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MANAGEMENT and PRODUCTIVITY of PERENNIAL GRASSES in the NORTHEAST II. SMOOTH BROMEGRASS

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Management and Productivity of Perennial Grasses in the Northeast: II. Smooth Bromegrass

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Preface

This publication describes experiments conducted by several experiment stations in the Northeastern Region of the United States, under the auspices of Northeastern Regional Technical Committee NE-29. C. S. Brown, Maine Agricultural Experiment Station; A. M. Decker, Maryland Agricultural Experiment Station; G. A. Jung, West Virginia Agricultural Experiment Station; K. E. Varney, Vermont Agricultural Experiment Station, R. C. Wakefield, Rhode Island Agricultural Experiment Station; and M. J. Wright, New York, Cornell University, Agricultural Experiment Station were responsible for the collection, statistical analyses, and interpretation of data. A manuscript was then prepared from these station summaries by M. J. Wright. Preparation and organization of the final manuscript was the responsibility of G. A. Jung.

The authors gratefully acknowledge the contributions of Prof. B. A. Brown, Connecticut, Storrs, Agricultural Experiment Station and Drs. W. K. Kennedy and M. R. Teel, New York, Cornell University, Agricultural Experiment Station for assistance in planning the experiments; of Dr. V. G. Sprague, U.S. Regional Pasture Research Laboratory for his assistance in assembling the weather data; and of Dr. R. L. Reid, West Virginia Agricultural Experiment Station for nutritive evaluations.

SUMMARY

Experiments were conducted in six Northeastern states to test the effects of harvesting at several stages of growth, fertilizing with nitrogen at two rates and cutting the aftermath at two heights on yield, persistence and forage quality.

1. Annual yields of weed-free, oven-dry bromegrass forage ranged from less than one ton to over six tons per acre. The highest yields obtained at each location each year averaged 4.8 tons of dry matter per acre. Harvesting the first crop at progressively later growth stages increased yields markedly, as did increasing the rate of nitrogen fertilization from 100 or 150 pounds per acre to 300 or 400 pounds per acre.

2. Under certain conditions, bromegrass was observed to produce more than three tons of aftermath per acre. Timely harvesting of the spring crop resulted in aftermath yield increases of approximately 33 per cent and changing the seasonal rate of nitrogen fertilization from 100 or 150 pounds per acre to 300 or 400 pounds per acre increased yields 71 per cent.

3. Reserves, as measured by amount of etiolated regrowth, were not affected in a consistent manner by time of first crop removal or by cutting an aftermath crop at two stubble heights. Reserves in the fall were consistently low when the first crop was cut at the early head stage in conjunction with the low rate of nitrogen fertilization and cutting the first aftermath to a stubble height of 3½ inches.

4. Bromegrass stands were relatively sensitive to early harvesting of the spring crop, but this effect was variable among locations.

5. Cutting the first vegetative aftermath crop to a stubble height of 3½ instead of 1½ inches had little effect on total yields and generally only a short time effect on aftermath production except at Vermont where yields were increased 24 per cent.

6. Delaying first crop harvest beyond the full head stage of growth resulted in a large reduction in digestibility of dry matter and protein and in acceptability of bromegrass forage by sheep. Quality of aftermath crops of bromegrass appeared to be affected little by time of harvest.

Management and Productivity of Perennial Grasses in the Northeast: II. Smooth Bromegrass

REGIONAL INVESTIGATIONS concerned with the productivity and management of smooth bromegrass (**Bromus inermis** Leyss.) were initiated in the Northeastern United States in 1949 by a regional technical committee. In the first study, six varieties of bromegrass were grown alone or with legumes and compared using a pasture or a silage cutting management system (39). In later experiments bromegrass was grown in association with alfalfa or ladino clover to study the effect of varying the time of spring or fall cutting on yields of dry matter (40). Bromegrass was also used in association with alfalfa in experiments comparing band and broadcast seeding techniques (41) and in seedling management studies (43). These investigations have enabled agronomists to define the limits of usefulness of bromegrass under environmental conditions in the Northeast.

The breeding of bromegrass varieties particularly adapted to the Northeast is being conducted by the geneticists and plant breeders of Regional Technical Committee NE-28 (42). A concurrent regional project (NE-24) is concerned with variations in the nutritive value of bromegrass and other forage.

Emphasis in the previous regional management studies was logically placed on grass-legume associations that are characteristic of farm practice on croplands of the region. However, poor soil drainage, soil sites difficult to work, winter heaving losses, root and crown rot diseases, and insect damage are conditions that may suggest or dictate pure grass culture instead. Furthermore, the cost of nitrogen fertilization has changed in recent years so that farmers can consider the culture of pure grass stands with nitrogen fertilization.

Investigations reported here were designed to study the relationships between physiological and morphological plant development and management of perennial grasses. Such studies were necessary in order to determine practices most conducive to stand persistence with maximum total and aftermath production of high quality forage.

This bulletin presents the results of experiments in which stands of Lincoln smooth bromegrass at Orono, Maine; and Ithaca, New York; and stands of Saratoga smooth bromegrass at College Park, Maryland; Ithaca, New York; Kingston, Rhode Island; and Burlington, Vermont, were subject to nearly identical management for either two or three years. In addition, certain of these management treatments were imposed on stands of Lincoln bromegrass at Morgantown, West Virginia. Similar experiments were conducted simultaneously with reed canarygrass, orchardgrass, and timothy by the same regional technical committee (NE-29).

LITERATURE REVIEW

Smooth bromegrass (**Bromus inermis** Leyss.) is a rhizomatous perennial that has been adopted for forage purposes in Canada and in the United States from the Canadian border to as far south as Oklahoma. Although initial success was in the cool, sub-humid northern Great Plains, its use has spread east and south because of its drought tolerance, longevity, and productivity. A number of superior strains have been bred or recognized, named, and released. Varietal comparisons in a Northeast regional study (39) indicated that "southern types" were better adapted to the environmental conditions of the Northeast than were "northern types." Lincoln, a "southern type," was one of the first varieties introduced and remains one of the most widely used varieties in the Northeast (9), whereas Saratoga is one of the newest, having been bred in New York and made available to farmers just as the experiments reported here were begun. Bromegrass ranks far below timothy in seed useage in all twelve northeastern states, but seed sales of bromegrass are currently greater than those of orchardgrass in six of the states, and these two species rank either second or third among perennial forage grasses.

There have been studies on the adaptability, productivity, compatibility, chemical composition, nutritive value, palatability, and general suitability of smooth bromegrass at a number of experiment stations over a period of several decades. Reviews of agronomic studies on smooth bromegrass are numerous (21, 37, 56, 58, 64). In this review, attention will be centered on the effects of cutting management and nitrogen fertilization on yield, persistence, and nutritive value.

Growth Habit

The germination and emergence of smooth bromegrass follow conventional patterns (27). Seedlings of bromegrass begin to tiller shortly after emergence (21) and reach a peak of tiller formation in late summer (15). Rhizome formation begins as early as three weeks (61) or as late as six months (27) after the seedling emerges, and tends to be somewhat seasonal. Varietal differences in tiller and rhizome formation may be large if the conditions for development of individual seedlings are highly favorable, but in conventional closed stands, differences tend to be small (21, 56). In general, the rate of tiller and rhizome development is greater with plants of "southern" eco-types. The rhizome system consists of younger, whitish portions arising from older, brownish portions that are encased in papery modified leaf sheaths. The life-span of individual rhizomes is not known with certainty but is believed to be a year or less (15). Rhizomes form buds that give rise to aerial shoots and other rhizomes.

A deeply-penetrating root system is characteristic of smooth bromegrass (23, 32), although a high percentage of the root mass is located in the upper few inches of soil (18, 29).

In the mature plant, flowering stems elongate in the spring and reach anthesis by late May or early June in the northeastern United States. A second group of stems emerges from the soil about anthesis (30, 58) and elongates but does not flower. The characteristic featherlike appearance of these shoots, which have many leaves and progressively shortened internodes, is not observed in the greenhouse under long photoperiods and favorable soil conditions. Shoots that emerge late in the growing season are leafy, but the internodes do not elongate.

Cutting Management

It is well known that stands of smooth bromegrass, like those of other erect-growing grasses, persist longer and maintain maximum vigor when harvested infrequently and when cut at advanced stages of maturity (38, 39, 54). An early-stage cutting produced a depression in yields of both bromegrass and timothy in Quebec (4). Under Wisconsin conditions, Spain (56) found that bromegrass growing in association with Kentucky bluegrass and ladino clover produced the most numerous and heaviest tillers when it was allowed to reach the ripe-seed stage before a single annual cut. Spain also observed that development was severely limited by clipping each time the bromegrass reached 6 or 12 inches in height, and to a lesser extent by a schedule of clipping once at heading and at a 12-inch stage thereafter.

The yield under infrequent harvesting may be rather low even though, competitively, bromegrass is successful (56). Fortmann (16), however, obtained slightly higher yields at Ithaca, New York, from two cuts per season than from three; both of these systems produced about twice as much bromegrass as a four-cut system, regardless of whether the bromegrass was grown alone or with alfalfa. In recent years, multi-cut management systems for alfalfa-brome mixtures have proved destructive to the bromegrass in several trials (54) and have discouraged sowing of bromegrass with alfalfa where stands are to be intensively managed.

Under northeastern conditions, smooth bromegrass tends to make a larger contribution in an alfalfa-bromegrass mixture at the first harvest than in aftermath harvests. Although deficiencies of moisture or nitrogen or both have usually been held responsible, Teel (58) has suggested that one reason for scanty regrowth of bromegrass is injudicious timing of harvest. If many young shoots are decapitated by the mower that is cutting the previous crop of forage, there may be an enforced and prolonged delay before the next set of buds is ready to form topgrowth. Detailed studies at Wisconsin (45, 52, 55) of carbohydrate reserves in the storage organs of bromegrass left uncut, or cut two or three times a season, have supported the idea that bud conditions and carbohydrate reserves (mostly fructosans) combine to limit regrowth.

Eastin **et al.** (13) detected large varietal differences in yield, fructose content, and tiller weight in the regrowth of bromegrass, as well as an expected beneficial effect of delayed first harvest. They found evidence that growth regulators were active early in the stem elongation cycle, an observation which is consistent with the intervals of tillering that one observes in bromegrass (30, 56). Seven weeks after cutting, fructose content of stem bases was lowest in plants cut at the early head stage, medium in those cut at earlier stages, and highest in those cut after heading.

Fertilization with Nitrogen

Numerous experiments have confirmed that fertilization with nitrogen increases not only yield of forage and crude protein per acre (1, 5, 7, 12, 16, 53, 62, 63), but also yield of seed (6, 20), number of fertile shoots, and number of florets per panicle (14, 36, 64). The effects of nitrogen fertilizer on underground parts have been studied less often and the results have been less consistent than those obtained with aerial parts. Some experiments with underground parts indicate that nitrogen retards growth (10, 19, 64) and others indicate that it promotes growth (48) or that there is an interaction between stage of growth at harvest and nitrogen fertilization (56). Recent investigations by MacLeod (33) showed that nitrogen fertilization increased the weight of storage organs and etiolated regrowth of bromegrass.

The timing of nitrogen fertilization has also been studied repeatedly, with most results favoring spring over fall applications for maximum effectiveness and efficiency. Summer-applied nitrogen has been useful where moisture was plentiful.

The five varieties of bromegrass tested by Fortmann (16) responded similarly to six nitrogen fertilization treatments even though the V x F interaction was in some cases statistically significant.

The rates of nitrogen fertilization tested in various experiments with bromegrass have involved applications as high as 600 lbs. of N per acre per year (56). There has usually been a yield response even to the highest rates used, although Kennedy (26) noted that a combination of heavy nitrogen application and frequent cutting degraded stands to unsatisfactory levels in a single season.

Nitrogen fertilization did not appear to influence the development of bacterial blight and brown leaf spot diseases in two varieties of bromegrass grown at Madison, Wisconsin (5). Bromegrass is known to be susceptible to seedling diseases. Recent studies in Michigan (35) indicate that on organic soils a complex of root rotting diseases may thin stands as early as the second year.

Nutritive Value

Analyses of smooth bromegrass tissue range from a few determinations of individual or proximal constituents to comprehensive and detailed inventories (8). Only a few relatively recent studies of the latter kind will be cited here.

In comparisons among smooth bromegrass and seven other important perennial forage grasses harvested at several growth stages, Phillips **et al.** (46) rated bromegrass as "medium" in content of all five proximal constituents high to medium in fiber, and medium in lignin. Because data for all eight species were averaged in the paper, seasonal trends in bromegrass cannot be distinguished from the general trend. In the data on chemical composition, an abundance of highly significant interactions occurred between stage of harvest and species.

A series of research reports by Smith and associates at Wisconsin has provided comprehensive data regarding the influence of maturation on the content of major constituents (60) and micronutrients (31) in bromegrass as well as estimates of nutritive value (3). They compared alfalfa, bromegrass, ladino clover, red clover, and alfalfa-bromegrass. Van Riper and Smith found that the concentration of crude protein and carotene in bromegrass was higher in summer growth than in spring growth. Protein content of summer growth was especially high in bromegrass grown with alfalfa; under these conditions the crude protein content was in the same range as in summer forage of alfalfa or red clover. Bromegrass had the lowest content of crude fiber, however, when it was grown alone. Bromegrass grown alone was richer in fat (ether extract) content than the other forages, but the highest value recorded was less than 3.4 per cent on a dry matter basis. Percentages of nitrogen-free extract were relatively stable during maturation and uniform among species, although bromegrass grown alone ran somewhat higher than average. It was also slightly above average in ash content. Calcium content followed no clear trend, but bromegrass contained only about one-third as much calcium as the legumes of the mixture. There was a narrow range in phosphorus content among the forages; bromegrass grown in association with alfalfa was highest. In potassium content, bromegrass was generally highest.

