Oregon and *Bromus tectorum* L.If the requirements of medusahead completely overlap those of *Bromus tectorum*, it could spread widely in the Great Basin, where it now has a start in the northern, low-altitude fringe of this physiographic province (39).

Environmental Factors

Medusahead grows over a wide range of climatic conditions. Annual precipitation on medusahead sites throughout the four Western States ranges from 10 inches to 40 inches. Medusahead grows where precipitation occurs during fall, winter, and spring (36). Seasonal distribution of precipitation is more significant than total precipitation in meeting the species moisture requirements (48).

Medusahead grows where extended periods of great cold are lacking (32). Moreover, some of these climates are extremely hot. Medusahead requires a cold treatment and possibly light stimulus after germination for seed formation to occur. In one study, successful seed formation occurred after exposing seedlings to nightly temperatures of 37° F. for 14 days in the field. The seedlings matured in the greenhouse (2).

Soil conditions suitable for growth of medusahead are somewhat variable. Favorable environmental factors related to medusahead distribution were soils with a high clay content, well-developed profiles, and areas receiving run-off water from adjacent sites (7). Less susceptible to invasion were well-drained soils and those developed from rocks weathered to coarse-textured sands showing poorly developed profiles. Late maturity of the species in relation to other annual grasses and its subsequent requirements for high water-holding capacity clay soils are the accepted explanation for medusahead abundance on clay soils (71).

Growth Characteristics

Medusahead is able to compete effectively with desirable forage species because of the following growth characteristics: (1) it germinates in the fall, roots continuing to grow all winter; (2) it is a prolific seed producer; (3) it produces a heavy litter residue.

Medusahead germinates significantly faster and more fully than either cheatgrass or bluebunch wheatgrass (*Agropyron spicatum*) (17). Medusahead seedling roots begin post-germination growth in the fall, and grow all winter, thus effectively removing available soil moisture from nearby native bunchgrasses and annuals. Medusahead also matures later than cheatgrass because its root system remains functional for a longer period of time.

Medusahead is a highly prolific seed producer (56) with germination rates of 98 percent (42). In dense stands, plant numbers range from 1,500 to 2,000 per square foot on valley bottom soils, and 500 plants per square foot on scablands (56). The average number of seeds per head for the two sites studied were 8.7 and 5.6, respectively.

Once medusahead becomes established, it grows in dense stands, forming a mat of stems 2 to 5 inches thick (12). It is often thought that the high silica content of medusahead may be the reason it is slow to decompose (3). Evidence indicates the dense litter cover is important in the competitive relationship with cheatgrass because cheatgrass fails to grow under three inches of litter cover (9, 14). Medusahead's litter also is an extreme fire hazard in the summer and ties up soil nutrients ordinarily available for plant growth. However, it has been reported that the accumulation of slowly decomposing litter may be advantageous through safeguarding the loss of soil by wind and water erosion in deteriorated areas susceptible to erosion (61).

Nutritional Characteristics

Moisture content, crude protein, crude fat, crude fiber, and lignin contents of medusahead are comparable to cheatgrass and many desirable species at similar growth stages (3). However, the ash content of medusahead was found to be much greater than that of cheatgrass and many other grasses. The ash of medusahead contained approximately 72 to 89 percent silica, and amounted to more than 10 percent of the dry weight of the plant. The high silica content of medusahead is thought to be the basis for its harshness. The long, barbed awns and sharp, hard seeds of the mature plant injure eyes and mouths of livestock.

Although numerous reports have indicated that medusahead is unpalatable, other investigators have found heavy livestock grazing on immature plants in early spring (23, 30, 63). Range fertilization, especially with N, offers a possible way to improve the palatability of medusahead and to encourage its early use by grazing animals (30). An *in vitro* nutritive evaluation revealed that immature medusahead had a higher cellulose digestion value as compared to a mixture of desirable annual range forage species (64).

Control Methods

Most studies on medusahead have been concerned with control and suppression after it has become established. The results of herbicide, mechanical, burning, and fertilization treatments are summarized in Tables I through IV.

Table 1. A summary of chemical treatments and their effectiveness in controlling medusahead as reported in the literature

Herbicide	Rate	Comments	Effectiveness	Reference
Atrazine	1/4 lb/A	Applied in September	+[1]	27
	1/2 lb/A	Increased medusahead	–[2]	70
	1 lb/A	Applied late fall	+	62
	1 lb/A	Applied with 2,4-D (2 lb/A)	+	74
	2 lb/A		+	5, 61, 63
	2 lb/A	Followed by application of a soil fumigant (methyl bromide)	+	51
	2 lb/A	Plus disc harrowing	+	70
Amino triazol	2 lb/A		90%	8
	6 lb/A		100%	8
	high rate	Cost prohibitive	+	2
Bromacil	1 lb/A	Applied late fall	+	62
CDAA	2,4,8 lb/A	Applied in September	–	27
	2 lb/A		–	34
	RNG[3]		–	2
CDEC	RNG		–	2
CIPC	6 lb/A	With discing	100%	8
	8 lb/A		90%	8
	2,4,8 lb/A		–	27
	high rate	Cost prohibitive	+	2
	RNG		+	48
	RNG	Gave outstanding control on an annual grassland	+	34
Dalapon	1 lb/A		–	34
	2 lb/A		+	48, 61, 63
	2 lb/A	Applied 30 days after emergence	96%	26
	2 lb/A	Applied late April (boot stage)	90%	41
	2 lb/A	Applied mid-April to mid-May effective by burning litter before application	+	19
	2 lb/A	With or without discing	100%	8
	3 lb/A	May cause damage to perennials	+	61
	3 lb/A	Applied 30 days after emergence	100%	26
	3 lb/A	Applied between germination and boot stage	+	12
	3 lb/A	Applied in April	+	18
	4 lb/A		97%	41
	4 lb/A		+	33, 36
	2-6 lb/A	Combined with disc harrowing and furrowing	+	70
	low rate		+	2
	RNG	Effective if combined with other control measures	+	58
	RNG	Followed by 2,4-D	+	59, 60
DNBP	RNG	With 40 gal. weed oil + 60 gal. H_2O	+	36
Dowpon	3 lb/A	Applied with 2,4-D	+	59
Diuron	2 lb/A	Plant composition changed from medusahead to cheatgrass	+	77
	20 lb/A	Practical to use on small patches of medusahead	+	19
EPTC	2,4,8 lb/A	Applied in September	+	27
	4 lb/A		+	36
	RNG	Gave outstanding control on an annual grassland	+	34

[1] + = treatment was effective
[2] – = treatment was not effective
[3] RNG = rate not given in report

Table 1. (Continued)

Herbicide	Rate	Comments	Effectiveness	Reference
IPC	4 lb/A	Applied with .75 lb/A 2,4-D (fall)	+	62
	6 lb/A		50%	8
	6 lb/A	With discing	100%	8
	8 lb/A		100%	8
	high rate	Cost prohibitive	+	2
	RNG		+	48
Isocil	1 lb/A		+	61, 63
Monuron	1/2 lb/A		–	34
	1/2, 1, 2 lb/A	Applied in September	–	27
Paraquat	1/2 lb/A	Applied in winter	+	28
	RNG		–	62, 70, 16
	1/2 lb/A	Two-leaf stage	–	75
Picloram	3 lb/A	Pre-emergence application sufficiently suppressed medusahead	+	73
Siduron	3 lb/A	Pre-emergence application sufficiently suppressed medusahead	+	73
	RNG	In the greenhouse, controlled seedlings of medusahead	+	68
Simazine	1/2, 1, 2, 4 lb/A		+	27
	2-4 lb/A		+	36
	RNG	Effective control on an annual grassland	+	34

Table 2. A summary of mechanical treatments and their effectiveness in controlling medusahead as reported in the literature

Mechanical	Comments	Effectiveness	Reference
Plowing (moldboard)	plowing alone	95%	8
	effective if combined with other control measures	+[1]	58, 60
	plowing with herbicide	100%	8
	plowing in spring	+	48
	effective if first burned	+	19
	spring tillage, summer fallow	+	12
	effective only on limited areas	+	61
	spring plowing followed by discing	+	16
Discing (harrow)	discing alone	50%	8
	disced in spring	+	48, 61
	disc-harrowed and summer fallowed	+	70
	effective if combined with other control measures	+	58, 60
	discing with herbicide	100%	8
	effective if first burned	+	19
	combined with seeding and fertilization	+	36
Mowing		+	11
	plus grazed	+	63

[1] + = treatment was effective

Table 3. A summary of burning treatments and their effectiveness in controlling medusahead as reported in the literature

Burning	Comments	Effectiveness	Reference
	On an annual grassland	60-90%	18
	On an annual grassland	+[1]	11, 40, 43
	Burning alone	–[2]	48
	Burning alone in spring	–	8
	Increase forage availability	+	28
	Downslope and into wind	+	42
	Increased medusahead	–	78
	Plus tillage and fall seeding	+	12
	Plus tillage and herbicide	+	59
	Plus intensive range improvement practices	+	36
	Burning effective if proceeded by other control measures	+	60
	Burning will enhance the effectiveness of tillage and herbicidal treatments	+	58

[1] + = treatment was effective
[2] – = treatment was not effective

Table 4. A summary of fertilization treatment and its effect on medusahead

Fertilizer	Rate	Comments	Reference
NH_4NO_3	150 lb/A	Reduced medusahead by increased competition from forbs and grasses	33
N	85 lb/A	Improve palatability of medusahead	61
	35 lb/A	Improve palatability of medusahead	62
	160 lb/A	90% utilization	3
	20 lb/A	40% utilization	3
	60 lb/A	Applied as 16-20-0 fertilizer, improved palatability	29
	150 lb/A	Reduced the soil moisture below the field capacity early in the season (near the first of April)	38
	40 lb/A	Produced lush growth	
P	150 lb/A	Treatment was similar to the check plot	38
Single super phosphate	400 lb/A	Improve palatability of medusahead	18
Treble super phosphate	100 lb/A	Reduced medusahead by increased competition from forbs and grasses	33
N + P	150 lb/A-N 200 lb/A-P	Combination of nitrogen and phosphorus resulted in an interaction that gave increased yield of forage	38
N + P	375 lb/A	Improved utilization when consumption was forced	30

Briefly, dalapon and atrazine have been proven to be effective in controlling medusahead. Spring tillage with summer fallow has given better control if combined with chemical treatment. Results of burning trials have been highly variable, and when used alone, satisfactory results were not always obtained. The most important benefit from burning is removal of the dense mat of litter that impedes tillage, lowers the effectiveness of herbicides, and prevents preparing a high-quality seedbed. It also has been reported that livestock will graze medusahead more freely where the old growth of medusahead is absent. Burning is most effective when burns are slow and seed moisture above 30 percent or when used with herbicides and tillage practices. On annual grasslands, range fertilization has been effective in reducing the density of medusahead by competition from fertilized forbs and grasses. Livestock have been known to relish fertilized immature medusahead plants. Any control practice that involves a herbicide, mechanical, or burning treatment, should include establishment of adapted perennial grasses to prevent re-establishment of medusahead.

Literature

1. BAKER, H. G. 1972. Migration of Weeds, p. 327-347. *IN:* Taxonomy, Phytogeography and Evolution. D. H. Valentine, ed. London. Academic Press Inc. (London) Ltd.

   Species discussed include *Cynodon dactylon, Pennisetum clandestinum, Trifolium repens, Sorghum* spp., *Prosopis glandulosa, Acacia farnesiana, Leucaena glauca* (= L. *leucocephala*) and *Taeniatherum caput-medusae*. It is pointed out that removal of a weed (e.g. *Hypericum perforatum* in N. California by biological control) must be followed by resowing with desirable species if the vacant niche is not to be filled by other weeds.

2. BOVEY, R. W. 1959. A study of growth, composition and environmental factors in the control and utilization of *Elymus caput-medusae* L. M.S. Thesis. University of Idaho, Moscow. 97 p.

   Herbicides CIPC, IPC, amitrol, and dalapon were found to be effective in controlling medusahead rye. CIPC, IPC, and amitrol are required at higher rates and consequently costs become prohibitive. Dalapon proved to be the most desirable herbicide tested because of the effective low rate per acre and the lower costs involved. CDAA and CDEC were found to be ineffective. Greenhouse studies on nitrogen fertilization revealed 40 pounds/acre of actual nitrogen produced lush growth which appeared to be attractive to livestock. Seedlings exposed to nightly temperatures of 37° fahrenheit or lower for approximately 14 days resulted in vernalization and subsequent floral initiation. Medusahead grown on arid, neutral, and alkaline soils was not limited to any one soil type. Ensiling medusahead did not produce a safe palatable feed because of the high silica content. Chemical composition studies on medusahead and downy brome (*Bromus tectorum*) revealed moisture, crude fat, crude fiber, protein, and lignin contents were reasonably equal between the two species at similar stages of growth. The ash content of medusahead generally was found to be more than double that of downy-brome. Control by grazing is improbable because of the inherent unpalatability of this species.

3. BOVEY, R. W., D. Le TOURNEAU, and L. C. ERICKSON. 1961. The chemical composition of medusahead and dov[illegible] brome. Weeds 9:307-311.

   The moisture, crude protein, crude fat, crude fiber, and lignin contents of medusahead (*Elymus caput-medusae*) were comparable to that of downy brome and many desirable grass species. The ash content of medusahead, however, was found to be much greater than that of downy brome and of many other grasses. The ash of medusahead contained silica amounting to more than 10 percent of the dry weight. The high silica content of medusahead is the basis of its harshness and may explain partially its unattractiveness to livestock. The high silica content also may be the reason why the plant is slow to decompose in the field. Nitrogen fertilization increased forage consumption by cattle and horses. Medusahead silage, whether pure or modified with additives, was unacceptable to sheep.

4. BRANNON, T. A. 1972. Some interactions between nitrate-nitrogen and temperature in portions of the life cycle of four range grasses. M.S. Thesis. Washington State Univ., Pullman. 69 p.

   Under conditions of low nutrient nitrate, medusahead produced more top growth relative to its potential than did cheatgrass. Slow decomposition of medusahead litter tied up soil nitrogen longer than cheatgrass litter. The combination of these two characteristics of medusahead can at least in part explain how medusahead is able to invade established cheatgrass stands.

5. CHRISTEN, M. D., J. A. YOUNG, and R. A. EVANS. 1974. Control of annual grasses and revegetation in ponderosa pine woodlands. J. Range Manage. 27:143-145.

   Atrazine (1.12 kg/ha) controlled *Taeniatherum asperum* and *Bromus tectorum* sufficiently to permit the establishment of perennial wheatgrass (*Agropyron intermedium*) in a ponderosa pine (*Pinus ponderosa*) woodland previously burned in wildfires. Autumn application of atrazine greatly improved survival of *P. ponderosa* and bitterbrush (*Purshia tridentata*) seedlings transplanted to plots the following spring. *P. tridentata* seedlings established naturally in areas treated with atrazine. The herbicide treatment reduced competition from annual grasses, and, apparently, created a desirable habitat for seed caching by rodents. Higher rates of atrazine controlled most herbaceous vegetation and promoted the growth of *P. ponderosa* seedlings. Failure to establish perennial grasses resulted in reinvasion by annual grasses.

6. DAHL, B. E. 1967. Environmental factors related to medusahead distribution. M.S. Thesis, Univ. of Idaho, Moscow, Idaho. 122 p.

   Multiple correlation analysis revealed that next to competition from other vegetation, the structural development of the soil B horizon and the topographic position were the most influential site characteristics in determining medusahead and cheatgrass adaptability. Soils poorly aerated were preferred by medusahead. Soils with well-developed profiles were usually dominated by cheatgrass. Medusahead preferred grumusols and other montmorillonite-type clay soils. Azonal and Entisol soils were not susceptible to medusahead invasion. No relationship between medusahead or cheatgrass to a moisture or temperature gradient could be detected, but medusahead was limited to the more mesic topographic positions in arid areas. In the 9- to 11-inch precipitation zone, a strongly developed clay B horizon within 10 to 12 inches of the soil surface was seemingly required for medusahead occupancy. Available soil moisture in areas with less than 9.5 to 10 inches of annual precipitation does not endure long enough for medusahead to complete its life cycle. Greenhouse pot studies revealed cheatgrass used more water than medusahead until it matured; but because of later phenological development, medusahead required water for a longer period and had a higher total requirement.

7. DAHL, B. E., and E. W. TISDALE. 1975. Environmental factors related to medusahead distribution. J. Range Manage. 28:463-468.

The extent to which medusahead wildrye (*Taeniatherum asperum* = *T. caput-medusae*), an annual grass of low forage value, had spread at the expense of perennial grasses on depleted Idaho rangelands was studied in a number of areas varying in altitude, soil structure, and climate. Factors favorable to medusahead encroachment were soils with a high clay content, well-developed profiles, and areas receiving run-off water from adjacent sites. Less susceptible to invasion were well-drained soils and those developed from rocks that weathered to coarse-textured sands showing poorly developed profiles. These soils tended to be dominated by cheatgrass (*Bromus tectorum*), a grass with some value as a livestock forage. Avoiding depletion of native perennial vegetation was helpful in resisting invasion by medusahead on susceptible soils in areas at risk.