The study of micro-nutrient content (31) ranked bromegrass very high in manganese, low in cobalt and zinc, and about average in iron and copper. All values were well above concentrations regarded as essential for plants, but for the nutrition of ruminants bromegrass grown alone tended to have too little cobalt and copper at more mature growth stages.

Bromegrass has enjoyed a reputation for nutritiousness and palatability among livestock feeders. In experiments, however, it has not always demonstrated such an advantage. Bromegrass aftermath was reported to be less nutritious than reed canarygrass aftermath in grazing studies (17) with steers. Bromegrass grown alone was the least digestible (**in vitro**) of the five forages tested at six growth stages by Baumgardt and Smith (3) one year, and among the lowest the other year. On the other hand, Pritchard **et al.** (47) found that Lincoln bromegrass was somewhat more digestible at early stages of growth than five other perennial grasses tested. There was an almost linear decline in digestibility (**in vitro**) of bromegrass during the first cycle of growth. The digestibility of the component leaf, head, and stem fractions did not decline at the same rate. The leaf fraction lost digestibility more slowly than the other two, and all three fractions were equally digestible about June 5.

The nutritive value of two varieties of bromegrass, Canada Common and Sac, was compared with Sterling orchardgrass and Climax timothy by Krueger **et al.** (28) in a trial that included both **in vivo** and **in vitro** methods, as well as chemical analyses. The two varieties of bromegrass were slightly different in relative maturity, and in protein, fiber, and lignin content. They were nearly identical in apparent digestibility (DDM). However, Canada Common, the somewhat later and less fibrous variety, was preferred by the test animals (goats). The nutritive value indexes (NVI) were not significantly different. The stage chosen for harvest, approximately 50 per cent headed, was reached May 21 by orchardgrass, May 29 by the two bromegrasses, and June 16 by timothy. Corresponding DDM values were 73.8, 70.7, 70.2, and 66.6 per cent. The differences in DDM between species were statistically significant, but differences in intake and NVI between orchardgrass and bromegrass were not. Upper internodes were more digestible **in vitro** than lower internodes, contrary to the findings of Pritchard **et al.** (47). In any shoot segment, leaf blades appeared to be most desirable chemically, stems were intermediate, and leaf sheaths were least desirable.

The merits and shortcomings of various methods of estimating nutritive value of forages, including bromegrass, continue to stimulate discussion and further experimentation. J. T. Reid included some pure bromegrass forages in the almost 100 samples from which his equation %DDM = 85.0 − 0.48 x (number of days between April 30 and harvest date) was derived (49). He reports (personal communication) that subsequent experiments with bromegrasses have verified the soundness of this relationship under conditions at New York. However, at more southerly latitudes it has been shown (50) that decline in digestibility occurs at a slower rate than at stations such as New York or Maine. The very strong year-to-year variations observed in the **in vitro** trials at Wisconsin led Baumgardt and Smith (3) and Homb (22) to rely on stage of growth to introduce a correction factor in regression equations.

Nitrogen fertilization has tended to improve the digestibility of crude protein and, to a small extent, digestible energy content of first and second cutting bromegrass at New Jersey (2, 34). Similar conclusions were drawn by Colovos **et al.** (7) from a study at New Hampshire. The increase in protein content, with increasing rates of nitrogen, was essentially linear in New Jersey (2). At the highest rate of fertilization bromegrass forage was higher in protein, and the protein was more digestible, than alfalfa with which it was compared.

More important than a decline in digestibility with an advance in maturity is the associated decline in acceptability by animals. Reid and Jung (50) found digestibility and intake to be highly correlated for Lincoln bromegrass (.94**), Climax timothy, and Potomac orchardgrass but not for Kentucky 31 tall fescue or Kentucky bluegrass. They also reported (51) that the molar percentages of acetic acid in the rumen increased as sheep consumed the first crop of bromegrass harvested at progressively later stages of maturity. Moreover, there was a highly significant negative correlation (−.95) between the nutritive value (dry matter digestibility x intake) and the concentrations of acetic acid.

In voluntary intake studies with sheep at Michigan, Ingalls **et al.** (24) and Thomas **et al.** (59) found consumption of bromegrass to exceed the consumption of reed canarygrass. However, the former group concluded that intake of bromegrass was less than that obtained with alfalfa, whereas the latter group concluded that consumption of the two species was similar.

The literature reviewed here provides fairly complete information on yields under usual field conditions, responses to major nutrients, and changes in certain chemical constituents in harvested forage. But because information on the morphology, physiology, and ecology of bromegrass is meager, the results of many field experiments, some seemingly in conflict, are beyond explanation at present.

MATERIALS AND METHODS

The experimental area at each station was located on a well- or moderately well-drained soil of medium to good fertility that had been uniformly fertilized in previous years. Approximately six months prior to seeding, each area was treated with herbicides to eliminate volunteer grasses and was limed to raise the soil pH to at least 6.5. Eighty pounds of N, 70 pounds of P, and 128 pounds of K were worked into the soil just prior to seeding. The seedings were made at all locations in 1959 (Table 1) using one seed source, and satisfactory stands were obtained except at Maine and Vermont where drought necessitated reseeding. The new stands at Maine and Vermont were cut under a lenient schedule in 1960 to permit good establishment. Vigorous stands with good ground cover were obtained at both locations by the fall of 1960. After the grass was established, broadleaf weeds were controlled with 2,4-D. Annual applications of 66 pounds of P and 240 pounds of K per acre were made during 1960, 1961, and 1962 with one-half applied in mid-

TABLE 1

Site Description and Seeding Dates

Location	Elevation (ft.)	Latitude	Growing Degree Days*	Soil Type	Variety Grown	Seeding Date (1959)
Orono, Me.	182	44° 52′	3,657	Buxton Silt Loam	Lincoln	May 13 July 8 (reseeded)
Burlington, Vt.	331	44° 28′	3,714	Hadley Fine Sandy Loam	Saratoga	May 6-7 Sept 23 (reseeded)
Kingston, R.I.	100	41° 29′	3,849	Bridgehampton Silt Loam	Saratoga	May 7
Ithaca, N.Y.	950	42° 27′	3,952	Williamson and Kibbie Silt Loam	Lincoln Saratoga	April 22-23
College Park, Md.	415	38° 59′	5,046	Sassafras Silt Loam	Saratoga	August 27
Morgantown, W. Va.	1,240	39° 39′	5,060	Cavode Silt Loam	Lincoln	May 15 Sept. 10 (overseeded)

*March 1 to September 26 with base of 40°F (11)

summer and the other half after the last harvest each fall.

In the first year, the "low-nitrogen" plots received 15 pounds per acre in early spring, 30 pounds per acre after each of the first two harvests, and 25 pounds per acre after the final fall harvest. The "high nitrogen" rates were 55, 110, and 25 pounds, respectively. For the second and third years, the low N treatments received 25 pounds of nitrogen shortly after growth began in the spring and after each harvest throughout the growing season. For the high rate, the time of application was the same, but 75 pounds of N were used except following the final fall harvest, when only 25 pounds were applied.

For the first harvest, one group of plots was uniformly cut to a 2½-inch stubble when the plants of the high nitrogen treatment were in the pre-joint (PJ) growth stage. Most of the stem tips were less than 2½ inches above the soil surface. A second group was harvested when the plants reached the early head (EH) growth stage, with heads beginning to emerge on less than 10 per cent of the plants. A third group of plots was cut when plants reached early bloom (EB), with anthers visible on less than 10 per cent of the plants. A fourth group of plots was harvested when the plants were in the past bloom (PB) growth stage, two weeks after early bloom. Dates of first and subsequent harvests at each location are given in Appendix Table 1.

Two cutting heights were imposed at the second harvest of all plots except those cut at the pre-joint growth stage. On those, the differential stubble cut was applied at the third harvest. This differential cut was made when the growing points of the aftermath tillers of bromegrass on the high nitrogen plots were between 1 and 3 inches above the soil surface. One-half of the plots were cut at a 1½-inch stubble height to remove most of the active growing points and one-half were cut at a 3½-inch stubble height to retain most of the active growing points. On harvests conducted after the differential stubble height cut, all plots were harvested at a uniform 2½-inch stubble height when the plants of the high nitrogen plots were at a late joint or retillering stage. Cutting was rarely delayed longer than six weeks regardless of grass development.

Residual treatment effects following three harvest years were determined by cutting all plots when bromegrass was in early head at Rhode Island and Maryland, early bloom at Vermont and New York, and past bloom at Maine. A uniform application of nitrogen was made on all plots in early spring of the residual harvest year.

The experimental design was a randomized complete block with three replications. All yield data, plant notes, and chemical data were taken from a basic plot of 6 x 20 feet. Adjacent plots treated in exactly the same manner as the basic plot were used for food reserve studies on Lincoln at New York.

Dry matter yields were determined and botanical composition of the forage was estimated at each location at each harvest. Botanical separations were made whenever necessary to permit accurate determination of weed-free grass yields. At each station, notes were taken throughout the study on vigor, stand density, and general appearance of the plants.

In order to measure the effect of treatment on the regrowth potential of the bromegrass, six 3-inch plugs were taken from each plot immediately following the last harvest each season and following the termination of the experiment. These plugs were uniformly trimmed and placed in a dark chamber at a temperature of 75°F. The material was kept moist and was uniformly fertilized with nitrogen. Etiolated growth was then used as a measure of plant reserves or regrowth potential (57).

In vitro digestibility determinations of selected field samples harvested in 1962 at Maine, New York, Maryland, and West Virginia were made at West Virginia University according to the method described by Jung **et al.** (25).

EXPERIMENTAL RESULTS

Total Seasonal Yields

Yields of weed-free, oven-dry bromegrass forage ranged from less than one ton per acre per year to over six tons per acre per year during the experiment (Tables 2, 3, and 4). For the entire series of trials the average yield (Appendix Table 5) was approximately 3.2 tons per acre.

Total yields tended to decline from year to year, but since the effects of management and age were confounded with those of progressively droughtier seasons, the decline is difficult to analyze. During the drier seasons responses were confined to narrow ranges and the variability of yields increased at some stations. The weed component was eliminated from the gross yields and this still further reduced the apparent differences due to treatments.

From the beginning, it was clear that delaying the first harvest raised total yield for the season. The highest yield obtained was never from plots that were cut at the pre-joint (PJ) or early head (EH) stage, even though these plots were usually cut more often than the ones cut first at anthesis (EB) or past bloom (PB). There was, moreover, a tendency for the early-cut plots at Vermont and New York to fall further behind the others in yield as the management systems were repeated. An illustration of this can be found in the data from New York. If the total seasonal yield from plots cut initially at various stages is set at 100, it can be seen that yields in successive years declined according to stages in a similar way for both varieties:

Stage at First Harvest	Year	Relative Yield	
		Lincoln	Saratoga
	1st	100	100
Pre-joint	2nd	57	65
	3rd	31	35
	1st	100	100
Early head	2nd	52	75
	3rd	37	41
	1st	100	100
Early bloom	2nd	71	89
	3rd	45	47
	1st	100	100
Past Bloom	2nd	99	94
	3rd	55	53

At West Virginia, Lincoln bromegrass was harvested at the four stages but received only one (high) level of nitrogen and one (high) stubble treatment. Yields the first year were all high, but by the third year management effects were shown dramatically:

Total Yield (T/A) of Lincoln Bromegrass

Stage at First Harvest	1960	1961	1962	Three-Year Average
Pre-joint	3.40b	3.10bc	.93bc	2.48c
Early head	4.04ab	3.00c	.38c	2.47c
Early bloom	4.32a	3.92ab	1.46b	3.23b
Past bloom	4.39a	4.56a	2.39a	3.78a