8. ERICKSON, L. C., C. LAMBERT, and R. S. PARISH. 1956. Chemical and cultural treatments for the control of medusahead rye. Res. Prog. Rep. WWCC. p. 20-21.

Cultural treatments were definitely helpful in controlling medusahead. A moldboard plow gave approximately 95 percent control, and plowing in combination with herbicides attained 100 percent control. Discing alone gave approximately 50 percent control; while discing plus dalapon or amino triazole at a 2 lb/A rate gave 100 percent control. Six pounds per acre of IPC or CIPC were necessary for 100 percent control on disced areas. Burning alone in the early spring attained little control, although it gave an additive effect in combination with the herbicides, as compared to check treated areas. Dalapon at all rates —2 pounds and up—gave 100 percent control. Amino triazole gave 100 percent control at the 6-lb. rate and approximately 90 percent control at the 2-lb. rate. It took 8 lbs. per acre of IPC to give 100 percent control, and the 6-lb. rate gave approximately 50 percent control. Eight pounds of CIPC gave approximately 90 percent control.

9. EVANS, R. A., and J. A. YOUNG. 1970. Plant litter and establishment of alien annual weed species in rangeland communities. Weed Sci. 18:697-703.

Plant litter that covers the soil surface acts as a layer of insulation, moderating temperature and moisture, and creating favorable microsites for germination and establishment of annual weed species on rangeland communities. Litter cover is an important factor in succession among annual species which culminates in dominance by downy brome and medusahead in these communities.

10. EVANS, R. A., and J. A. YOUNG. 1972. Microsite requirements for establishment of annual rangeland weeds. Weed Sci. 20:350-356.

In trials on clay and sandy loam soils during 1969-71, germination and establishment of downy brome (*Bromus tectorum*), medusahead (*Taeniatherum asperum*), and tumble mustard (*Sisymbrium altissimum*) were increased when buried 1 cm deep, by soil movement and pitting the soil surface compared to broadcast sowing on the surface of smooth soil. These conditions maintained temperatures and soil and atmospheric moisture in the range required for establishment.

11. FURBISH, P. 1953. Control of medusahead on California ranges. J. Forest. 51:118-121.

Medusahead, a weedy annual grass, has become established on northern California ranges. Preliminary results indicate controlled burning to be an economically effective method. Mowing and chemicals may have a place in the control program. Its spread to new areas may be minimized by proper handling of livestock.

12. GOEBEL, C. J., J. R. NELSON, and G. A. HARRIS. 1969. Medusahead—a threat to Washington rangeland. Washington State Univ., Ext. Serv. Circ. 359. 3 p.

Medusahead has infested 120,000 to 150,000 acres in eastern Washington. The forage has an unusually high silica content, making it low in nutrient value. Also, the sharp awns frequently cause punctures and infection of eyes, throat, and other tissues in livestock. Once medusahead becomes established, it grows in dense stands, forming a mat of undecomposed stems two to five inches thick. The dense litter is an extreme fire hazard in the summer, ties up soil nutrients ordinarily available for plant growth, and shades or smothers out seedlings of valuable forage species. Application of 3 lbs. of dalapon in 10 to 20 gallons of water per acre was effective in controlling medusahead if applied before the boot stage but after most of the medusahead had germinated. Spring tillage with summer fallow usually gives better control than chemical treatment. Burning helps destroy seed and reduce next year's stand, but should be followed with tillage for satisfactory control. Any control operation should include establishment of adapted perennial grasses to prevent re-establishment of medusahead.

13. GOEBEL, C. J., and G. BERRY. 1976. Selectivity of range grass seeds by local birds. J. Range Manage. 29:393-395.

On steep or rocky areas in depleted semi-arid Pacific Northwest range, where broadcast rather than mechanical sowing must be practiced, selective feeding by local birds may alter the balance of desirable forage species. In studies of six perennial grasses the small seeds of *Poa ample* and *Festuca ovina* were selected in preference to those of larger-seeded *Agropyron* spp. by wild birds (25 species were observed in 1969). Seeds least preferred were those of the annuals *Bromus tectorum* and *Taeniatherum asperum*. Resowings under litter cover were successfully hidden from most birds until germination.

14. HARRIS, G. A. 1965. Medusahead competition. p. 66-69. *IN:* Proc. of the Cheatgrass Symposium, Vale, Oregon. (Portland) Bureau of Land Management.

Evidence indicated that dense litter cover which accumulated under medusahead stands was important in the competitive relationship with cheatgrass. Cheatgrass failed to grow under three inches of litter cover.

15. HARRIS, G. A., and A. M. WILSON. 1970. Competition for moisture among seedlings of annual and perennial grasses as influenced by root elongation at low temperature. Ecology 51:530-534.

Rapidly elongating *Bromus tectorum* and *Taeniatherum asperum* roots penetrated the soil ahead of *Agropyron spicatum* roots and used available moisture. In contrast, *Agropyron desertorum* roots penetrated the soil almost as rapidly as *B. tectorum* and *T. asperum* and remained in favorable moisture. These differences in root penetration resulted in lower leaf water potentials and poorer survival in *A. spicatum* than in *A. desertorum*. The results suggest that in areas where root growth occurs at low temperatures and where lands are infested with *B. tectorum* and *T. asperum*, seedlings of *A. desertorum* would be more successful than seedlings of *A. spicatum*.

16. HARRIS, G. A., and C. J. GOEBEL. 1976. Factors in plant competition in seeding Pacific Northwest ranges. Washington State Univ. Agr. Exp. Sta., Bull. 820. 21 p.

Medusahead is quite similar to cheatgrass in life history and ecological adaptation. However, several competitive advantages were attributed to medusahead which in combination could result in the displacement of cheatgrass by medusahead. Medusahead seed had greater germinability under adverse conditions of low temperature and high moisture tension than cheatgrass or bluebunch wheatgrass. Medusahead grew faster than cheatgrass at low temperatures and matured seed about two weeks later. Medusahead litter accumulated to depths of 5 to 10 cm, limiting germination and growth of cheatgrass by reducing nitrate release. Medusahead was more vigorous at low nitrate levels than cheatgrass. After germination in the fall, medusahead and cheatgrass roots continued to grow throughout the winter. Medusahead roots reached 100 cm depths by early February; cheatgrass roots reached 90 cm by mid-March. Medusahead root diameter is relatively large, and cells were thick-walled throughout. It was reasoned that this heavier suberization makes possible translocation of soil water throughout relatively hot, dry surface soil layers, accommodating a later phenology in medusahead. Treatment of medusahead with paraquat on burned plots gave no better control than without the chemical treatment. Spring plowing followed by discing gave the best control of medusahead.

17. HARRIS, G. A. 1977. Root phenology as a factor of competition among grass seedlings. J. Range Manage. 30:172-177.

Medusahead germinated significantly faster and more completely than either cheatgrass or bluebunch wheatgrass. Cheatgrass and medusahead seedling roots began post-germination growth at a more rapid rate than bluebunch wheatgrass and continued thus all winter. Medusahead roots grew slightly faster than cheatgrass roots. Cheatgrass and medusahead roots effectively removed available soil water at depths where bluebunch wheatgrass roots were growing.

18. HARWOOD, L. 1960. Programs to control medusahead. Proc. Calif. Sec., Soc. Range Manage. Fresno, Calif. p. 45-49. (Mimeo release.)

Dalapon was applied at rates varying from 2 to 8 lb/A. Rates higher than 3 lb/A gave 95 to 100 percent kill of medusahead. Fall discing, followed by seeding Mt. Barker sub-clover at 9 lb/A and adding 400 lb/A of single super phosphate, reduced the number of medusahead seed heads per square foot from 165 to 24. Medusahead was reduced 60 to 95 percent by burning. All burns should be downhill with a minimum amount of wind. Where it is economically feasible, burning should be followed by reseeding and fertilization.

19. HIGGINS, R. E., and P. J. TORELL. 1960. Medusahead: range menace. Univ. of Idaho Agr. Exp. Sta., Ext. Bull. 331. 4 p.

Medusahead competition is most severe where there is overuse of desirable species. The long, rough awns and sharp, hard seeds cause injury to the eyes and mouths of both sheep and cattle. The awned seeds are blamed for sores in the flanks of sheep. Wool is docked because of the presence of medusahead seed. Temporary control of the weed can be accomplished by moldboard plowing, disc, plowing, or by applying 2 lbs. of dalapon per acre from mid-April to early May. Treatments are more effective if the medusahead litter is first removed by burning. However, unless a forage species can be established to compete with medusahead, the area will be quickly reoccupied by the weed.

20. HIRONAKA, M., and E. W. TISDALE. 1958. Relative rate of root development of medusahead and cheatgrass. Res. Prog. Rep. WWCC. p. 28.

The aerial portion of medusahead and cheatgrass changed little from December to March, while root length increased significantly during this period. Root elongation was similar in the two species from December to March. No root growth took place when maximum-minimum temperatures under the litter were 37° and 19° F. Because of early maturity of cheatgrass, differences in root length in the spring were difficult to evaluate. However, the study did indicate that medusahead may have a slight advantage over cheatgrass for soil moisture.

21. HIRONAKA, M. 1961. The relative rate of root development of cheatgrass and medusahead. J. Range Manage. 14:263-267.

The relative rate of root development of medusahead and cheatgrass was studied. Rate of vertical root penetration of the two annual grasses was about equal, but cheatgrass reached maximum branching a few weeks earlier than medusahead. Maximum root development coincided closely with time of full inflorescence for the two species. Because medusahead matures later, its root system remains functional for a longer period than those of cheatgrass. When the two species are growing together, the water requirement for cheatgrass must be satisfied before medusahead is able to complete its life cycle.

22. HIRONAKA, M., and E. W. TISDALE. 1963. Secondary succession in annual vegetation in southern Idaho. Ecology 4:810-812.

Secondary succession inside an exclosure was followed from 1938 to 1961. *Bromus tectorum* became the dominant species a few years after the site was protected from rabbits, replacing the annual forb stage in plant succession. In turn, *Bromus tectorum* was followed by *Sitanion hystrix*, a relatively short-lived perennial grass. From the viewpoint of livestock forage, conversion from *Bromus tectorum* dominance to that of *Sitanion* may not always be warranted because of the relative good forage qualities of the brome. In the case of areas dominated by an annual grass of low livestock preference, such as *Elymus caput-medusae* (medusahead), replacement with *Sitanion* in areas that cannot be artificially seeded with other perennial forage species would be highly desirable.

23. HIRONAKA, M. 1965. The medusahead problem, p. 62-65. *IN:* Proceedings of the Cheatgrass Symposium, Vale, Oregon. (Portland) Bureau of Land Management.

In the sagebrush grass region, medusahead represents the highest annual grass stage in secondary succession. Medusahead is better able to make fuller utilization of site resources than cheatgrass. Replacement of cheatgrass is apparent because of the higher reproductive success of medusahead. Cattle will graze medusahead more freely where the old growth of medusahead is absent. With heavy use, old growth does not accumulate and greater use of medusahead can be obtained during the pre-head stage.

24. HIRONAKA, M., and B. W. SINDELAR. 1973. Reproductive success of squirreltail in medusahead infested ranges. J. Range Manage. 26:219-221.

Squirreltail (*Sitanion hystrix*), a native perennial bunchgrass, exhibited an ability to become established in medusahead dominated ranges in Idaho. The reproductive success of squirreltail seedlings averaged 2.6 percent after 18 months in plots that were broadcast seeded on unprepared seedbeds. Rapid physiologic development of squirreltail seedlings appeared to be the most important characteristic to explain its successful establishment.

25. HIRONAKA, M., and B. W. SINDELAR. 1975. Growth characteristics of squirreltail seedlings in competition with medusahead. J. Range Manage. 28:283-285.

In the glasshouse, a competition study among several densities of medusahead (*Taeniatherum asperum*) and a constant number of squirreltail (*Sitanion hystrix*) seedlings was conducted over an 85-day period. At the end of the experiment the average root weight of squirreltail was greater than that of medusahead, even though the average shoot weight of medusahead was greater in all treatments where the two species were grown together. Squirreltail contributed only a small proportion of the total leaf length produced in containers with high densities of medusahead, but the proportion remained relatively constant throughout the experiment. In treatments where medusahead densities were low to moderate, the proportion of total leaf length produced by squirreltail decreased steadily with time.

26. KAY, B. L. 1963. Effects of dalapon on a medusahead community. Weeds 11:207-209.

Dalapon (2,2-dichloropropionic acid) was applied to a predominately medusahead (*Elymus caput-medusae* L.) community at rates of 1, 2, 3, 4, and 5 lb/A and at four stages of growth. Low rates of dalapon gave better control when applied at early growth stages than the same rates applied later. Reduction in total ground cover was less from December and February applications than from March applications. Dalapon at 3 lb/A applied 30 days after emergence gave 100 percent kill of medusahead. Two lb/A gave 96 percent or better control when applied during the vegetative stage (December, February, March). Both 2 and 3 lb/A applied in December, and 2 lb/A in February left a favorable balance of species among the remaining forage plants.

27. KAY, B. L., and C. M. McKELL. 1963. Pre-emergence herbicides as an aid in seeding annual rangelands. Weeds 11:260-264.

Simazine, EPTC, and atrazine were shown to aid the establishment of rose clover (*Trifolium hirtum* All.) and harding grass (*Phalaris tuberosa* Hitch.) by reducing competition from resident annual plants, primarily medusahead (*Elymus caput-medusae* L.). The success of pre-emergence herbicides was shown to depend on fall precipitation in amounts great enough to permit seed germination and plant growth before winter temperatures became limiting.

28. KAY, B. L. 1965. The medusahead problem in California—what progress is research making? p. 74-80. *IN:* Proceedings of the Cheatgrass Symposium, Vale, Oregon. (Portland) Bureau of Land Management.

Medusahead (*Elymus caput-medusae* L.) acreage in California is still growing in both the Mediterranean and High Desert areas. Paraquat sprayed during the winter at .5 lb/A removed medusahead from range seedings of desirable clovers. A heavy litter residue, always present with medusahead, is desirable. Paraquat remains on the litter and controls new weeds as they intercept the litter. Weed control in minimum litter accumulation was only temporary. Medusahead burning removed the litter and made the new forage crop available to livestock.

29. LUSK, W. C., M. B. JONES, P. J. TORELL, and C. M. McKELL. 1960. Utilization and palatability of medusahead by sheep as affected by growth stage and soil fertility. Proc. Calif. Sec. Soc. Range Manage. Fresno, California. p. 41-45. (Mimeo release.)

Sheep appeared to prefer fertilized strips of medusahead, and it was apparent that heavy grazing was damaging the plant. Measurements indicated that 25 percent of vegetation in the fertilized strip was medusahead, compared to 65 percent medusahead in the unfertilized strip. Results of this study showed medusahead may be eaten by sheep during most of its growth stages, particularly before the formation of seedheads.

30. LUSK, W. C., M. B. JONES, P. J. TORELL, and C. M. McKELL. 1961. Medusahead palatability. J. Range Manage. 14:248-251.

A grazing test was conducted with sheep to investigate the palatability of medusahead on fertilized and unfertilized annual range. The results indicated that: (1) sheep, given a free choice, did eat medusahead as long as it was green, (2) sheep held in a small plot area ate some medusahead even when it had headed out and dried, (3) heavy grazing in the spring resulted in a thinned stand of medusahead at maturity as compared to a dense stand of medusahead resulting from light or no grazing, and (4) consumption with forced grazing showed that fertilized medusahead was grazed more than unfertilized medusahead since a greater amount of medusahead was taken from the fertilized plots early in the season. This resulted in less medusahead on the grazed-fertilized areas late in the season as compared to grazed-unfertilized areas. However, palatability measured by esophageal fistula technique suggested there was no difference between the percentage of medusahead in the diet from fertilized and unfertilized areas.

31. MacLAUCHLAN, R. S., H. W. MILLER, and O. K. HOGLUND. 1970. Lana vetch for medusahead control. J .Range Manage. 23:351-356.

Overseeding with Lana vetch (*Vicia dasycarpa* Ten.), a self-perpetuating annual legume, appeared to suppress medusahead. Lana vetch can be successfully established without seedbed preparation, offering a practical method of controlling medusahead on rough terrain.

32. MAJOR, J. 1958. Responses of medusahead (*Elymus caput-medusae* L.) to different planting dates. WWCC. Res. Prog. Rep. p. 29.

Plantings were made monthly from August 1956 to March 1957. One-half the plants were kept in a greenhouse and the other half outside. Medusahead requires cold treatments after germination for normal completion of its life cycle. The short days of autumn also provide a necessary stimulus.

33. MAJOR, J., and C. M. McKELL. 1958. Relations of medusahead (*Elymus caput-medusae* L.) to fertilization, dalapon, and soil moisture. Res. Prog. Rep. WWCC. p. 27.

NH_4NO_3 at 150 lbs/A of N alone and with P at 100 lbs/A as treble superphosphate gave good yield response of medusahead and other weedy annuals. In April, medusahead was more abundant on the fertilized than unfertilized plots. In June, medusahead was less abundant on the fertilized plots because of increased rates of moisture depletion. Medusahead did benefit from late spring moisture on plots not fertilized because it had not been reduced in density by competition from fertilized forbs and grasses. The few medusahead plants left on the dalapon-treated sites responded more to late rains than the relatively few mature medusahead plants on the heavy N-fertilized plots.