TABLE 2

Dry Matter Produced by Smooth Bromegrass in the First Harvest Year*

Stage at First Harvest	N	After-math Cut	Total Yield (T/A) Me. (L)**	Vt. (S)**	R.I. (S)	N.Y. (L)	N.Y. (S)	Md. (S)	Aftermath Yield (T/A) Me. (L)	Vt. (S)	R.I. (S)	N.Y. (L)	N.Y. (S)	Md. (S)
Pre-joint	High	High	3.19ef[1]	3.28de	2.31cd	4.07de	4.70e	3.83cde	1.29ab	1.88ab	1.66b	1.26de	2.23c	1.87ab
	High	Low	3.18ef	3.13de	1.78def	3.90e	4.59e	3.82de	1.37a	1.68ab	1.11bcd	1.13fg	1.94de	1.90ab
	Low	High	2.00g	3.01e	1.07fg	3.14f	3.38g	2.98fg	0.56ef	1.75ab	0.60de	0.58h	0.90h	1.79abc
	Low	Low	2.18g	2.28f	1.03g	3.48ef	3.37g	2.97g	0.64def	1.09de	0.59de	1.22ef	0.92h	1.30bcd
Early head	High	High	3.29ef	4.12abc	3.16b	5.70ab	5.33cd	2.90g	0.97bcd	2.04a	2.16a	2.79a	2.84b	1.49a-d
	High	Low	3.21ef	3.24de	2.56bc	5.81a	5.72bc	3.35efg	0.85cde	1.23cd	1.61b	2.96a	3.15a	1.97ab
	Low	High	2.89f	3.18de	1.66d-g	4.08de	3.89f	1.98h	0.49efg	1.27cd	0.97cde	1.63bcd	1.54f	0.95d
	Low	Low	2.95ef	3.18de	1.52efg	4.14de	3.90f	2.74g	0.77de	1.24cd	0.76cde	1.46cd	1.49f	1.65abc
Early bloom	High	High	4.77a	3.61cde	3.99a	5.69ab	6.15ab	4.27a-d	1.41a	0.45f	1.57b	1.96b	2.15cde	1.77abc
	High	Low	4.56ab	3.88a-d[2]	3.95a	5.59abc	6.08ab	4.69ab	1.18abc	0.64f	1.57b	1.77bc	2.04de	1.79abc
	Low	High	4.20bc	3.57cde	1.97cde	4.82cd	4.58e	3.76def	0.68def	0.44f	0.65de	0.90fg	1.05gh	1.17cd
	Low	Low	4.19bc	3.78bcd	1.81de	5.01bc	4.93de	3.70def	0.71def	0.45f	0.54e	0.91fg	1.06gh	1.16cd
Past bloom	High	High	4.01cd	4.46ab	4.55a	5.52abc	6.55a	5.04a	0.61def	1.37bcd	1.55b	1.73bc	2.34c	2.15a
	High	Low	4.27abc	4.28abc	3.95a	5.77ab	6.14ab	4.63abc	0.66def	1.24cd	1.29bc	1.79bc	2.16cd	2.10a
	Low	High	3.66de	4.65a	2.05cde	5.02bc	4.70e	4.16bcd	0.18g	1.02de	0.65de	0.82gh	1.10gh	1.48a-d
	Low	Low	3.57de	4.45ab	2.32cd	4.99bc	4.86de	3.90b-e	0.35fg	0.96de	0.84cde	0.79gh	1.18g	1.15cd
Averages:														
PJ			2.64u	2.93t	1.55t	3.65t	4.01t	3.35s	0.96r	1.60r	0.99s	1.05t	1.50t	1.72r
EH			3.06t	3.43s	2.23s	4.93s	4.71s	2.74t	0.77s	1.45r	1.38r	2.21r	2.26r	1.54r
EB			4.43r	3.71s	2.93r	5.28rs	5.44r	4.10r	1.00r	1.15s	1.08s	1.39s	1.58t	1.47r
PB			3.88s	4.46r	3.22r	5.33r	5.56r	4.43r	0.45t	0.49t	1.08s	1.28s	1.70s	1.72r
	High		3.81w	3.75w	3.28w	5.26w	5.66w	4.07w	1.04w	1.32w	1.57w	1.92w	2.36w	1.89w
	Low		3.20x	3.51x	1.68x	4.34x	4.20x	3.25x	0.55x	1.03x	0.70x	1.04x	1.16x	1.33x
		High	3.49y	3.74y	2.60y	4.76y	4.91y	3.62y	0.77y	1.28y	1.23y	1.46y	1.77y	1.60y
		Low	3.52y	3.53y	2.36z	4.84y	4.95y	3.70y	0.82y	1.07z	1.04z	1.50y	1.73y	1.63y
C. V.%			8.0	10.8	16.0	9.0	5.7	11.2	23.8	25.2	25.7	15.2	8.0	20.5

*Me. and Vt. 1961, other stations 1960

**Lincoln (L) Saratoga (S)

[1]Values having the same letter are from the same statistical population at the 5 per cent level of significance. Comparisons may be made within each column.

[2](a-d) means includes a, b, c, and d

TABLE 3

Dry Matter Produced by Smooth Bromegrass in the Second Harvest Year*

Stage at First Harvest	N	Aftermath Cut	Total Yield (T/A)						Aftermath Yield (T/A)					
			Me. (L)**	Vt. (S)**	R.I. (S)	N.Y. (L)	N.Y. (S)	Md. (S)	Me. (L)	Vt. (S)	R.I. (S)	N.Y. (L)	N.Y. (S)	Md. (S)
Pre-joint	High	High	2.74c[1]	1.74ef	3.91b	2.56de	2.94e	3.79cd	0.98ab	1.17cde	2.12a	0.45gh	1.40e-h	2.38a
	High	Low	2.35cd	1.30fg	3.57b	2.45de	3.22de	3.03ef	0.97ab	0.86efg	2.24a	0.64e-h	1.47d-g	1.99b
	Low	High	1.55ef	1.37fg	2.27cde	1.72f	2.07f	2.59fg	0.39ef	0.87efg	1.65bc	0.39h	0.74i	1.53cd
	Low	Low	1.33ef	0.81g	1.89de	1.64f	2.24f	2.47g	0.24f	0.57g	1.34cde	0.44gh	0.96hi	1.52cde
Early head	High	High	1.71de	3.11cd	3.58b	2.90d	4.30bc	4.46b	0.54c-f[2]	1.97a	1.69bc	1.26bc	2.41a	2.70a
	High	Low	1.87de	2.06ef	3.35bc	2.92d	3.98bc	4.16bc	0.63b-f	1.51bc	1.87ab	1.12cd	2.05ab	2.37a
	Low	High	1.54ef	1.74ef	1.67e	2.47de	3.00e	2.50g	0.30ef	1.10de	0.90ef	1.07cd	1.74b-f	1.51cde
	Low	Low	0.92f	1.46fg	2.01de	2.05ef	2.97e	2.48g	0.24f	0.98ef	1.18de	0.85def	1.61b-g	1.43de
Early bloom	High	High	3.76a	3.87abc	5.35a	4.68bc	5.70a	4.69b	0.93abc	1.74ab	1.45bcd	1.14cd	1.90bcd	1.93b
	High	Low	3.69ab	2.11ef	5.23a	4.27c	5.64a	4.50b	1.19a	0.94efg	1.28cde	0.80d-g	1.79b-e	1.75bcd
	Low	High	2.97bc	2.56de	3.01bcd	3.03d	4.20bc	2.94efg	0.51def	1.05e	0.68f	0.50fgh	1.51c-g	1.19ef
	Low	Low	1.85de	1.97ef	2.82bcd	3.06d	3.86cd	2.65fg	0.30ef	0.65fg	0.57f	0.61fgh	1.29gh	1.06f
Past bloom	High	High	3.80a	4.15ab	5.22a	5.83a	6.03a	5.45a	0.70b-e	1.47bcd	1.33cde	1.75a	1.96b	1.82bc
	High	Low	3.68ab	4.43a	5.43a	5.78a	5.90a	5.48a	0.88a-d	1.54b	1.39cd	1.52ab	1.93bc	1.84bc
	Low	High	3.05abc	3.33bcd	3.33bc	5.03b	4.62b	3.26de	0.26f	0.84efg	0.63f	1.11cd	1.34fgh	0.92f
	Low	Low	2.72c	3.03cd	3.27bc	4.42bc	4.42bc	3.41de	0.36ef	0.87efg	0.54f	0.99cde	1.38e-h	1.10f
Averages:														
PJ			1.99s	1.30u	2.91s	2.09u	2.62u	2.97u	0.64r	0.87t	1.84r	0.48u	1.14t	1.86r
EH			1.51t	2.09t	2.65s	2.58t	3.56t	3.40t	0.43s	1.39r	1.41s	1.08s	1.95r	2.00r
EB			3.07r	2.63s	4.10r	3.76s	4.85s	3.69s	0.73r	1.10s	0.99t	0.76t	1.62s	1.48s
PB			3.31r	3.73r	4.31r	5.27r	5.24r	4.40r	0.55rs	1.18s	0.97t	1.29r	1.65s	1.42s
	High		2.95w	2.84w	4.35w	3.92w	4.71w	4.44w	0.85w	1.40w	1.67w	1.09w	1.86w	2.10w
	Low		1.99x	2.04x	2.64x	2.93x	3.42x	2.79x	0.32x	0.87x	0.93x	0.75x	1.32x	1.28x
		High	2.64y	2.73y	3.65y	3.53y	4.11y	3.71y	0.58y	1.28y	1.31y	0.96y	1.63y	1.75y
		Low	2.30z	2.15z	3.34y	3.32y	4.03y	3.52z	0.60y	0.99z	1.30y	0.87y	1.56y	1.63z
C.V%			16.9	18.9	17.6	10.7	9.1	7.6	37.7	17.0	18.5	21.6	14.9	10.6

*Me. and Vt. 1962, other stations 1961
**Lincoln (L) Saratoga (S)
[1]Values having the same letter are from the same statistical population at the 5 per cent level of significance. Comparisons may be made within each column.
[2](c-f) means includes c, d, e and f

TABLE 4

Dry Matter Produced by Smooth Bromegrass in the Third Harvest Year

Stage at First Harvest	N	Aftermath Cut	Total Yield (T/A)				Aftermath Yield (T/A)			
			R.I. (S)*	N.Y. (L)*	N.Y. (S)	Md. (S)	R.I. (S)	N.Y. (L)	N.Y. (S)	Md. (S)
Pre-joint	High	High	2.40b[1]	0.92f	1.49ef	3.02de	1.68ab	0.47a-d	0.47d	1.27ab
	High	Low	2.25bc	1.32def	1.35f	2.38f	1.53abc	0.48a-d	0.50d	1.29ab
	Low	High	1.24ef	1.22def	1.37f	1.65i	0.83de	0.30cd	0.44d	1.02c
	Low	Low	1.06f	1.02ef	1.36f	1.66i	0.70ef	0.19d	0.53d	1.02c
Early head	High	High	2.68b	1.97b-e[2]	2.00c-f	3.37cde	1.72ab	0.66abc	0.93abc	1.39a
	High	Low	2.57b	1.74c-f	2.22b-f	2.95e	1.87a	0.77a	1.12a	1.28ab
	Low	High	1.29ef	1.83c-f	1.58ef	1.55i	0.89de	0.61abc	0.56d	0.78d
	Low	Low	1.30ef	1.78c-f	1.82def	1.79hi	0.92de	0.57a-d	0.76bcd	1.08bc
Early bloom	High	High	3.96a	2.76abc	2.62a-d	3.55abc	1.54abc	0.75ab	0.65cde	1.10bc
	High	Low	4.12a	2.57abc	3.10ab	3.42bcd	1.56abc	0.56a-d	1.01ab	1.18abc
	Low	High	2.20bc	2.14bcd	2.33a-e	1.85ghi	0.93de	0.37bcd	0.46d	0.67de
	Low	Low	1.81cd	2.00b-e	2.24b-f	1.86ghi	0.57ef	0.32cd	0.45d	0.73d
Past bloom	High	High	3.72a	3.41a	3.10ab	3.98a	1.17cd	0.76ab	0.61cd	1.09bc
	High	Low	3.81a	2.96ab	3.14a	3.85ab	1.35bc	0.72ab	0.63cd	1.22abc
	Low	High	1.65de	2.72abc	2.82abc	2.28fg	0.38f	0.54a-d	0.34e	0.53e
	Low	Low	1.66de	2.61abc	2.79abc	2.19fgh	0.53ef	0.43a-d	0.35e	0.61de
Averages:										
PJ			1.74u	1.12u	1.39u	2.18u	1.19s	0.36t	0.49t	1.15r
EH			1.96tu	1.83t	1.91t	2.42t	1.35r	0.65r	0.84r	1.13r
EB			3.02r	2.37s	2.57s	2.67s	1.15s	0.47st	0.64s	0.92s
PB			2.71s	2.93r	2.96r	3.08r	0.86t	0.61rs	0.48t	0.86s
	High		3.19w	2.21w	2.38w	3.32w	1.55w	0.65w	0.74w	1.23w
	Low		1.53x	1.92w	2.04x	1.85x	0.72x	0.42x	0.49x	0.79x
		High	2.39y	2.12y	2.16y	2.66y	1.14y	0.56y	0.56y	0.97z
		Low	2.32y	2.00y	2.25y	2.51z	1.13y	0.51y	0.67y	1.05y
C.V.%			11.7	27.0	21.1	9.7	19.0	40.4	31.2	11.3

*Saratoga (S) Lincoln (L)

[1]Values having the same letter are from the same statistical population at the 5 per cent level of significance. Comparisons may be made within each column.

[2](b-e) means includes b, c, d and e

Fertilization with nitrogen at the heavier rate produced an average increase in yield of about 20 per cent in Vermont, 25 per cent in Maine, 25-30 per cent in New York, 50 per cent in Maryland, and 90 per cent in Rhode Island. This order of response is in accord with ability of soils to supply nitrogen from organic matter, and also with limitations imposed by drought in Vermont, Maine, and New York. Again, the confounding of two influences interfered with meaningful interpretation. But it is clear that at Rhode Island, where moisture was fairly abundant, the lack of nitrogen limited the growth of bromegrass. Deficiencies were noted late in the season at other stations also, and rate of nitrogen fertilization was therefore increased in 1961 at all locations.

Differential height of cutting one aftermath growth the first year had very little effect on total seasonal yields. Where there was a statistically significant advantage, it lay with the high or apex-sparing cutting system.

The extra nitrogen was most productive of extra yield at Maine and New York in the first harvest season on plots cut early. In Rhode Island and Maryland, however, the additional nitrogen was most beneficial on plots cut late.

At Rhode Island (first season) and Maryland (second and third seasons), the response to nitrogen was influenced considerably by cutting height. Cutting the aftermath to 1½ inches was most adverse when combined with the high rate of nitrogen and first harvest at the pre-joint stage. Yields were 25-30 per cent higher in plots cut at 3½ inches rather than at 1½ inches.

Aftermath Yields

One of the principal objectives of the experiment was the redistribution of yield during the growing season. One measure of success in this attempt is the quantity of aftermath obtained. Yields of weed-free, oven-dry aftermath forage are reported in Tables 2, 3, and 4.

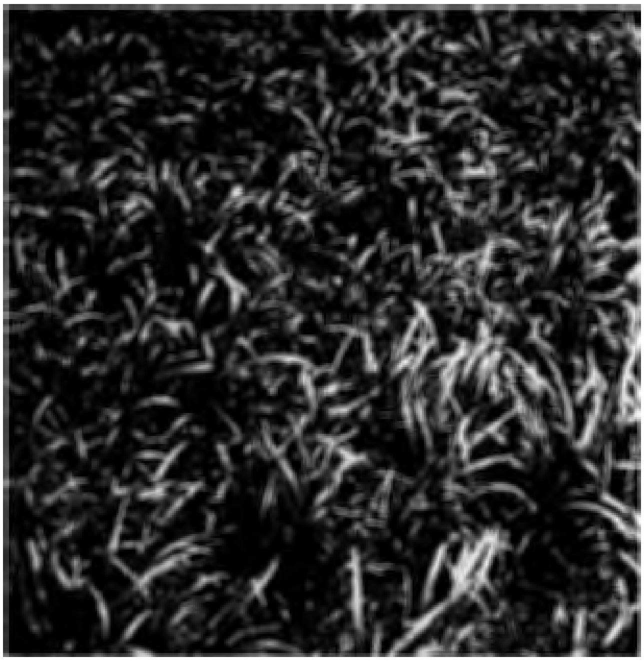
The reader should bear in mind that aftermath yields reported for the pre-joint treatment are totals for the third and any subsequent harvests, whereas yields listed under other stages are totals for the second and subsequent harvests. This distinction was adopted for the pre-joint treatment because the differential height of cut, which was the principal tool in attempted redistribution, was necessarily delayed until the third cutting. For the pre-joint treatment, the first cut was made at a pre-joint stage and the second when the same crop of stems was heading. In other plots, cuts above or below the apex level, in the regrowth, could be made at the second harvest since the first crop of stems was removed in the first cut. In terms of dates, then, the "aftermath" reported here for grass cut at the pre-joint stage began to grow later in the season than did the aftermath for grass cut at early head. Because of the adverse effects of summer heat and drought, this difference may be important.