34. MAJOR, J., C. M. McKELL, and B. L. KAY. 1958. Control of medusahead (*Elymus caput-medusae* L.) by several pre-emergence herbicides and competition with resident and reseeded species. Res. Prog. Rep. WWCC. p. 26-27.

EPTC, CDAA, CIPC, simazine, dalapon, and monuron were applied in the fall on a California annual grassland dominated by medusahead. Rates of application were applied at three geometrically increasing rates starting with 1/2 lb/A for monuron and simazine, 1 lb/A for dalapon, and 2 lbs/A for EPTC, CDAA, and CIPC. After 4.35 inches of rain, rose clover (*Trifolium hirtum*) and Harding grass (*Phalaris tuberose*) were band seeded at about 8 lbs/A of each, with 200 lbs/A of 16-20-0 fertilizer. EPTC, CIPC, and simazine gave effective control of resident grasses, including medusahead. Simazine had eliminated most other vegetation as well. The EPTC and CIPC plots had excellent bur clover (*Medicago lisfida*) stands from resident seed. Plots treated with CDAA, dalapon, and monuron differed little from the checks.

35. MAJOR, J. 1960. Medusahead—origin and current status. Proc. Calif. Sec. Soc. for Range Manage. Fresno, California. p. 35-39. (Mimeo release.)

These species of medusahead were identified from the standpoint of morphology and geographical distribution. The original *Elymus caput-medusae* that Linnaeus named grows in Spain, Portugal, and southern France. This Medusahead taxon was called subspecies, *bobartii* by Ascherson and Graebner. The second species has been called *crinitus*. It occurs from North Africa, the southern Balkans, through the Middle East to Soviet Central Asia. The third species, our western American weed, has been called *asper*. It occurs from Hungary through the Ukraine to Tadzhikistan. The generic name *Taeniatherum* was invented by Nevski, a Russian taxonomist. *Taeniatherum asperum* is now the accepted name of our medusahead because of the morphological and geographical differences of the three species.

36. MAJOR, J., C. M. McKELL, and L. J. BERRY. 1960. Improvement of medusahead infested rangeland. Calif. Agr. Exp. Sta., Ext. Serv. Leaf. 123. 3 p.

Medusahead is invading California's rangelands at a serious rate. Small spot infestations must be controlled, even at a high cost, to ensure against spread of the weed to uninfested areas. Chemicals applied at the proper time and rate are effective in controlling medusahead. Reseeding spot infestations is a necessary follow-up treatment. On widespread, long-established stands of medusahead, chemical control is not economically feasible. Under such conditions, the more productive locations should be chosen for improvement by burning and cultivation, combined with seeding legumes, fertilizing with phosphorus or sulfur, or seeding aggressive, locally adapted perennial grasses. Seeding operations should be followed by proper livestock management.

37. MALLORY, J. 1960. Soil relationships with medusahead. Proc. Calif. Sec., Soc. Range Manage. Fresno, Calif. p. 39-41. (Mimeo release.)

Dense stands of medusahead occurred on soils with loam, clay loam, or clay surface texture, with good water-holding capacity. These soils had a blocky or platy structure, not granular or crumb. Soils supporting dense stands of medusahead have a reaction ranging from calcareous to moderately acid, although most of them were slightly acid.

38. McKELL, C. M., J. MAJOR, and E. R. PERRIER. 1959. Annual range fertilization in relation to soil moisture depletion. J. Range Manage. 12:189-193.

Fertilizer treatments of 150 lbs. N per acre, 200 lbs. phosphorus per acre, and 150 lbs. nitrogen plus 200 lbs. phosphorus per acre were applied to an annual grassland. Medusahead plants that received application of nitrogen reduced the soil moisture below the field capacity (0.3 bar) earlier in the season than on the phosophorus or non-fertilized plots. Combination of nitrogen and phosphorus resulted in a significant interaction that gave increased yield of medusahead. Growth of summer-growing, annual weeds was considerably retarded by depletion of soil moisture at all depths where fertilizer was applied.

39. McKELL, C. M., J .P. ROBISON, and J. MAJOR. 1962. Ecotypic variation in medusahead, an introduced annual grass. Ecology 43:686-698.

Medusahead seeds were collected from 13 locations in California, Oregon, Washington, and Idaho. Significant in percent germination, rate of root growth, plant height, and phenology were observed. Seeds collected from locations with relatively low precipitation had the lowest germination percentages; seeds from locations with relatively high precipitation had the highest germination. Root elongation was more rapid from seed collected in Washington and California than in Oregon. The time interval of heading between plants from California and Oregon was 38 days; the seed-maturity interval between plants from these two locations was 15 days.

40. McKELL, C. M., A. M. WILSON, and B. L. KAY. 1962. Effective burning of rangelands infested with medusahead. Weeds 10:125-131.

Medusahead (*Elymus caput-medusae* L.) matures later in the spring than most associated species, and has a seed head moisture content of more than 30 percent for approximately a month after leaves and stems begin to dry. High temperature is more injurious to seed viability when seed moisture content is high. Control burns of medusahead infested rangeland were most effective in late afternoon when burning slowly (into a mild wind) and at the soft dough stage of medusahead seed development.

41. MORTON, H. L., P. J. TORELL, and R. H. HAAS. 1958. The effects of rate and date of dalapon application on control of medusahead rye, *Elymus caput-medusae* L. Res. Prog. Rep., WWCC. p. 25-26.

Rates of 1.0, 2.0, and 4.0 pounds of dalapon per acre were applied on April 27, May 31, and June 26, 1956, the dates corresponding to the two-leaf, late boot, and dough stages of growth respectively. All treatments were applied in water equivalent to 40 gallons per acre with a power sprayer. The 2.0 pound rate applied on April 27, 1956, was most effective in controlling medusahead.

42. MURPHY, A. H., and D. TURNER. 1959. A study on the germination of medusahead seed. Calif. Dept. of Agri. Bull. 48:6-10.

Burning medusahead in the dry stage offered an economical method of control. Fire decreased the seed crop of this annual, thus diminishing the number of plants in the next growing season. The most effective fire burned slowly and was directed toward burning downslope and against the wind. The opposite of this created a fast flash fire and many seedheads were left unburned. Seed germination was higher on poorly burned areas whereas little germination occurred on well-burned sites.

43. MURPHY, A. H., and W. C. LUSK. 1961. Timing medusahead burns to destroy more seed-save good grasses. Calif. Agric. 15:6-7.

Control of medusahead (*Elymus caput-medusae*) on rangeland is a major problem on many acres in California. The purpose of burning is to destroy the seed in the head before it shatters and is deposited in the ground. In many circumstances, where burning is properly accomplished, the medusahead stand will be substantially reduced during the next growing season. Burning as soon as soft chess (*Bromus mollis*) is shattering seed, and while medusahead is still intact, favors the seed survival of soft chess during a fire. Other factors that also must be considered when burning include the condition of other fuel, weather, terrain, and time of day.

44. MUTCH, R. W., and C. W. PHILPOT. 1970. Relation of content to flammability in grasses. For. Sci. 16:64-65.

Medusahead and cheatgrass were found to differ greatly in total ash content. Ash contents of cheatgrass and medusahead were 5.04 and 18.49 percent, respectively, while silica-free ash contents were 0.99 and 1.35 percent. Thermoanalyses indicated pyrolytic similarity between the two grasses. Results suggested the silica fraction should be discounted when relating ash content to pyrolysis and ignition processes of wildland fuels.

45. NAKAI, Y., and S. SAKAMOTO. 1977. Variation and distribution of esterase isozymes in *Heteranthelium* and *Taeniatherum* of the tribe *Triticaea, Gramineae.* Bot. Mag. Tokyo 90:269-276.

Esterase isozyme variations of *Heteranthelium piliferum, Taeniatherum asperum* and *T. crinitum* collected in Iraq, Turkey, and Iran were analyzed by gel isoelectric focusing. In *H. piliferum*, two types of esterase zymogram, H1 and H2, were found. It was demonstrated that a pair of allelic genes, which is shown in the heterozygotes, controls the difference between type H1 and H2. Two types of esterase zymogram, T1 and T2, were observed in two species of *Taeniatherum.* The majority of strains having type H1 of *H. piliferum* and type T1 of *T. crinitum* was distributed in the highly elevated plateau of the Anatolian and Iranian highlands, while strains with H2 and T2 of these two species were found in the western foothills of the Zagros Mountains, the Tigris basin of Mesopotamia, and the central Anatolian plateau.

46. NELSON, J. R., and A. M. WILSON. 1969. Influence of age and awn removal and dormancy of medusahead seeds. J. Range Manage. 22:289-290.

The effects of seed age and awn removal were studied in two medusahead strains having different postmaturity seed dormancy characteristics. Awn removal increased the percentage germination. The proximity of removed awns inhibited the germination of deawned seeds. Dormancy of intact seeds and inhibitory effects of awns decreased with increasing age of seeds.

47. NELSON, J. R., G. A. HARRIS, and C. J. GOEBEL. 1970. Genetic vs. environmentally induced variation in medusahead, *Taeniatherum asperum* (Simonkai) Nevski. Ecology 51:526-529.

The influence of seed-nursery environment on genecological characteristics of 20 medusahead strains was studied. Environmentally induced variation was observed in germination, early height development, and winter survival. Small but significant variation dates of spike emergence and anthesis, caused by differences in seed-nursery environment, were observed. Results suggest that the common practice of attaching genecological significance to wild-grown seed may be subject to error, especially in germination and early phenological stages after germination.

48. PARISH, R. L. 1956. A study of medusahead rye, *Elymus caput-medusae* L., including some of the morphological and physiological factors influencing its growth and distribution, and determining some possible methods for its control on Idaho ranges. M.S. Thesis. Univ. of Idaho, Moscow. 79 p.

Moisture requirements of medusahead rye indicate the time precipitation occurs is of greater significance in its propagation than is the total precipitation. Seedling measurements of medusahead rye were made during the growing season. Soils supportiing dense stands of medusahead had a pH range from 6.65 to 7.00. The root system of medusahead rye is shallow and is not extensive in development. Medusahead seedlings emerge from soil depths up to 1 1/2 inches, if the soil surface is compact, and from a maximum of one inch in sand. Medusahead rye seed maintained over a six-month period was approximately 15 percent dormant. Limited usage of chemicals—amino triazol, IPC, and CIPC—for medusahead rye control on ranges appeared practicable and possible. Dalapon gave good control at a low rate. Cultural treatments applied in the spring did aid in the control of medusahead rye, especially in combination with chemical treatments. Plowing and discing significantly reduced stands. Burning in the spring did not give appreciable control. Of plowed, disced, burned, and check cultural plots, reseeded perennial grasses became established only in the plowed plots. Species showing some degree of success in establishment were intermediate wheatgrass, crested wheatgrass, and beardless wheatgrass.

49. REDONDO, P. B., C .E. LUIS, M. A. PUERTO, and J. M. GOMEZ. 1974. Description of four stages in secondary succession in Sayago pastures. Revista Pastos. 4:235-245.

A typical example of secondary plant succession in a zone with relatively fertile soil in S. W. Zamora province, Spain, is described. The study was carried out on four plots previously cultivated and abandoned for (a) 2 years, (b) 5 years, (c) 10 years and (d) 20 years. Botanical composition of the four plots is given. In (a) *Vulpia myuros* and *Bromus commutatus* were dominant. In (b) *Gaudinia fragilis, Cynodon dactylon, Bromus commutatus, Elymus (= Taeniatherum) caput-medusae* and *Vulpia bromoides* were dominant. The greatest differences between plots (b) and (c) were an increase in *B. commutatus* and *Vicia angustifolia* and decrease in *V. myuros, V. bromoides, Trifolium campestre, T. glomeratum* and other spp. In (d) *Arrhenatherum elatius, Festuca rubra, F. pratensis, G. fragilis* and *T. pratense* were dominant.

50. ROBOCKER, W. C. 1973. Production potential of four winter annual grasses. J. Range Manage. 26:69-70.

In nursery trials on an individual plant basis in 1962-4, average herbage DM yields of *Bromus tectorum, B. japonicus, B. brizaeformis* and *Taeniatherum asperum* (= *T. caput-medusae*) were 6.9, 7.7, 4.9, and 3.8 g/plant, respectively. The results were considered to support the view that *T. asperum* in *B. tectorum* should be selectively controlled with diuron.

51. ROBOCKER, W. C., and R. D. SCHIRMAN. 1976. Re-seeding trials on Columbia basin rangelands dominated by winter annual grasses. J. Range Manage. 29:492-497.

A series of trials was conducted north of the Snake River to determine the feasibility of establishing crested wheatgrass (*Agropyron cristatum*) on rangeland dominated by *Bromus tectorum* and *Taeniatherum asperum.* Excellent control of annual grasses and broad-leaved weeds was obtained with several herbicides, atrazine at 1.1 kg/ha as a fallow treatment before sowing being the most satisfactory. Late autumn or early spring sowing using a rangeland drill, modified to give some seedbed preparation in the row, combined with control of annual weeds, provided favorable conditions for germination and emergence of *A. cristatum* seedlings; nevertheless, in most experiments they failed to establish. Trials with a soil fumigant (methyl bromide) resulted in excellent stands of established plants, indicating that microbiological factors may be a primary cause of the failure of seedings under stress.

52. SAKAMOTO, S. 1968. Interspecific hybrid between the two species of the genus *Taeniatherum* of the tribe *Triticeae.* Rep. Nat. Institute of Genetics 19:39-40.

The genus *Taeninatherum* comprises two diploid annual species (2n = 14), *asperum* and *crinitum.* A strain of *Taeniatherum asperum* was crossed reciprocally with a strain of *Taeniatherum crinitum.* Only three F_1 plants were obtained; one from *Taeniatherum asperum x Taeniatherum crinitum* and two from the reciprocal combination.

53. SAVAGE, D. E., J. A. YOUNG, and R. A. EVANS. 1969. Utilization of medusahead and downy brome caryopses by chukar partridges. J. Wildl. Manage. 33:975-978.

Chukar partridges (*Alectoris graeca*) in separate groups were fed rations consisting of caryopses of downy brome (*Bromus tectorum*) and medusahead (*Taeniatherum asperum*), and commercial game farm pellets. The birds readily ingested the caryopses of both grasses. The caryopses of medusahead appeared to be largely indigestible. Severe weight losses occurred when birds were fed caryopses of either species. Birds fed downy brome appeared in better condition than those fed medusahead.

54. SCHOOLER, A. B., A. R. BELL, and J. D. NALEWAJA. 1972. Crosses between *Hordeum jubatum* L. and *Taeniatherum asperum* (Sim.) Nevski to determine genomic relationships. Crop Sci. 12:542-544.

F_1 hybrids were obtained from crosses between *Hordeum jubatum* L. (2n=28) and *Taeniatherum asperum* (Sim.) Nevski (2n=14). The F_1 hybrids had a chromosome complement of 2n=21 and were self-sterile. Chromosome behavior was irregular in microsporocytes of the hybrids examined. Chromosome doubling was induced in F_1 hybrids by colchicine treatment and partially self-fertile amphiploid intergeneric hybrids (2n=42) were produced. Cytological observations showed many micronuclei in the microspores which resulted from chromosome fragmentation during meiosis II. The F_1 intergeneric hybrids and amphiploid resembled the *Hordeum* parent more closely than *Taeniatherum* but were smaller than either parent in most morphological characteristics. There was only slight evidence of a genome relationship between the two genera.

55. SHARP, L. A., and E. W. TISDALE. 1952. Medusahead, a problem on some Idaho ranges: a preliminary study. Forest, Wildl., and Range Exp. Sta., Univ. of Idaho. Res. Note 3, 9 p.

Medusahead is an annual immigrant from Portugal and Spain that is becoming a serious problem on rangelands in west central Idaho. The exact time of introduction to this country is not known, but the first collection was made in 1901 near Steptoe, Washington, by G. R. Vasey. Estimates show approximately 30 thousand acres of rangeland in Idaho are infested with medusahead. Areas of main infestation are those with 10 to 20 inches of precipitation, formerly covered with a sagebrush-grass or bunchgrass type vegetation. Medusahead normally germinates in the fall with seed head formation occurring in early spring. Seeds mature in the latter part of June or first part of July. Forage value of medusahead is extremely low and where it is grazed by livestock some mechanical injury has been reported. A cover of medusahead is beneficial in preventing soil erosion. Litter accumulations in medusahead stands add to the organic matter of the soil.

56. SHARP, L. A., M. HIRONAKA, and E. W. TISDALE. 1957. Viability of medusahead seed collected in Idaho. J. Range Manage. 10:123-126.

Medusahead produced a large amount of seed annually, and fairly high viability is attained even when seed is collected while the heads still retain a greenish color. Carry-over of viable seed in both litter and soil is shown to occur for at least one year. Fire-damaged seed from burned areas did not germinate in the laboratory, but substantial numbers of undamaged seeds from the burned areas germinated readily.