The aftermath yield tables contain values as large as 3 tons and as small as 0.2 tons. Although there were one or more instances where highest yields of aftermath followed an initial harvest at each of the four stages, in most cases large yields in summer and fall came from plots where cutting started early (pre-joint or early head).

Increasing the rate of fertilization with nitrogen was effective in raising yields of aftermath at each location each year. Most increases ranged from 50 to 100 per cent. Considering the quantity of nitrogen applied however, the increase in tonnage was small, reaching a ton in only one case. Nevertheless, it should be noted that this can be attributed in part to drought. Furthermore, it was noted at Maryland that bromegrass responded better to the additional nitrogen than did orchardgrass under dry conditions.

In a few instances, there was a favorable response to the apex-sparing management. Such was the case at Vermont where aftermath yields were increased 24 per cent. Also, this is vividly illustrated in photographs of Maryland plots (Figure 1) and in a graphic portrayal of dry matter production at New York (Figure 2). The yield advantage (Figure 2) from cutting to a stubble height of 1½ inches rather than 3½ inches was usually compensated for in the following harvest.

Extra plots at New York were cut each spring at an early jointing stage of growth. It was the-



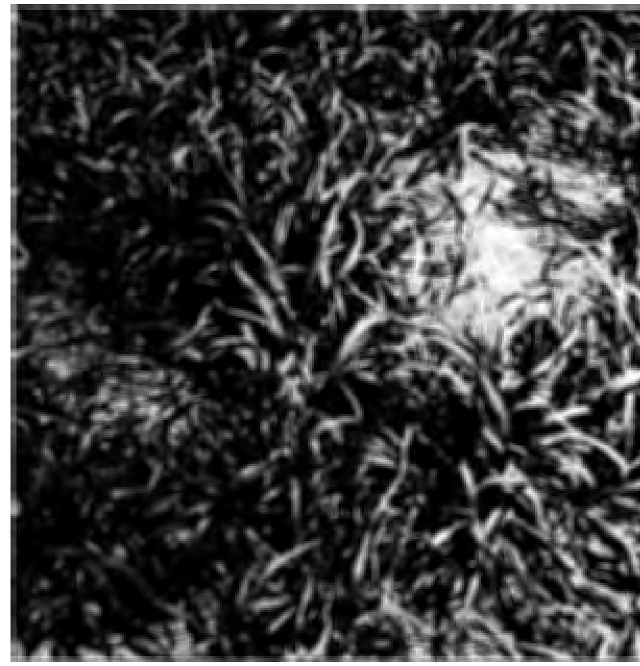


Figure 1. Aftermath of Saratoga bromegrass (Maryland, 1962) fertilized at the high rate of nitrogen and cut each spring at the pre-joint stage of growth. The stubble height at the third harvest was 3½ inches in Figure 1-A (left) and 1½ inches in Figure 1-B.

orized that food reserves would be depleted more at this stage of growth than at either the pre-joint or early head stage of growth. Plots first cut at early jointing and then cut high yielded three times as much as their counterparts in the third harvest, and some benefit persisted until the end of the season.

The two cutting treatments and two nitrogen fertilizer rates interacted more noticeably on aftermath yields than on total yields. These interactions were statistically significant in several cases at Rhode Island and Maryland. In one-half of all observations it was shown that effectiveness of nitrogen fertilization was dependent upon time of first harvest. Influence of nitrogen was usually greatest when the first harvest was taken at early head; although in a few instances, it was advantageous to delay cutting even longer.

Estimation of Reserves

The average weight of regrowth produced in the dark by sod plugs taken from all plots of Lincoln bromegrass at Ithaca, New York, is summarized in Table 5, together with a tabulation of significant tests. In 1960, 1961, and 1962 the plugs were collected in October, and in 1963 they were collected in June following a residual harvest.

Reserves in the fall were consistently low when the first harvest had been taken at early head in conjunction with the low rate of nitrogen and the cutting of the first aftermath at 3½ inches. The higher level of nitrogen was associated with better regrowth in the dark in all three years of differential management, but the benefit was rather small. It is difficult to account for many of the differences observed because of their inconsistency from year to year. As an example, the effect of leaving a high stubble was to produce more regrowth in the dark in 1960, but in 1961 this treatment had no effect on regrowth and in 1962 it was markedly unfavorable.

Variability in etiolated regrowth measurements taken after a residual harvest was so great (C.V. 83 per cent) that relatively large differences among treatments were non-significant.

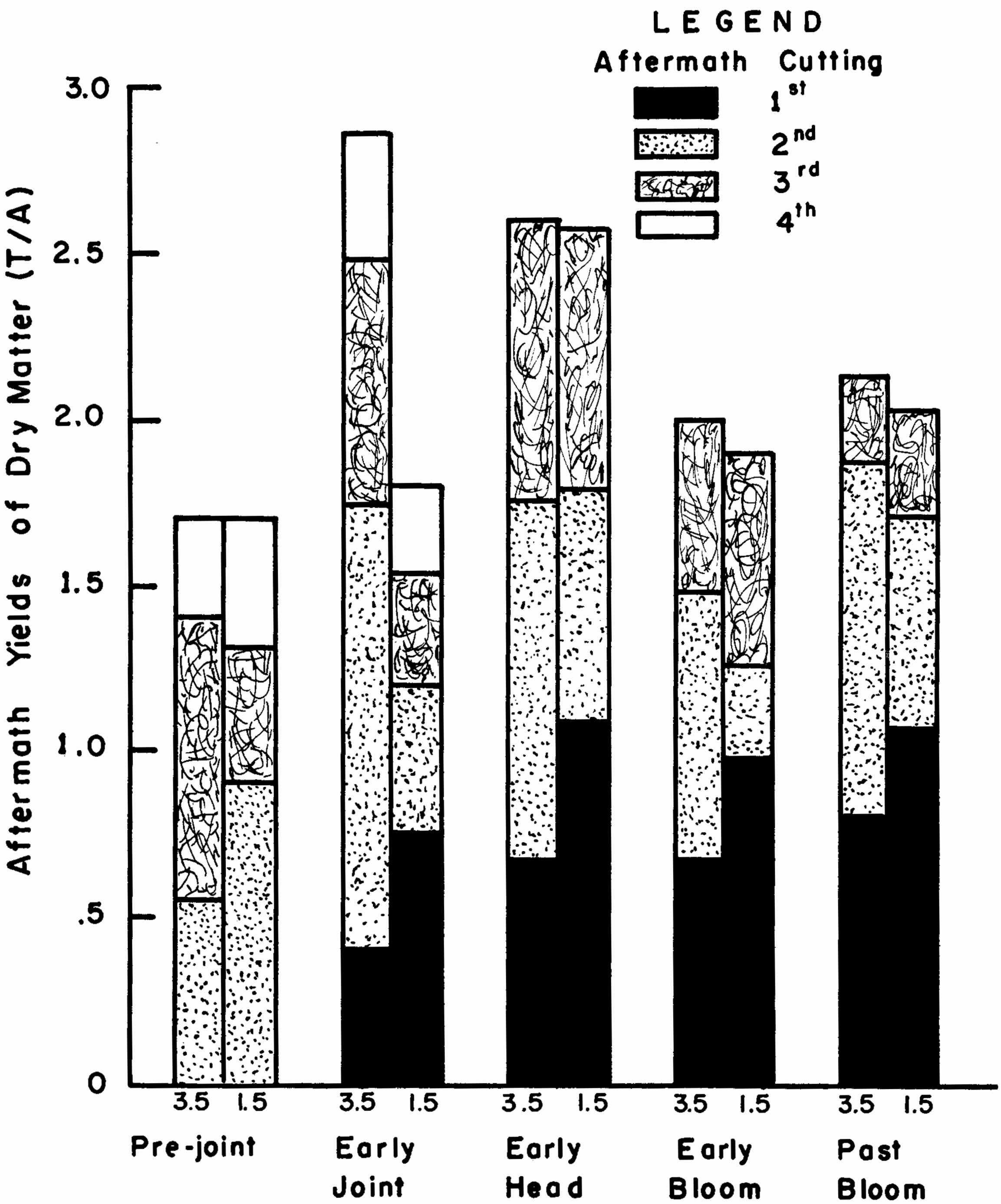


Figure 2. Seasonal distribution of aftermath yields of Saratoga bromegrass at New York in 1960-61.

Stands

Stands were rated according to per cent ground cover each spring. Ratings in Tables 6, 7, and 8 are those following the previous year's management schedule. They do not include the ratings made at the beginning of the trial when the stands were relatively uniform.

TABLE 5

Growth Produced in the Dark by Lincoln Bromegrass at New York

Stage at First Harvest	N	Cutting Height	Etiolated dry weight (mg) produced per three-inch plug following: Fall Harvests 1960	1961	1962	Residual Harvest 1963
Pre-joint	High	High	313a[1]	126ab	134a	70a
	High	Low	225bcd	110abc	159a	64a
	Low	High	238bc	135a	93a	49a
	Low	Low	193def	107abc	154a	54a
Early head	High	High	178ef	119abc	145a	39a
	High	Low	182def	113abc	154a	73a
	Low	High	158f	78c	102a	58a
	Low	Low	199cde	82bc	169a	60a
Early bloom	High	High	316a	118abc	136a	42a
	High	Low	200cde	116abc	173a	47a
	Low	High	230bcd	118abc	121a	62a
	Low	Low	197c-f[2]	102abc	148a	29a
Past bloom	High	High	214b-e	121abc	145a	46a
	High	Low	212b-e	135a	154a	73a
	Low	High	242b	85bc	144a	44a
	Low	Low	220bcd	88bc	101a	39a
Averages:						
PJ			242r	120r	135r	59r
EH			179t	98s	143r	58r
EB			236rs	114rs	145r	45r
PB			222s	107rs	136r	51r
	High		230w	120w	150w	57w
	Low		210x	99x	141x	49w
		High	236y	113y	128z	51y
		Low	204z	107y	152y	55y

[1]Values having the same letter are from the same statistical population at the 5 per cent level of significance. Comparisons may be made within each column.
[2](c-f) means includes c, d, e and f

Thinning of stands was rapid at Maine and New York and almost imperceptible at Maryland. When thinning occurred, it was influenced by the management applied. The plots that were cut at advanced stages maintained better stands than those that were cut first at the pre-joint or early head stage each year. The injurious effect of early defoliation was especially pronounced at Maine. Nitrogen fertilization at the higher rate was associated with thinner stands in many instances. Cutting the aftermath closely was unfavorable at Rhode Island and Maryland.

A set of photographs taken at Rhode Island illustrates the cumulative effects of first harvest management early in the third year (Figure 3). All four plots received the same aftermath cutting management. The stand in the first photograph (Figure 3A) was badly thinned, whereas the stand in Figure 3B was moderately thick, although the only difference in management was a two-week delay of the first cutting. Good stands were found in plots cut just as early (Figure 3C) or even earlier (Figure 3D), provided the lower rate of nitrogen was used. The combination of an early first cut and heavy nitrogen fertilization was undesirable to a lesser extent at other locations. This confirms the observations made by Kennedy (26). The combination of an early first cut and a high rate of nitrogen was sometimes made even more undesirable by close cutting. This was particularly true at Maryland.

Thinning of stands was not continuous in all cases. At both Rhode Island (Table 8) and West Virginia (data not presented), there was

TABLE 6

Stand Ratings of Smooth Bromegrass in the Spring of the Second Harvest Year

Stage at First Harvest	N	Aftermath Cut	Stand Rating (1 = 10%, 10 = 100% Ground Cover)				
			Me. (L)	R.I. (S)	N.Y. (L)	N.Y. (S)	Md. (S)
Pre-joint	High	High	4.0bc[1]	8.3abc	6.3cde	7.0ab	7.3cde
	High	Low	3.7c	6.0d	6.3cde	6.7abc	4.3g
	Low	High	4.0bc	8.3abc	6.3cde	6.3bc	9.3a
	Low	Low	3.7c	7.0cd	5.3e	6.0c	9.0ab
Early head	High	High	4.3bc	7.0cd	6.3cde	6.3bc	8.0a-d[2]
	High	Low	4.3bc	6.3d	6.0de	6.3bc	8.0a-d
	Low	High	5.3ab	8.3abc	6.0de	6.3bc	8.3a-d
	Low	Low	4.3bc	8.0bc	6.0de	6.3bc	9.0ab
Early Bloom	High	High	5.7a	9.0ab	7.3abc	7.3a	6.3ef
	High	Low	5.7a	8.6ab	7.3abc	7.0ab	5.7fg
	Low	High	6.0a	8.3abc	7.0bcd	6.7abc	8.3a-d
	Low	Low	5.3ab	8.3abc	6.7cd	6.3bc	8.7abc
Past bloom	High	High	5.7a	9.7ab	8.3a	7.0ab	7.7b-e
	High	Low	5.7a	9.0ab	8.0ab	7.0ab	7.0def
	Low	High	6.0a	9.3ab	7.3abc	6.7abc	8.7abc
	Low	Low	5.0abc	9.7ab	7.3abc	6.3bc	8.3a-d
Averages:							
PJ			3.8s	7.4t	6.1t	6.5rs	7.5s
EH			4.6rs	7.4t	6.1t	6.4s	8.3r
EB			5.7r	8.6s	7.1s	6.8r	7.2s
PB			5.6r	9.4r	7.8r	6.8r	7.9rs
	High		4.9w	8.0w	7.0w	6.8w	6.8x
	Low		5.0w	8.4w	6.5x	6.4x	8.7w
		High	5.1y	8.5y	6.8y	6.7y	8.0y
		Low	4.7y	7.9z	6.6y	6.5y	7.5z
C. V.%			14.6	10.1	4.5	3.4	13.6

[1]Values having the same letter are from the same statistical population at the 5 per cent level of significance. Comparisons may be made within each column.