57. SWENSON, C. F., D. Le TOURNEAU, and L. C. ERICKSON. 1964. Silica in medusahead. Weeds 12:16-18.

Collections of plants of medusahead, *Elymus caput-medusae* L., were made from natural infestations in Nez Perce County and Washington County in northern and southern Idaho, respectively. The ash and silica content (dry weight basis) decreased as the plant matured. The total ash of the entire plant contained from 72 to 89 percent silica. Similar percentages of silica in ash were obtained in the culms, heads, and seeds of the plant. X-ray diffraction patterns and polarizing microscope examinations showed the mineral form of silica to be opal. Heavy deposition of silica was found in the barbs of awns, in the epidermis of the leaves, culms, glumes, and seeds, and in strands beneath the epidermis.

58. TORELL, P. J., L. C. ERICKSON, and R. H. HASS. 1961. The medusahead problem in Idaho. Weeds 9:124-131.

Medusahead, *Elymus caput-medusae* L., is the worst range weed in Idaho because of its rapid migration, its vigorous competitive nature, and its extremely low forage value. Burning, dalapon, discing, and plowing in various combinations have provided control of two successive medusahead seed crops before seeding desired forage species. A single burn will not remove sufficient medusahead seed to permit the successful establishment of wheatgrasses. Burning will enhance the effectiveness of tillage and herbicide treatments by removing the heavy layer of medusahead litter, by destroying some seed, and by placing the remaining seed in contact with the mineral soil where they can be germinated and subsequently destroyed.

59. TORELL, P. J. 1967. Dowpon—an aid to reseeding medusahead-infested rangeland. Down to Earth 23:6-8.

Dowpon grass-killer applied at 3 pounds in 10 gallons of spray per acre consistently was effective in controlling medusahead. In chemical fallow, use of Dowpon after burning controlled medusahead but cheatgrass and broadleaf weeds developed. Other tests indicated successful control of these weeds with timely application of Dowpon and 2,4-D herbicides. Tillage was not required to obtain establishment of wheatgrass seedlings.

60. TORELL, P. J., and L. C. ERICKSON. 1967. Reseeding medusahead-infested ranges. Univ. of Idaho, Agr. Exp. Sta., College of Agr. Bull. 489. 17 p.

Investigations in the revegetation of medusahead-infested ranges in southwestern Idaho revealed two essential factors: (1) Control of annual weed species is necessary, for the competing vegetation is a complex of annual weeds rather than medusahead alone (2) two successive crops of annual weeds should be treated before seed formation to reduce weed seed

reserve, enhancing survival of wheatgrass seedlings. Under certain experimental conditions, these requirements were satisfied by each of the following dual treatment schedules: tillage plus tillage, tillage plus herbicide, burning plus tillage, and burning plus herbicide. The effective treatments included at least one tillage operation. The most desirable herbicide treatment was dalapon followed by 2,4-D. Burning was particularly desirable as the first of a dual treatment schedule. The most important benefit from burning was removal of the dense mantle of medusahead litter that impedes tillage, lowers the effectiveness of herbicides, and prevents preparing a quality seedbed. Although the dual weed control treatments reduced the annuaal weed populations, a large quantity of dormant weed seed remained in the soil. An application of atrazine showed promise for overcoming this difficulty. Because of high seed vigor, Nordan crested wheatgrass is the most desirable grass for reseeding medusahead infested ranges in southwestern Idaho.

61. TURNER, R. B., C. E. POULTON, and W. L. GOULD. 1963. Medusahead—a threat to Oregon rangeland. Oregon State Univ., Agr. Exp. Sta., Spec. Rep. 149. 22 p.

Medusahead is one of the primary range weed problems in Oregon. Estimates indicate medusahead occurs throughout an area in excess of 2 million acres in Oregon. In Oregon, medusahead has been growing within a mean annual precipitation range of 11 to 40 inches. Generally, the weed has been observed on clay loams and heavy clays which have a high waterholding capacity. Since medusahead matures two to three weeks later than cheatgrass (*Bromus tectorum* L.), the ecological amplitude of cheatgrass may extend beyond that of medusahead into areas of progressively drier climate. The low palatability of medusahead and mechanical injury to grazing animals resulting from the long, barbed awns and sharp seeds greatly reduce livestock grazing capacity of rangelands. The accumulation of slowly decomposing litter considerably safeguards the loss of soil by wind and water erosion in areas that are overgrazed and susceptible to erosion. Practices which offer some degree of control include tillage, seeding, burning, application of herbicides, and grazing management. Range seeding, when properly combined with other practices such as tillage, burning, or use of herbicides, seems to be the most positive and sure control of medusahead. Results of burning trials have been highly variable; and, used alone, satisfactory results cannot be attained. Results from studies in eastern Oregon indicate dalapon and atrazine give adequate control of medusahead at rates of 2 pounds of active chemical per acre. Although numerous reports have indicated that medusahead is unpalatable to all classes of livestock, other investigators have found that heavy grazing in spring resulted in a thinned stand of medusahead; whereas, light or no grazing resulted in a dense stand. Range fertilization, especially with nitrogen, offers a possible means of improving the palatability of medusahead to encourage its use by grazing animals.

62. TURNER, R. B. 1965. Medusahead control and management studies in Oregon. p. 70-73. *IN:* Proc. of the Cheatgrass Symposium, Vale, Oregon. (Portland) Bureau of Land Management.

On sites containing medusahead which are suitable for tillage, control of the weed and replacement by perennial type seeded forage are easily attainable. Conversely, on sites which are shallow, steep or rocky, with an inherently low forage potential, the problem of medusahead replacement has no immediate solution by conventional means. Atrazine and bromacil (Hyvar-x by duPont's label), both soil sterilants, have been effective in controlling medusahead and cheatgrass at rates of 1 pound per acre (active material) applied in late fall and 1/2 pound per acre applied in early spring or fall, respectively. IPC (4 pounds per acre) plus 2,4-D (3/4 pounds per acre), applied in late fall or winter, has given adequate control of medusahead and cheatgrass. Crested wheatgrass germination has been attained by drill seeding in the spring after application. Paraquat, a herbicide reported to give good annual grass control, has given very poor medusahead control under eastern Oregon conditions. Medusahead vigor actually was increased from this herbicide. Comparative medusahead clippings following 35 lbs/acre of nitrogen showed that cattle relished the fertilized plots.

63. TURNER, R. B. 1969. Vegetation changes of communities containing medusahead (*Taeniatherum asperum* (Sim.) Nevski) following herbicide, grazing, and mowing treatments. Ph.D. Thesis. Corvallis, Oregon State University. 199 p.

Although high variations resulted among herbicide treatments, frequencies of cheatgrass (*Bromus tectorum*) and medusahead were reduced after applications of atrazine (2 lb/acre) and isocil (1 lb/acre). Vigor of bluebunch wheatgrass (*Agropyron spicatum*) increased markedly from the reduction in annual plant competition. A rate of 1 1/2 lb/acre of atrazine substantially reduced the frequency of Sandberg's bluegrass (*Poa secunda*). The response of sheep to two ecological sites was clearly evident. Complete utilization of medusahead was readily attained by grazing in a *late grazed* mesic pasture, but highly ineffective even with more sheep days grazed on a xeric pasture. California oatgrass (*Danthonia californica*) plants were weakened considerably by competition from medusahead. Marked increase in vigor resulted for this perennial grass in the early-late mowed treatment. It was concluded that rapid improvement should be possible providing medusahead was removed by grazing management and late mowing on all but two of the stands studied.

64. VAN DYNE, G. M. 1962. Micro-methods of nutritive evaluation of range forages. J. Range Manage. 15:303-314.

Results of preliminary studies concerning the development and modification of techniques for *in vitro* and *in vivo* nutritive evaluation of range plants were discussed. Several types of forage samples and cellulose sources were used. Immature medusahead wild rye generally had the highest cellulose digestion values of all forages at different times of digestion.

Cellulose digestion of mature medusahead wildrye was similar to that of the mature mixed annual range forage for fermentations of greater than 24 hours.

65. WILSON, A. M., D. E. WONDERCHECK, and C. J. GOEBEL. 1974. Responses of range grass seeds to winter environments. J. Range Manage. 27:120-122.

Grass seeds enclosed in cotton-screen bags were placed 2.5 cm deep in soil in the field in November, January, or March and tested for germination at 10 degrees C in the laboratory at frequent intervals. In general, the number of days to 25 percent germination decreased with increasing exposure in the field. After one month of exposure, the order of species in decreasing germination rate was *Bromus tectorum*, *Taeniatherum asperum* (= *T. caput-medusae*), *Agropyron desertorum*, *A. sibiricum*, *A. spicatum*, and *B. inermis*. The order of seedling emergence was the same except that *T. caput-medusae* emerged before *B. tectorum*. It was concluded that seeds might be safely sown in winter or very early spring on ranges at low altitudes in the Northwest.

66. YOUNG, J. A., R. A. EVANS, and R. E. ECKERT, JR. 1968. Germination of medusahead in response to temperature and afterripening. Weed Sci. 16:92-95.

Requirements for germination of 23 medusahead (*Taeinatherum asperum* (Sim.) Nevski) selections were investigated in relation to temperature and afterripening requirements, and were compared with the germination characteristics of other grasses. Medusahead germinated best at 10 to 15 C. Germination percentages were markedly lower at 20 and 25 C. Unlike medusahead, germination of all competing or replacement species tested was markedly decreased at lower temperatures (10 C). Above 15 C, medusahead selections had strong afterripening requirements which decreased over time. Shortly after maturity, medusahead caryopses germinated only at low temperatures (10 and 15 C). Germination temperatures became less dominant after a 180-day afterripening period.

67. YOUNG, J. A., R. A. EVANS,and R. E. ECKERT JR. 1968. Germination of medusahead in response to osmotic stress. Weed Sci. 16:364-368.

Requirements for germination and rate of juvenile root and shoot elongation of 23 medusahead (*Taeniatherum asperum* (Sim.) Nevski) selections were investigated in relation to osmotic stress. These were compared with the germination and elongation characteristics of other grasses. Aqueous solutions of different osmotic pressures were obtained by dissolving polyethylene glycol in water. Successive 4-bar increases in osmotic pressure markedly reduced medusahead germination until germination terminated at 16 bars. Other grass species exhibited higher germination than medusahead under osmotic stress. Medusahead juvenile root and shoot elongation under low and moderate osmotic pressure exceeded all other species tested.

68. YOUNG, J. A., R. A. EVANS, and R. E. ECKERT JR. 1969. Population dynamics of downy brome. Weed Sci. 17:20-26.

In one series of testing in the greenhouse, siduron controlled seedlings of downy brome and medusahead but did not harm seedlings of either crested or intermediate wheatgrass.

69. YOUNG, J. A., R. A. EVANS, and R. E. ECKERT, JR. 1969. Emergence of medusahead and other grasses from four seeding depths. Weed Sci. 17:376-379.

Emergence of 23 medusahead (*Taeniatherum asperum* (Sim.) Nevski) selections from four seeding depths in two soils were investigated and compared with that of other grasses. Increased depth markedly reduced total emergence of medusahead and variability among selections. Selections of intermediate wheatgrass (*Agropyron intermedium* (Host) Beauv) and pubescent wheatgrass (*Agropyron trichophorum* (Link) Richt.) and downy brome (*Bromus tectorum* L.), among other grasses, greatly exceeded medusahead in emergence from all depths. Standard crested wheatgrass (*Agropyron desertorum* (Fisch. ex Link) Schult.) had less emergence than medusahead from all depths. The 3- and 4-inch planting depths exceeded the coleoptile length of medusahead. When medusahead emerged from these depths, the first true leaf was recurved and chlorotic.

70. YOUNG, J. A., R. A. EVANS, and R. E. ECKERT, JR. 1969. Wheatgrass establishment with tillage and herbicides in a mesic medusahead community. J. Range Manage. 22:151-155.

Intermediate wheatgrass seedlings were successfully established in a medusahead community in 1965, 1966, and 1967 with mechanical or chemical-fallow treatments. Summer fallowing by disc harrowing was the most successful treatment. The most productive wheatgrass stands suppressed but did not eliminate medusahead.

71. YOUNG, J. A., and R. A. EVANS. 1970. Invasion of medusahead into the Great Basin. Weed Sci. 18:89-97.

Characterization of soil and vegetation assemblages, many of which are infested with medusahead (*Taeniatherum asperum* (Sim.) Nevski), on the margin of the Great Basin was investigated. Interpretations of these assemblages provided an index of the validity of the basic environmental unit of this ecosystem which can be manipulated through weed control and revegetation techniques. Vertisol (churning clay soils) sites with sparse native plant communities were more susceptible to medusahead invasion than more complex low sagebrush (*Artemisia arbuscula* Nutt.) or low sagebrush-woodland communities on related clay soils. If the more complex communities were degraded to a low seral state, medusahead can invade and occupy the site. Wet meadows and burned coniferous forest sites at high elevations were the only sites where medusahead occurred on soils with textures other than clay. Big sagebrush (*Artemisia tridentata* Nutt.) communities on medium to coarse textured soils were very resistant to medusahead invasion. The restriction of medusahead to certain sites controls the mechanism of invasion and interacts with the breeding system of the species to influence its evolution.

72. YOUNG, J. A., R. A. EVANS, and B. L. KAY. 1970. Phenology of reproduction of medusahead, *Taeniatherum asperum*. Weed Sci. 18:451-454.

The phenology of reproduction was highly variable among 23 selections of medusahead (*Taeniatherum asperum* (Sim.) Nevski). Selections with markedly early and late maturity were observed. Phenology generally was consistent during four years of testing at Reno, Nevada, and during two years at Davis, California. Individual selections differed greatly in phenology between two locations. Some of the selections exhibited phenotypic plasticity in phenology when grown in competition with other weeds.

73. YOUNG, J. A., and R. A. EVANS. 1970. Weed control in wheatgrass seedbeds with siduron and picloram. Weed Sci. 18:546-549.

Pre-emergence applications of 3 lb/A of 1-(2-methylcyclohexyl)-8-phenylurea (siduron) plus 0.3 lb/A of 4-amino-3,5,6-trichloropicolinic acid (picloram) sufficiently suppressed competition from downy brome (*Bromus tectorum* L.) or medusahead (*Taeniatherum asperum* (Sim.) Nevski) and associated broadleaf species to allow marginal establishment of intermediate wheatgrass (*Agropyron intermedium* (Host.) Beauv., var. Amur) seedlings. The technique was only successful on semi-arid range sites with above-average soil moisture and moderately dense stands of weed grasses. The range in tolerance of the three species to siduron is very similar, but downy brome is slightly more susceptible than medusahead or intermediate wheatgrass. There is a significant negative relation between plant moisture stress and root length of intermediate wheatgrass plants when root elongation is suppressed by low rates of siduron.

74. YOUNG, J. A., and R. A. EVANS. 1971. Medusahead invasion as influenced by herbicides and grazing on low sagebrush sites. J. Range Manage. 24:451-454.

Responses of vegetation after herbicide applications and grazing were observed in the low sagebrush community. Removal of the shrub cover with 2,4-D did not necessarily lead to an increase in medusahead because the perennial grasses quickly made use of the released environmental potential. Spraying 2,4-D for brush control combined with application of atrazine for herbaceous weed control further increased perennial grasses when not grazed. However, when grazed, medusahead greatly increased at the expense of perennial grasses within three years following treatment.

75. YOUNG, J. A., R. A. EVANS, and B. L. KAY. 1971. Response of medusahead to paraquat. J. Range Manage. 24:41-43.

Medusahead plants from 23 sources were susceptible to paraquat at Davis, California, but resistant to applications of this herbicide at Reno and Stead, Nevada. Differences in response were not because of ecotypic variability among the sources. The differences in susceptibility between the cis and transmontane populations apparently were because of differences in unidentified characteristics of the two environments.

76. YOUNG, J. A., R. A. EVANS, and B. L. KAY. 1971. Germination of caryopses of annual grasses in simulated litter. Agron. J. 63:551-555.

A technique was developed for germinating grass caryopses in simulated litter, without the base of the caryopses in contact with a liquid moisture-supplying substrate. Litter germination of five annual species of bromegrass and medusahead differed markedly in response to temperature from 10 to 25 C, compared to germination of the same species in petri dishes. The species also differed in their rates of root elongation and root persistence under repeated drying cycles at incubation temperatures from 10 to 25 C. The differences in litter germination among annual grasses investigated may be the basis for dominance of one species over another under specific temperature regimes.

77. YOUNG, J. A., and R. A. EVANS. 1972. Conversion of medusahead to downy brome communities with diuron. J. Range Manage. 25:40-43.

Application of diuron at 2 lb/acre changed plant communities from medusahead to downy brome dominance. This conversion lasted for at least three years and greatly increased utilizable forage.

78. YOUNG, J. A., R. A. EVANS, and J. ROBINSON. 1972. Influence of repeated annual burning on a medusahead community. J. Range Manage. 25:372-375.

Three one-acre blocks were burned three consecutive years. An increase of medusahead and decrease in downy brome were observed. Changes in densities of annual grasses from burning were not a result of destroying the caryopses, but probably were caused by alteration of the seedbed environment. No changes were observed in perennial grass populations in relation to burning.