[2](a-d) means includes a, b, c and d

a marked improvement between spring 1962 and spring 1963. With a lenient cutting management on all plots during two subsequent years, stand differences disappeared at West Virginia. At Maryland, the stands seemed to be thickening throughout the study.

Thinning of stands is undesirable mainly because it may limit yields or encourage invasion by weeds. The relationship between stand and yield was tested by a uniform stage of harvest at the conclusion of the experiment. This relationship is discussed in the section on "Residual Effects." Weed encroachment is described in the section which follows.

Weed Infestations

Adulteration of the forage with unsown species is indicated in Table 9, which reports percentages of bromegrass in first-harvest samples at two stations. It is clear that the most nearly pure bromegrass stands were those allowed to mature before the first cut. Regular use of 2,4,-D suppressed invasion by broadleaf weeds. The grasses that invaded were both annual and pe-

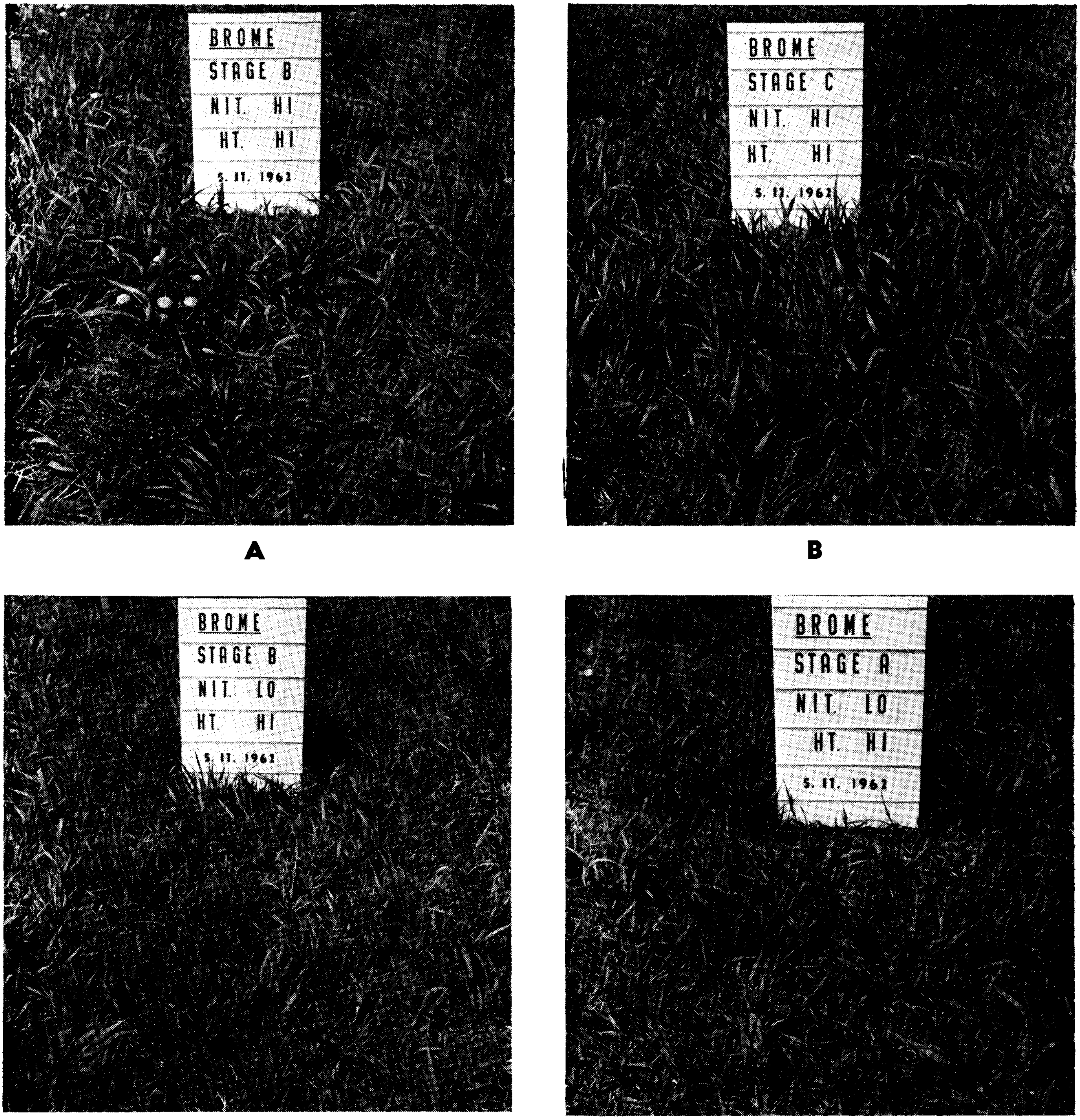


Figure 3. Aftermath of Saratoga bromegrass grown at Rhode Island in 1962. *Bromegrass in Figure 3-A was cut at early head each spring, and that in Figure 3-B was cut at early bloom. The high rate of nitrogen fertilizer was used on both stands. Bromegrass in Figure 3-C was cut at early head, and that in Figure 3-D was cut at the pre-joint stage of growth. The low rate of nitrogen fertilizer was used on both stands.*

rennial. The bromegrass plots at Connecticut had to be dropped from the experiment after one year of cutting because of an infestation of downy bromegrass. Cutting treatments that thinned the stands also promoted contamination by weedy grasses.

TABLE 7

Stand Ratings of Smooth Bromegrass in the Spring of the Third Harvest Year

Stage at First Harvest	N	After-math Cut	Stand Ratings (1 = 10%, 10 = 100% Ground Cover) R.I. (S)	N.Y. (L)	N.Y. (S)	Md. (S)
Pre-joint	High	High	3.0fg[1]	3.7ab	2.7ab	7.8bcd
	High	Low	2.7fg	4.0ab	2.7ab	4.8e
	Low	High	7.3a-d[2]	4.0ab	3.3ab	8.7abc
	Low	Low	6.3bcd	3.7ab	3.3ab	8.8abc
Early head	High	High	4.0ef	3.0b	2.0b	8.3a-d
	High	Low	1.3g	4.3ab	2.3b	8.0bcd
	Low	High	8.0ab	5.3ab	4.3ab	9.0ab
	Low	Low	5.3de	4.7ab	3.0ab	8.7abc
Early bloom	High	High	6.7a-d	4.7ab	3.0ab	7.0cd
	High	Low	5.7cde	3.3ab	2.3b	6.3d
	Low	High	8.7a	4.3ab	4.3ab	9.0ab
	Low	Low	7.7abc	3.7ab	3.7ab	9.3a
Past bloom	High	High	7.3a-d	5.7a	3.0ab	8.7abc
	High	Low	7.3a-d	5.0ab	4.0ab	8.5a-d
	Low	High	8.3ab	5.3ab	5.0a	9.5a
	Low	Low	8.7a	5.3ab	5.4a	9.0ab
Averages:						
PJ			4.8s	3.8s	3.0r	7.5s
EH			4.7s	4.3rs	2.9r	8.5rs
EB			7.2r	4.0s	3.3r	7.9s
PB			7.9r	5.3r	4.1r	8.9r
	High		4.8x	4.1w	2.7x	7.4x
	Low		7.5w	4.6w	3.9w	9.0w
		High	6.7y	4.5y	3.5y	8.5y
		Low	5.6z	4.2y	3.1y	7.9z
C. V. %			18.5	14.5	14.8	8.2

[1]Values having the same letter are from the same statistical population at the 5 per cent level of significance. Comparisons may be made within each column.
[2](a-d) means includes a, b, c and d

The effect of nitrogen was not the same at the two stations. At Vermont the principal problem was annual grasses, especially crabgrass. This was controlled in the spring of the second year with the herbicide Zytron. At New York, in the plots that were cut early there was a sudden, brief dominance of yellow foxtail in mid-summer of the first harvest year (Figure 4). Lesser amounts appeared in the late-cut plots, and virtually none in the orchardgrass plots nearby. Foxtail was never more than a minor constituent in the New York plots in the years that followed, but both Kentucky bluegrass and quackgrass made rapid invasion, the former in plots where the lower rate of nitrogen was used and the latter where the heavier rate was used. These grasses were not present in all plots initially and although they tended to spread to, and occasionally across plot boundaries, there were some plots with rather thin stands of bromegrass which remained virtually weed-free to the end of the trial.

Weediness was reduced at the conclusion of the experiment at New York if the uniform early-bloom harvest made then was later than the one (PJ, MJ, or EH) used in the three years preceding. In Vermont, on the contrary, the forage harvested at the end of the trial was generally weedier than it had been in the previous year. Previous height of cutting aftermath had a considerable effect on terminal weediness in Vermont, but not in New York.

Figure 4. Yellow foxtail (Setaria) *invasion of bromegrass plots at New York in* 1960.

Residual Effects of Management

A single harvest at a specific growth stage was made on all plots at the conclusion of the experiment to measure residual effects of two or three years of various management systems on yield. A small uniform application of nitrogen was made in the spring. The yields obtained at this residual harvest are reported in Table 10. Lower yields were frequently associated with harvesting previously at pre-joint [Maine, Vermont, Rhode Island, New York, (L)] or early head (Maine, Rhode Island) stages.

When the general deterioration of stands under early cut and high nitrogen fertilization is considered, it is remarkable that yields were rather uniform over all treatments. The largest and most consistent (except New York) residual treatment effect was in favor of previous heavy applications of nitrogen, presumably because some available nitrogen carried over and stimulated growth in the final year.

In both Maine and Vermont, residual yields suggested complex interactions of previous management treatments; but the most favorable combinations at Maine were not always most favorable at Vermont.

TABLE 8

Stand Ratings of Smooth Bromegrass in the Spring of the Residual Harvest Year

Stage at First Harvest	N	After-math Cut	Stand Ratings (1 = 10%, 10 = 100% Ground Cover)				
			Me. (L)	R.I. (S)	N.Y. (L)	N. Y. (S)	Md. (S)
Pre-joint	High	High	1.7cd[1]	5.3de	2.3b	2.3de	8.5cd
	High	Low	2.0cd	5.0e	3.0b	2.0e	7.3f
	Low	High	1.0d	7.7a-d[2]	3.3ab	3.0bcd	9.3ab
	Low	Low	1.3d	7.0a-e	2.7b	3.0bcd	9.2abc
Early head	High	High	1.7cd	5.3de	2.7b	2.3de	8.2de
	High	Low	1.7cd	6.0c-e	3.3ab	2.3de	8.5cd
	Low	High	1.3d	6.7a-e	4.3a	3.3abc	9.3ab
	Low	Low	1.0d	6.3b-e	3.3ab	2.7cde	9.0abc
Early bloom	High	High	2.7bc	9.0a	3.3ab	2.0e	8.7bcd
	High	Low	3.3ab	8.3abc	3.3ab	3.0bcd	7.8ef
	Low	High	4.0a	9.0a	3.3ab	3.3abc	9.0abc
	Low	Low	4.0a	8.0abc	3.0b	3.7ab	9.3ab
Past bloom	High	High	4.3a	7.3a-d	3.0b	2.7cde	8.8a-d
	High	Low	4.0a	7.3a-d	3.3ab	3.3abc	9.2abc
	Low	High	4.3a	8.3abc	4.3a	4.3a	9.5a
	Low	Low	4.0a	8.7ab	4.3a	3.3abc	9.3ab
Averages:							
PJ			1.5s	6.3s	2.8s	2.6s	8.6s
EH			1.4s	6.1s	3.4r	2.7s	8.8s
EB			3.5r	8.6r	3.2rs	3.0rs	8.7s
PB			4.2r	7.9r	3.7r	3.4r	9.2r
	High		2.7w	6.7x	3.6w	2.5x	8.4x
	Low		2.6w	7.7w	3.0x	3.3w	9.2w
		High	2.6y	7.3y	3.3y	2.9y	8.9y
		Low	2.7y	7.1y	3.3y	2.9y	8.7z
C. V. %			25.1	16.7	9.3	8.7	4.3

[1]Values having the same letter are from the same statistical population at the 5 per cent level of significance. Comparisons may be made within each column.
[2](a-d) means includes a, b, c and d

Nutritive Value

The digestibility of dry matter and crude protein of certain 1962 samples from Maine, New York, Maryland, and West Virginia were estimated at West Virginia with **in vitro** techniques (25). Results of these tests are reported in Table 11 and Figure 5. Lincoln bromegrass was generally inferior to Saratoga in dry matter digestibility at the later stages of growth and in protein digestibility of aftermath at New York. Digestibility of dry matter for Lincoln bromegrass was generally higher at Maine and New York than at West Virginia, whereas digestibility of protein for these samples was similar. Digestibility of dry matter and protein of Saratoga bromegrass aftermath was generally higher at Maryland than at New York.

The steep decline in values from stage to stage in the first crop and the small changes in the aftermath were as expected. The first aftermath of pre-joint harvesting was stemmy, headed material and its nutritive value was correspondingly low. Dry matter production per acre was found to increase over all growth stages, whereas digestible dry matter per acre did not increase after early bloom (Figure 5).

Studies on the nutritive value of Lincoln bromegrass at West Virginia (50, 51) show the importance of timely harvesting in the spring

TABLE 9

Bromegrass Content of First-Harvest Forage from Plots Receiving Different Management Schedules (Figures are Visual Estimates of Percentage by Weight)

			New York								Vermont		
			Lincoln				Saratoga				Saratoga		
Stage at First Harvest	**N**	**After-math Cut**	**1**	**2**	**3**	**R**	**1**	**2**	**3**	**R**	**1**	**2**	**R**
Pre-joint	High	High	100	96	27	55	100	97	44	71	100	61	56
	High	Low	100	96	40	62	100	98	49	62	100	30	38
	Low	High	100	95	32	70	100	94	53	76	100	54	45
	Low	Low	100	95	28	65	100	95	47	86	100	25	22
Mid-joint	High	High	100	94	63	68	100	98	70	76			
	High	Low	100	89	45	53	100	88	52	62		not	
	Low	High	100	91	58	72	100	92	48	83		included	
	Low	Low	100	87	52	68	100	85	45	80			
Early head	High	High	100	87	75	53	100	92	63	70	100	90	77
	High	Low	100	90	60	60	100	95	68	65	100	81	61
	Low	High	100	85	88	80	100	80	73	82	100	70	59
	Low	Low	100	77	78	78	100	85	75	87	100	59	41
Early bloom	High	High	100	95	70	70	100	99	77	62	100	99	77
	High	Low	100	95	68	75	100	93	85	83	100	78	49
	Low	High	100	93	85	77	100	93	85	80	100	92	66
	Low	Low	100	87	87	72	100	91	88	82	100	87	34
Past bloom	High	High	100	96	87	70	100	90	78	77	100	97	77
	High	Low	100	91	73	73	100	90	75	70	100	98	70
	Low	High	100	97	90	83	100	89	90	78	100	95	55
	Low	Low	100	96	87	87	100	92	88	83	100	96	50
Averages:													
PJ			100	96	32	63	100	96	48	74	100	42	40
MJ			100	90	54	65	100	91	54	75			
EH			100	85	75	68	100	88	70	76	100	75	60
EB			100	92	78	74	100	94	76	77	100	89	56
PB			100	95	84	78	100	90	83	77	100	96	63
	High		100	93	62	64	100	94	66	70	100	79	63
	Low		100	90	68	75	100	90	69	82	100	72	46
		High	100	93	68	70	100	92	68	76	100	82	64
		Low	100	90	62	69	100	91	67	76	100	69	46

(Figure 6). Using sheep in **ad lib.** feeding trials, the investigators found that both digestible dry matter and dry matter intake decreased with advance in plant maturity. This would be of considerable importance when animal performance (meat, wool, milk) was a primary concern. In contrast, the aftermath crops did not show marked changes in nutritive value.

DISCUSSION

Over most of the Northeast, census figures indicate that farm yields of hay are about 1.5 to 2.5 tons per acre per year. The highest yields obtained at each station each year (16 values) averaged 4.8 tons of dry matter per acre, whereas the lowest dry matter yields obtained at each station each year averaged 1.8 tons per acre. In other words, yields were increased 2.7 times with

TABLE 10

First Cutting Yields of Dry Matter Produced by Bromegrass Following Two (Maine, Vermont) or Three Harvest Years

Previous Treatment			First Harvest					
Stage at First Harvest	N	After-math Cut	Me. (L)	Vt. (S)	R.I. (S)	N.Y. (L)	N.Y. (S)	Md. (S)
Pre-joint	High	High	0.98d-g[1],[2]	1.27a-e	1.62b	2.00b	2.40a	2.15ab
	High	Low	1.66a-d	0.95c-f	1.78b	2.02b	2.37a	2.62a
	Low	High	0.46g	0.91def	1.60b	2.26ab	2.33a	1.02c
	Low	Low	0.40g	0.44f	1.66b	2.37ab	2.75a	0.99c
Early head	High	High	0.53fg	1.84ab	1.69b	2.01b	2.78a	1.80b
	High	Low	0.98efg	1.51a-d	1.95ab	2.27ab	2.42a	1.91b
	Low	High	0.88d-g	1.40a-e	1.47b	2.88a	2.65a	0.95c
	Low	Low	0.54fg	0.88def	1.46b	2.69ab	2.80a	1.04c
Early bloom	High	High	1.36b-e	1.91a	2.40a	2.54ab	2.08a	1.89b
	High	Low	1.76ab	1.33a-e	2.01ab	2.59ab	2.67a	2.02ab
	Low	High	2.00abc	1.38a-e	1.90ab	2.52ab	2.53a	0.97c
	Low	Low	1.22c-f	0.71ef	1.83b	2.58ab	2.64a	1.18c
Past bloom	High	High	2.17a	1.76ab	1.72b	2.60ab	2.73a	1.92b
	High	Low	1.35b-e	1.69abc	1.78b	2.97a	2.31a	1.93b
	Low	High	1.36b-e	1.29a-e	1.67b	2.54ab	2.16a	1.06c
	Low	Low	1.78abc	1.09b-f	1.68b	2.58ab	2.87a	0.97c
Averages:								
PJ			0.88s	0.89s	1.67s	2.16r	2.46r	1.70r
EH			0.73s	1.41r	1.64s	2.47r	2.66r	1.42r
EB			1.58r	1.33r	2.04r	2.56r	2.48r	1.52r
PB			1.66r	1.46r	1.72s	2.67r	2.52r	1.47r
	High		1.35w	1.53w	1.87w	2.38w	2.47w	2.03w
	Low		1.08x	1.01x	1.66x	2.55w	2.59w	1.21x
		High	1.22y	1.47y	1.76y	2.42y	2.46y	1.47y
		Low	1.21y	1.07z	1.77y	2.50y	2.60y	1.58y

[1]Values having the same letter are from the same statistical population at the 5 per cent level of significance. Comparisons may be made within each column.
[2](d-g) means includes d, e, f and g

the combination of certain fertilization and cutting practices. This is a large increase considering the occurrence of a droughty season and that the lower rate of nitrogen fertilization was at least 100 pounds per acre.

Taking the first harvest at progressively later stages of growth increased yields markedly. Seasonal yields of dry matter increased 17, 52, and 69 per cent when the first harvest was delayed from the pre-joint growth stage to early head, early bloom, or past bloom, respectively. Bromegrass grown with the higher rate of nitrogen yielded approximately 39 per cent more over the year than bromegrass grown at the lower rate of nitrogen. These responses are in contrast to those reported for reed canarygrass (44) in which the effect of nitrogen fertilization on yields was always greater than that of the first harvest cutting management. Cutting the first aftermath to different stubble heights had little effect on total yields of bromegrass.

Cutting the first crop at four (or sometimes five) growth stages each spring produced results which are only in partial agreement with the results of Teel (58). While total yields were reduced by cutting at early growth stages, aftermath yields generally were not reduced by early cutting. Moreover, measurements of accumulative effects resulting from continual cutting at early growth stages showed that no uniform response for the region was observed for total yields, residual yields, or stand ratings. An explanation for the discrepancy between Teel's observations and those obtained in this study

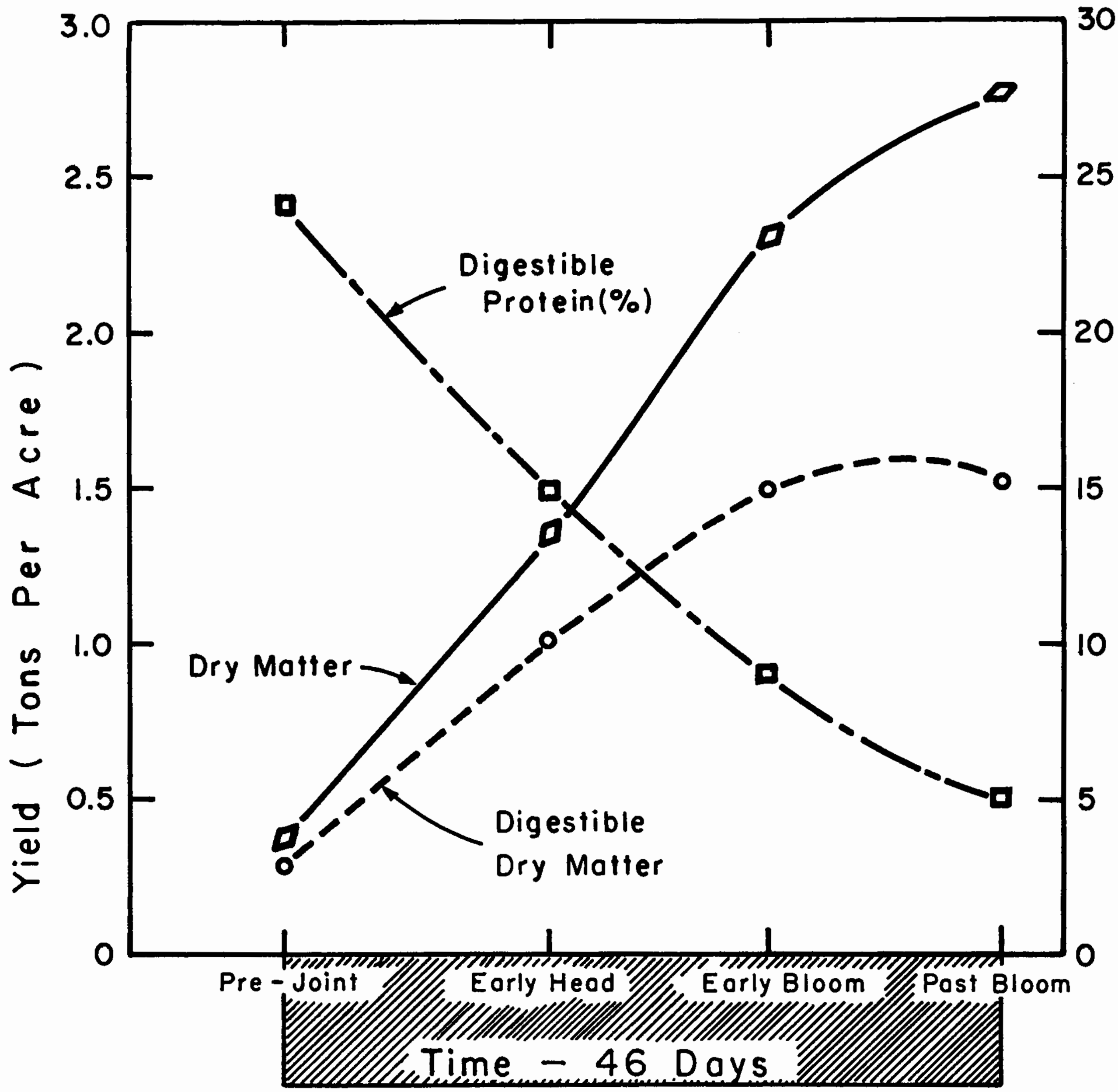


Figure 5. Trends of dry matter, digestible dry matter, and digestible protein for the spring growth of smooth bromegrass in 1962 at Maine, New York, and Maryland. Nitrogen was applied at a rate of 75 lbs./A in early spring.

might be that other stress factors determined the severity of cutting treatments. For example, **Helminthosporium bromi** sometimes infected bromegrass stands in this study. This foliar disease was particularly severe during 1961 at West Virginia, perhaps due to presence of heavy dews. It can be surmised that infected bromegrass would be less able to cope with other stress factors than if the bromegrass were disease-free (54). This may explain the greater effect of cutting management at West Virginia than at other locations.

Aftermath yields of dry matter in the region were increased on the average from 0.5 tons per acre to 2.0 tons per acre with certain fertilization and cutting practices. Aftermath yields averaged 33 per cent higher when the first crop was harvested at early heading instead of at past bloom and averaged 71 per cent higher when the rate of nitrogen fertilization was increased. It

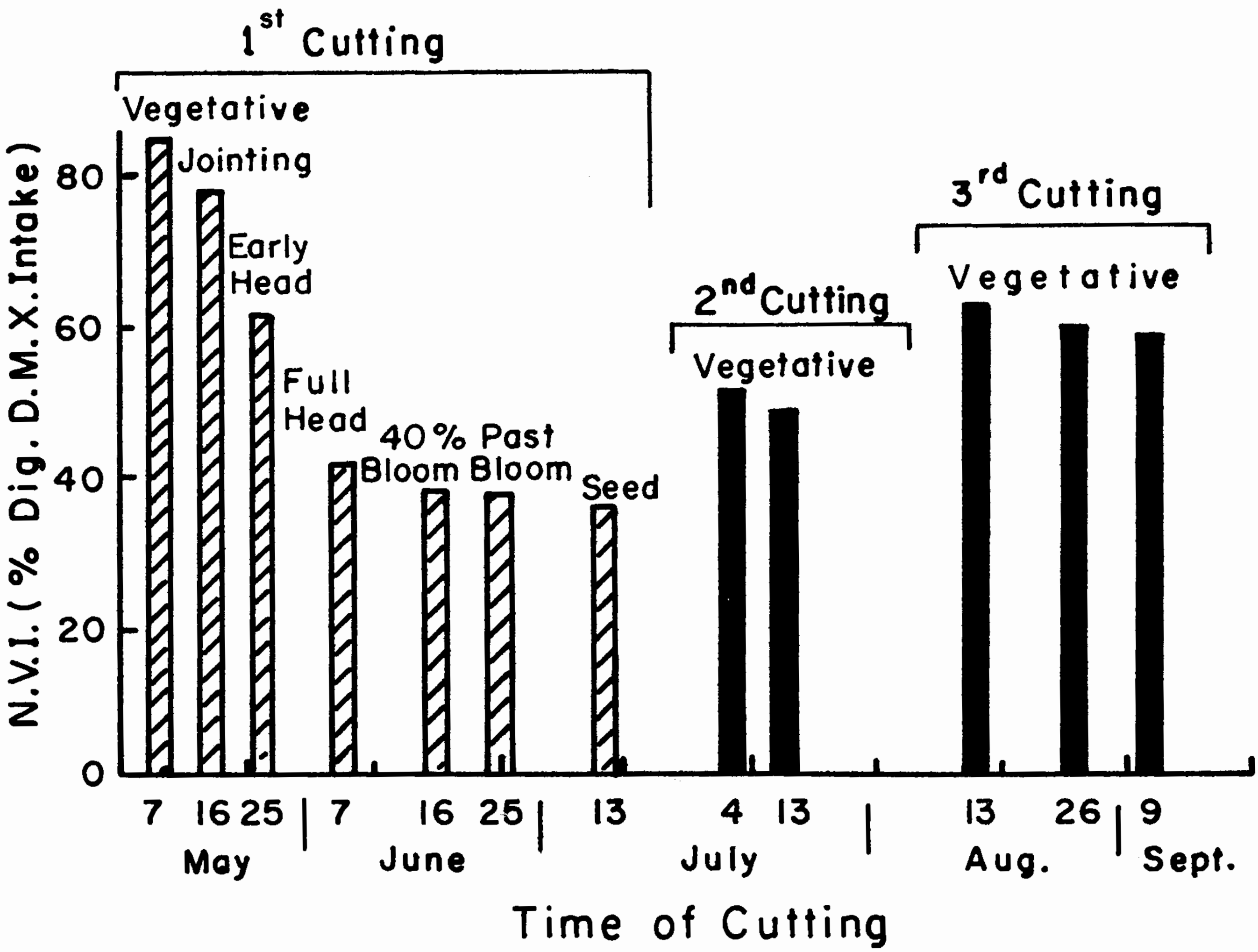


Figure 6. Effect of date of cutting on the Nutritive Value Index of Lincoln bromegrass at West Virginia in 1961. *(Data obtained from cooperative efforts with Regional Technical Committee NE-24—The Nutritive Evaluation of Forage—conducted by R. L. Reid, West Virginia Agricultural Experiment Station.)*

seemed likely that differential management of the shoot apices, based on careful observation of the recovery growth, would cause large differences in amounts of aftermath production. In Teel's experiments with bromegrass (58), optimum cutting management was far superior to badly-timed cutting. It is clear from Appendix Table 5, however, that in Northeastern experiments no great increase was achieved and most differences associated with height of cut were small and statistically insignificant.

It was noted that aftermath crops were affected most by interacting treatments at Rhode Island and Maryland, whereas these interactions occurred least frequently at the more northerly locations. This again might be related to greater stress from other factors such as temperature.

Even though there was a great deal of variability throughout the region, there was a tendency for greater stand loss and reduced yields when the spring crops were removed at an early stage of growth. The risk of stand injury appears great when harvests are taken at or before the early head stage. On the other hand, delaying first crop harvest beyond full head has been shown to result in a serious reduction of forage quality. An acceptable compromise for time of first harvest appears to be between the early and full head growth stages. Stands of bromegrass harvested at earlier growth stages should be leniently managed in mid-summer and fall to ensure complete recovery.

First harvest yields were generally higher at New York than at the other locations. This was

TABLE 11

Nutritional Evaluation of Smooth Bromegrass Forage Harvested in 1962

Stage at First Harvest	Sample Tested	Digestible Dry Matter (%)					Digestible Protein (%)				
		Me.	N.Y.		Md.	W. Va.	Me.	N.Y.		Md.	W. Va.
		Linc.	Linc.	Sara.	Sara.	Linc.	Linc.	Linc.	Sara.	Sara.	Linc.
Pre-joint	1st Harvest	86.1	83.4	83.8	81.3	65.1	23.3	26.1	26.2	21.7	21.7
	2nd Harvest	76.7	65.8	63.2	78.7	61.9	13.7	10.9	12.2	20.4	23.8
	3rd Harvest	77.5	*	68.1	77.4	58.4	20.0	*	16.5	24.3	18.5
Early head	1st Harvest	78.0	68.7	71.6	74.6	57.5	17.4	13.4	13.3	14.9	14.3
	2nd Harvest	78.0	62.9	70.9	74.2	60.8	21.1	12.8	14.8	21.9	17.9
Early bloom	1st Harvest	60.6	61.5	66.6	67.2	53.8	8.4	8.4	9.6	8.9	9.8
	2nd Harvest	75.2	58.9	68.2	75.9	52.7	19.9	12.7	15.2	22.7	15.4
Past bloom	1st Harvest	50.8	50.8	53.8	64.1	43.5	5.1	4.7	4.5	6.5	6.2
	2nd Harvest	71.1	*	*	72.4	60.4	20.4	*	*	20.9	21.0

*Sample insufficient for test

also noted in reed canarygrass investigations (44) and is believed to be related to a higher content of soil moisture (moderate drainage).

The finding that nitrogen fertilization increased etiolated regrowth is in agreement with the results of MacLeod (33). More important, however, is the finding that the factors under study affected the reserve status in a complex manner. Reserves were lowest during the fall in plants cut at the early head stage in spring in conjunction with the low rate of nitrogen and cutting the first aftermath crop to a stubble height of 3½ inches. This low level of reserves was increased approximately 40 per cent (three-year average) by changing either time of first harvest, rate of nitrogen fertilization, or by cutting the first aftermath crop to a stubble height of 1½ inches. That etiolated regrowth measurements of reserves are not related to carbohyrate reserves of bromegrass (33) appears important and deserves more attention. Two characteristic features of the etiolated regrowth (reserve) measurement are unsettling to the experimenter. The first is the very high variability in the data, and the second is the variation in stand that was often encountered when sample material was collected. In thin stands or where plants in various degrees of vigor are present, it is inevitable that the plants chosen will be better than the average over time. Thus, the samples taken from different plots will be more alike, and their ability to produce regrowth will be more comparable than would be the case if a group of plants were assigned to sampling dates at the beginning of the experiment and the value "O" given to those that died before the sampling date arrived.

Although a comparison of varieties was only a secondary objective of these experiments, an attempt was made during planning to balance the trials with Lincoln and Saratoga, both numerically and geographically. Forced abandonment of the bromegrass plots at Connecticut and New Jersey upset the balance, as did the necessary shortening of the trials at Maine and Vermont. Relatively little can therefore be stated with certainty about the relative performance of Lincoln and Saratoga under these management systems. In the direct comparison in New York, Saratoga was more productive of total and aftermath yield, and more responsive to nitrogen than Lincoln, while slightly less persistent in terms of stand density, with fewer weeds.

The potential yield and nutritive value combined with the rhizomatous growth habit of bromegrass make it a very desirable perennial forage grass. Nevertheless, considerably more information is needed before the performance of bromegrass is thoroughly understood. Specifically, explanations are needed for the diversity of responses observed in these studies and elsewhere. It has become imperative that a more thorough understanding of the structure and function of individual tillers and other plant parts, particularly under conditions of stress, be gained before the performance of an entire stand of tillers can be understood. In addition, information is scanty on factors, other than stage of growth, which affect the nutritive value of bromegrass.

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Appendix

TABLE 1

Harvest Schedules

Location and Year	Stage at First Harvest	Harvest Number 1st	2nd	3rd	4th	5th	6th	Total Harvests
First Harvest Year								
Maine (1961)	Pre-joint	5-26	6-21	7-31	8-29	9-28		5
	Early head	6-12	7-31	8-29	9-28			4
	Early bloom	6-30	8-11	9-28				3
	Past bloom	7-14	8-23	9-28				3
Vermont (1961)	Pre-joint	5-10	6- 1	6-28	8- 9	10- 9		5
	Early head	5-31	6-28	8- 9	10- 9			4
	Early bloom	6-20	7-17	8-31	10- 9			4
	Past bloom	7- 6	8- 1	10- 9				3
Rhode Island (1960)	Pre-joint	5-10	6- 1	7- 1	8- 3	9-23		5
	Early head	5-27	6-24	7-29	9-23			4
	Early bloom	6-21	7-19	8-30				3
	Past bloom	7- 5	8- 3	9- 7				3
New York (Lincoln 1960)	Pre-joint	4-25	6- 6	7-18	8-29	10-10		5
	Early head	5-26	7- 8	8-18	10-10			4
	Early bloom	6-16	7-21	8-31	10-10			4
	Past bloom	6-30	8- 8	9- 8	10-10			4
New York (Saratoga 1960)	Pre-joint	4-25	6- 6	7-18	8-29	10-10		5
	Early head	5-26	7- 8	8-18	10-10			4
	Early bloom	6-16	7-21	8-31	10-10			4
	Past bloom	6-30	8- 1	9- 8	10-10			4
Maryland (1960)	Pre-joint	4-22	5-27	7- 1	8-18	10-14		5
	Early head	5- 5	6-10	7-22	8-31	10-14		5
	Early bloom	5-27	7- 1	8-18	10-14			4
	Past bloom	6-10	7-18	8-31	10-14			4
Second Harvest Year								
Maine (1962)	Pre-joint	5-28	7- 2	8-22	10- 9			4
	Early head	6-13	7-31	9- 7	10- 9			4
	Early bloom	7- 2	8-17	10- 9				3
	Past bloom	7-19	8-31	10- 9				3
Vermont (1962)	Pre-joint	5-22	6-15	7-10	8-23	10-15		5
	Early head	5-29	6-25	8-20	10-15			4
	Early bloom	6-15	7-17	8-30	10-15			4
	Past bloom	7-10	8-13	10-15				3
Rhode Island (1961)	Pre-joint	5-11	6- 1	7- 5	8- 7	9-11		5
	Early head	5-29	7- 5	8- 7	9-11			4
	Early bloom	6-26	7-27	9- 5				3
	Past bloom	7- 5	8- 4	9-11				3
New York (Lincoln 1961)	Pre-joint	5-15	6-15	7-28	9-11	10-10		5
	Early head	5-29	7-20	8-23	10-10			4
	Early bloom	6-19	7-28	9-11	10-10			4
	Past bloom	7- 5	8- 1	9-11	10-10			4
New York (Saratoga 1961)	Pre-joint	5-15	6-15	7-28	9- 8	10-10		5
	Early head	5-29	7-12	8-15	10-10			4
	Early bloom	6-19	7-21	8-17	10-10			4
	Past bloom	7- 5	8- 1	9- 6	10-10			4
Maryland (1961)	Pre-joint	4-28	5-22	6-19	7-20	8-29	10- 6	6
	Early head	5-16	6-19	7-20	8-29	10- 6		5
	Early bloom	6- 8	7- 7	8-21	10- 6			4
	Past bloom	6-22	7-20	10- 6				3

TABLE 1 (Continued)

Location and Year	Stage at First Harvest	Harvest Number 1st	2nd	3rd	4th	5th	6th	Total Harvests
Third Harvest Year								
Rhode Island (1962)	Pre-joint	5-18	6- 8	7-11	8-15	10- 2		5
	Early head	6- 1	7- 9	8-15	10- 2			4
	Early bloom	6-18	7-20	8-23				3
	Past bloom	7- 5	8-13	10- 2				3
New York (Lincoln 1962)	Pre-joint	5- 4	6- 4	8-15	10-10			4
	Early head	5-22	7-16	9- 7	10-10			4
	Early bloom	6- 4	8- 3	9- 7	10-10			4
	Past bloom	6-20	8-17	10-10				3
New York (Saratoga 1962)	Pre-joint	5- 4	6- 4	7-26	9- 7	10-10		5
	Early head	5-22	7- 2	8-17	10-10			4
	Early bloom	6- 4	7-26	9- 7	10-10			4
	Past bloom	6-20	8-15	10-10				3
Maryland (1962)	Pre-joint	4-25	5-16	6-18	8- 7	10-19		5
	Early head	5-11	6-18	8- 7	10-19			4
	Early bloom	5-25	6-27	8- 7	10-19			4
	Past bloom	6- 8	7-18	8- 7	10-19			4

Residual Harvest Year (1963)

The common harvest was made on all plots as follows:

Maine	July 1	New York	(Lincoln)	June 19
Vermont	June 28		(Saratoga)	June 18
Rhode Island	June 13	Maryland		May 31

TABLE 2A

Bi-Weekly Precipitation

	Inches Total Precipitation													
	April 1-15	April 16-30	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15	September 16-30	Total Inches	Deviation + above N* — below N
1959														
Maine[1]	2.2	0.3	0.1	0.5	3.3	3.7	2.7	0.3	1.8	3.4	2.0	0.7	21.1	+1.5
Vermont	1.3	0.3	0.4	1.1	2.7	0.8	1.3	0.5	1.6	2.7	1.5	0.6	14.7	—5.0
Rhode Island	1.7	1.3	0.9	2.0	3.7	3.2	4.1	0.1	1.5	2.4	0.8	0.1	21.8	+0.3
New York	1.0	1.3	0.6	0.9	0.6	1.9	4.2	0.5	1.6	2.9	0.2	0.9	16.7	—4.2
Maryland	3.3	0.1	1.4	0.6	2.8	0.1	3.4	2.1	2.3	1.2	0.9	0.2	18.3	—6.2
West Virginia	2.7	1.6	1.7	0.9	0.5	0.7	1.4	2.1	1.1	2.1	0.1	1.0	15.8	—7.3
1960														
Maine	2.3	0.5	2.7	0.7	1.6	0.9	1.2	1.4	0.0	0.6	2.2	0.9	15.0	—4.6[1]
Vermont	1.2	1.4	2.0	1.6	0.8	2.8	1.0	2.4	0.9	0.6	3.7	1.2	19.6	—0.4
Rhode Island	2.7	0.5	2.4	1.6	1.3	0.5	3.5	0.8	1.3	0.5	1.8	5.5	22.2	+0.7
New York	1.4	0.9	2.7	2.4	2.4	1.2	0.7	0.8	1.2	1.3	3.7	0.3	19.0	—2.0
Maryland	2.5	0.5	3.0	1.5	1.1	0.4	2.9	3.0	3.9	0.9	5.2	0.7	25.6	+1.1
West Virginia	1.2	0.6	2.8	2.1	1.4	0.6	2.6	2.7	2.9	0.6	2.1	0.9	20.5	—2.6
1961														
Maine	1.8	1.8	0.6	4.7	1.1	1.0	0.7	1.0	0.2	0.6	0.6	2.3	16.4	—3.2[1]
Vermont	1.7	2.2	1.2	1.5	2.0	1.7	3.6	1.3	1.4	1.8	2.7	0.0	21.1	+1.5
Rhode Island	3.8	4.2	1.7	4.3	1.1	1.6	0.2	0.9	1.6	4.8	2.0	8.6	34.8	+3.3
New York	3.0	3.0	2.5	1.7	3.6	2.1	1.6	2.7	1.9	2.4	2.8	0.0	27.3	+6.4
Maryland	3.1	0.7	2.3	0.2	2.9	1.7	1.6	0.7	0.6	5.7	0.6	0.2	20.3	—4.2
West Virginia	2.1	2.0	1.4	1.4	3.8	3.0	3.3	2.3	3.1	0.8	1.2	3.2	27.6	+4.5
1962														
Maine	3.2	1.0	0.4	0.6	0.8	0.9	1.6	1.6	0.3	2.7	1.1	2.1	16.3	—3.3[1]
Vermont	1.8	0.8	1.1	1.1	0.4	2.7	2.1	3.9	2.8	0.7	2.4	1.1	21.5	+2.1
Rhode Island	3.0	0.1	1.1	0.8	3.4	2.1	1.4	0.4	1.8	2.3	0.2	3.6	20.2	—1.3
New York	1.9	0.8	0.6	0.4	2.1	0.1	0.2	1.1	2.0	1.7	1.3	3.2	15.3	—5.6
Maryland	3.0	0.2	0.6	2.5	1.1	2.2	0.7	0.8	0.1	0.1	0.5	2.4	14.2	—10.4
West Virginia	3.4	1.4	0.5	1.4	2.1	0.1	2.0	0.7	3.3	0.1	1.8[2]	2.3[2]	19.1	—4.0

*Normal (1931-1960)
[1]U.S.W.B. Old Town, Maine (other data from Orono, Maine)
[2]U.S.W.B. Airport Station

TABLE 2B

Bi-Weekly Air Temperature

Mean Daily Air Temperature

	April 1-15	April 16-30	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15	September 16-30	Mean Daily	Deviation + above N* — below N
1959														
Maine[1]	40	43	53	58	58	58	67	72	67	67	62	56	58.4	—0.3
Vermont	41	48	54	54	64	65	69	74	69	71	66	60	61.2	+0.6
Rhode Island	47	50	55	62	64	64	69	73	70	74	70	61	63.3	+2.2
New York	42	49	55	61	66	66	68	73	68	74	68	61	62.7	+2.2
Maryland	54	62	66	71	75	79	76	83	79	85	79	78	73.8	+5.1
West Virginia	50[2]	58[2]	63	64[3]	69	69[3]	73	76	74	78	71	67	67.9	+0.9
1960														
Maine	38	44	56	59	60	66	66	68	65	66	60	53	58.4	—0.3[1]
Vermont	41	49	61	63	63	68	68	69	67	67	61	57	61.2	—0.4
Rhode Island	44	52	53	59	63	67	67	68	68	70	65	58	61.2	+0.1
New York	42	58	53	60	61	66	65	68	67	67	63	62	60.9	+0.4
Maryland	56	66	57	69	73	74	75	77	78[4]	82	80	76[2]	71.9	+3.2
West Virginia	51	64	54	66	69	70	70	74	75	74	70	66	66.9	0.0
1961														
Maine	35	40	49	52	59	64	62	69	65	66	67	58	57.2	—1.5[1]
Vermont	36	44	51[3]	50[3]	62	65	65	71	69	66	71	60	59.2	—1.6
Rhode Island	42	48	53	56	65	64	68	73	68	71	74	63	62.1	+1.0
New York	36	46	54	53	64	63	65	72	67	68	72	61	60.1	—0.4
Maryland	46	57	64	58	77	72	76	83	78	78	87	74	70.6	+1.9
West Virginia	41	51	60	54	68	65	69	75	71	73	76	63	63.8	—3.1
1962														
Maine	39	41	44	47	58	63	60	62	64	63	57	49	53.3	—5.4[1]
Vermont	40	47	50	63	63	65[3]	63	65	65	66	61	50	58.2	—2.6
Rhode Island	44	50	49	60	62	67	66	66	68	66	63	56	59.8	+1.3
New York	39	52	52	64	62	68	66	66	66	68	62	52	59.7	—0.8
Maryland	53	61	65	77	78	82	80	78	77	80	74	64	72.4	+3.7
West Virginia	44	56	63	72	70	72	73	69	72	73	68[2]	57[2]	65.8	—1.1

*Normal (1931-1960)
[1]U.S.W.B. Old Town, Maine (other data from Orono, Maine)
[2]U.S.W.B. Airport Station
[3]Estimated value 2-6 days missing
[4]U.S.W.B. College Park, Maryland

TABLE 3A

Analysis of Variance (F Values) of Bromegrass Yields Produced in the First Harvest Year

States	Stage	Nitrogen	Cutting Height	SXN	SxCH	NxCH	SxNxCH
			Total Yield				
Maine	98.4**	58.5**	< 1	4.0*	< 1	< 1	< 1
Vermont	32.0**	4.4*	3.3	2.4	2.0	< 1	1.8
Rhode Island	42.7**	196.0**	4.1	5.9**	< 1	3.4	< 1
New York (L)	40.3**	55.1**	< 1	3.8*	< 1	< 1	< 1
New York (S)	79.9**	327.1**	< 1	1.1	< 1	1.2	1.7
Maryland	4.1**	4.7**	< 1	1	< 1	< 1	< 1
			Aftermath Yield				
Maine	20.9**	82.7**	< 1	3.5*	< 1	3.1	< 1
Vermont	32.9**	11.5**	6.1*	< 1	2.3	< 1	2.4
Rhode Island	3.98*	106.1**	4.9*	< 1	< 1	3.2	< 1
New York (L)	60.7**	185.8**	< 1	10.8**	1.3	1.2	3.4*
New York (S)	74.3**	860.0**	1.1	7.0**	2.1	2.0	3.8*
Maryland	1.6	33.2**	1.0	1.1	3.3*	< 1	< 1

* .05 level of probability
** .01 level of probability

TABLE 3B

Analysis of Variance (F Values) of Bromegrass Yields Produced in the Second Harvest Year

States	Stage	Nitrogen	Cutting Height	SXN	SxCH	NxCH	SxNxCH
			Total Yield				
Maine	51.0**	63.1**	7.9**	1.9	< 1	3.8	1.6
Vermont	59.1**	37.2**	19.6**	1.3	3.3*	1.4	2.3
Rhode Island	22.1**	92.9**	2.9	< 1	1.9	< 1	< 1
New York (L)	178.4**	89.1**	3.7	2.6	< 1	< 1	1.2
New York (S)	125.8**	147.1**	< 1	2.1	< 1	< 1	< 1
Maryland	57.0**	431.3**	5.6*	11.4**	1.9	2.2	< 1
			Aftermath Yield				
Maine	4.2*	67.2**	< 1	1.6	< 1	2.5	< 1
Vermont	14.8**	90.2**	26.3**	2.7	5.5**	2.5	1.0
Rhode Island	34.8**	112.3**	< 1	< 1	1.4	< 1	< 1
New York (L)	33.0**	49.0**	2.4	3.6*	< 1	3.0	1.1
New York (S)	23.9**	63.1**	< 1	< 1	1.6	< 1	< 1
Maryland	31.8**	261.4**	5.3*	3.1*	2.3	4.4*	< 1

* .05 level of probability
** .01 level of probability

TABLE 3C

Analysis of Variance (F Values) of Bromegrass Yields Produced in the Third Harvest Year

States	Stage	Nitrogen	Cutting Height	SXN	SxCH	NxCH	SxNxCH
			Total Yield				
Rhode Island	58.2**	433.1**	< 1	8.9**	< 1	< 1	< 1
New York (L)	24.3**	2.3	1.2	1.4	< 1	< 1	< 1
New York (S)	27.0**	6.2*	< 1	< 1	< 1	< 1	< 1
Maryland	32.0**	461.7**	6.2*	4.5*	< 1	5.3*	2.1
			Aftermath Yield				
Rhode Island	11.0**	178.1**	< 1	< 1	1.8	1.1	< 1
New York (L)	7.3**	9.4**	< 1	< 1	< 1	1.6	< 1
New York (S)	9.5**	21.0**	4.0	2.5	< 1	< 1	< 1
Maryland	18.0**	173.7**	6.2*	3.2*	< 1	2.7	2.8

* .05 level of probability
** .01 level of probability

TABLE 4

Analysis of Variance (F Values) of Bromegrass Spring Stand Ratings

States	Stage	Nitrogen	Cutting Height	SXN	SxCH	NxCH	SxNxCH
			Spring of Second Harvest Year				
Maine	17.9**	< 1	4.0	< 1	< 1	2.6	< 1
Rhode Island	16.7**	3.0	7.8**	3.0*	2.8	2.0	< 1
New York (L)	20.3**	7.6**	1.9	< 1	< 1	< 1	< 1
New York (S)	2.0	8.7**	1.4	2.0	< 1	< 1	< 1
Maryland	3.7**	60.4**	4.1	6.1**	3.0	5.5*	1.1
			Spring of Third Harvest Year				
Maine	53.3**	8.0**	< 1	1.2	< 1	< 1	< 1
Rhode Island	25.2**	72.9**	10.1**	4.8**	3.3*	< 1	< 1
New York (L)	3.1*	< 1	< 1	< 1	< 1	< 1	< 1
New York (S)	1.4	3.4	< 1	< 1	< 1	4.2*	2.1
Maryland	9.9**	65.1**	8.4**	7.1**	2.2	6.1*	4.2*
			Spring of Residual Harvest Year				
Rhode Island	12.6**	8.3**	< 1	1.9	< 1	< 1	< 1
New York (L)	3.7*	7.5*	< 1	2.2	< 1	5.4*	< 1
New York (S)	5.4**	26.2**	< 1	< 1	1.9	4.2*	1.6
Maryland	6.4**	65.6**	2.9	3.0	2.7	2.2	4.7*

* .05 level of probability
** .01 level of probability

TABLE 5

Average Dry Matter Produced by Smooth Bromegrass Over Two (Maine, Vermont) or Three Harvest Years

Stage at First Harvest	N	After-math Cut	Total Yield (T/A)						Aftermath Yield (T/A)					
			Me.	Vt.	R.I.	N.Y.(L)	N.Y.(S)	Md.	Me.	Vt.	R.I.	N.Y.(L)	N.Y.(S)	Md.
Pre-joint	High	High	2.96	2.51	2.87	2.52	3.04	3.55	1.14	1.58	1.82	0.73	1.37	1.84
	High	Low	2.77	2.22	2.53	2.56	3.05	3.08	1.17	1.30	1.63	0.75	1.30	1.73
	Low	High	1.77	2.19	1.53	2.03	2.27	2.41	0.48	1.28	1.03	0.42	0.69	1.44
	Low	Low	1.76	1.54	1.33	2.05	2.32	2.31	0.44	0.83	0.88	0.62	0.80	1.28
Early head	High	High	2.50	3.62	3.14	3.52	3.88	3.58	0.76	2.00	1.86	1.57	2.06	1.90
	High	Low	2.54	2.65	2.83	3.49	3.97	3.49	0.74	1.39	1.78	1.62	2.11	1.87
	Low	High	2.18	2.46	1.54	2.79	2.82	2.01	0.40	1.16	0.92	1.10	1.28	1.08
	Low	Low	1.94	2.32	1.61	2.66	2.90	2.34	0.50	1.11	0.95	0.96	1.29	1.39
Early bloom	High	High	4.26	3.94	4.44	4.37	4.82	4.17	1.17	1.10	1.52	1.28	1.57	1.60
	High	Low	4.12	3.00	4.44	4.14	4.94	4.20	1.18	0.69	1.47	1.04	1.61	1.57
	Low	High	3.58	3.06	2.39	3.33	3.70	2.85	0.60	0.84	0.75	0.59	1.01	1.01
	Low	Low	3.02	2.88	2.14	3.36	3.68	2.74	0.50	0.55	0.56	0.61	0.93	0.98
Past bloom	High	High	3.90	4.30	4.50	4.92	5.23	4.82	0.66	1.42	1.35	1.41	1.64	1.69
	High	Low	3.98	4.36	4.39	4.84	5.06	4.65	0.77	1.28	1.34	1.34	1.57	1.73
	Low	High	3.36	3.99	2.35	4.26	4.05	3.24	0.22	1.04	0.55	0.80	0.93	0.98
	Low	Low	3.14	3.74	2.42	4.01	4.02	3.19	0.36	0.92	0.64	0.74	0.97	0.95
Averages:														
PJ			2.32	2.12	2.06	2.29	2.67	2.83	0.81	1.50	1.34	0.63	1.04	1.57
EH			2.28	2.76	2.28	3.11	3.39	2.85	0.60	1.32	1.38	1.31	1.68	1.56
EB			3.75	3.17	3.35	3.80	4.29	3.49	0.86	1.12	1.07	0.87	1.28	1.29
PB			3.60	4.10	3.41	4.48	4.59	3.97	0.50	0.68	0.97	1.06	1.28	1.33
	High		3.38	3.30	3.64	3.80	4.25	3.94	0.95	1.36	1.60	1.22	1.65	1.74
	Low		2.59	2.78	1.91	3.06	3.22	2.63	0.44	0.95	0.78	0.73	0.99	1.14
		High	3.06	3.24	2.84	3.47	3.73	3.33	0.68	1.28	1.22	0.99	1.32	1.44
		Low	2.91	2.84	2.71	3.39	3.74	3.25	0.71	1.03	1.16	0.96	1.32	1.44