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FACTORS INFLUENCING THE ESTABLISHMENT OF IRRIGATED PASTURES IN NORTHERN COLORADO

By HERBERT C. HANSON



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CONTENTS

Introduction	5
Methods	6
Larimer County Farm Pasture.....	7
Summary of Results for the Larimer County Farm Pasture	16
Nelson Pasture	17
Summary of the Nelson Pasture.....	21
Gettman Pasture.....	25
Summary of Gettman Pastures.....	30
Hice Pasture	32
Summary of the Hice Pasture.....	36
Davis Pasture	37
Welty Pasture	38
Meredith Pasture	39
Discussion	40
Purposes of the Pasture.....	41
Topography	42
Soil Conditions	42
Climate	42
Supply of Irrigation Water.....	43
Preparation of the Seedbed.....	43
Selection of the Seed Mixture.....	43
The "Nurse Crop" and Its Treatment If Planted.....	48
Time and Method of Sowing.....	49
Weeds	49
Grazing During the First Season.....	49
Management	50
Summary and Conclusion.....	50
Literature Cited.....	52

FACTORS INFLUENCING THE ESTABLISHMENT OF IRRIGATED PASTURES IN NORTHERN COLORADO¹

HERBERT C. HANSON²

The scientific study of pastures has been neglected for a long time. Too often the pasture has been established on land that could be used in no other way and little or no attention paid to it. Crowther (3) has stated this attitude very aptly:

"Much of our grassland has suffered from the fatal facility with which a sward of sorts will establish itself and persist on most soils. It is all too easy to regard it as a gift of Providence, rather than as a valuable crop, to be developed and maintained at its most productive level like any other crop. Science also must bear some part of the blame for the backward condition of much of our grassland farming, since, until comparatively recently, it has received far from an adequate share of the interest and attention of our research workers."

In the last few years, however, a large number of pasture investigations have been launched, chiefly by state agricultural experiment stations and by the U. S. Department of Agriculture. Jones and Brandt (8) have summarized a large number of recent papers. It is beginning to be realized that pasture investigations are very complicated because of the large number of variable factors that enter into the establishment and maintenance of the pasture. Many of these factors cannot be controlled. Schuster (13) has listed a number of methods that have been employed in research work on pastures. Some of these are: Carrying capacity, clippings, plant population, cattle weights and surveys. Because of the complex nature of the pasture, "a jungle in which species are everlastingly struggling for existence" (Mercer, 11), and because of the great expense involved in a comprehensive study, various detailed problems, as effects of fertilizers and elimination of weeds, have usually been selected for investigation.

In the present paper a report is made of ecological studies on several irrigated pastures in Northern Colorado. Emphasis is placed upon the factors that influence the establishment of such pastures. The income that may be derived from the use of an established pasture may be largely dependent upon various factors during the period of establishment. It is advisable to consider these factors before starting a pasture in order to control them, or accommodate the pasture to them, as far as possible.

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METHODS

Various mixtures of grasses and clovers growing on farms were studied. In several cases the author recommended not only the seed mixture but also the methods of preparing the soil and of seeding. The pastures usually received only such treatment as fitted in with ordinary farm practices. In most cases the pastures suffered more or less from lack of proper care. The results secured in each pasture must be interpreted in relation to the care given. The wide variation in treatment increases the amount of data available for discussion of the factors concerned in the establishment of irrigated pastures (cf. Stapledon and Davies, 15).

The usual method of stating the seed mixture is to give the number of pounds of seed of each species that were planted per acre. The percentage of *weight* of each species may then be easily calculated. A more exact method, however, of stating the seed mixture is to give the approximate number of viable seeds, free from weeds, of each species (5). The number of pure live seeds of each constituent in the mixture may be secured by multiplying the number of seeds in 1 pound by the percentage of germination by the percentage of purity by the number of pounds used. The percentage of the number of pure live seeds of each species may then be calculated. Because of the difference in sizes and weights of seeds between species, the percentages based on the number of pure live seeds is very different from the percentages based on number of pounds per acre.

An even better method would be to use the potential number of established plants that may be expected under average field conditions from a pound of seed. In order to determine this number, or the "plant-producing efficiency" (Stapledon and Davies, 18:66) of a pound of seed it is necessary to multiply the average number of seeds in a pound by the percentage of germination by the percentage of purity by the percentage of establishment. Stapledon and Davies (18) found, on the basis of a large number of tests at Aberystwyth, that the percentage of viable seed that became established (counts made in autumn after seeding in spring) was 38 percent for meadow fescue, 37 for orchard grass, 30 for timothy and 56 for perennial ryegrass. These authors have used this "plant-establishment" method to analyze a standard mixture and as a basis for the development of new mixtures.

Undoubtedly the method advocated by Stapledon and Davies is the best to use but since there was an insufficient number of field tests on which to base establishment, the author was com-

pelled to use the number of pure live seeds. The best way to obtain percentages of pure live seeds is to have the seeds tested, before planting, for germination and for purity, in a seed laboratory. The Association of Official Seed Analysts of America have compiled data on the approximate number of seeds per pound, the percentages of germination and purity and the vigor of the seedlings. These data are given for several species in Table 1 (1).

Table 1.—Approximate Number of Seeds per Pound, Percentages of Germination and Purity, and Vigor of Seedling.

Kind of Seed	No. of Seeds per Pound	Germination Percentage	Purity Percentage	Vigor of Seedling
Kentucky blue grass.....	2,177,000	80	80.0	weak, due to small seed.
Brome grass, smooth.....	136,000	90	85.0	very strong
Clover, white.....	680,000	95*	99.8	strong
Clover, yellow sweet.....	258,500	95*	99.5	strong
Fescue, meadow.....	226,800	95	99.0	very strong
Orchard grass.....	521,600	90	80.0	very strong
Timothy.....	1,134,000	95	99.8	weak, due to small seed.
Wheat grass, slender.....	149,700	90	....	strong

*Includes hard seed

Quadrats, a meter square, were used for analyzing the vegetation. Several quadrats were located in each pasture. The aim was to place the quadrats so that they would be representative of the entire pasture. The methods used in studying the quadrats are presented in a recent paper by Hanson and Love (6).

LARIMER COUNTY FARM PASTURE

About 12 acres of fine sandy-loam soil were seeded on April 2, 1928, to the mixture shown in Table 2 (Fig. 1). A splendid, fine-grained seedbed had been prepared by plowing very early in the spring and by harrowing and floating. The surface sloped gently to the northeast. Certain parts were difficult to irrigate and became rather dry at times. During 1927 the west half of the pasture was in winter rye, seeded in the spring and used for pasture. In 1926 this part was in alfalfa. The east half was in sugar beets during 1927. The pasture mixture was seeded on well-prepared land by drilling in two directions at right angles to each other and the field was then harrowed in the direction of the first drilling. No nurse crop was used.



Fig. 1.—View of Larimer County Farm pasture showing east side in the foreground. Sept. 20, 1928.

Table 2.—Seed Mixture and Composition of Larimer County Farm Pasture, Seeded April 2, 1928.

Plants	Seed per acre		Stand Oct. 1, 1928				Stand Oct. 4, 1929		Stand Sept. 4, 1930	
	Lbs.	Pure, Live Seeds %	Ave. No. of Plants	Mix- ture Ratio %	Survi- val %	* Weeds Ratio %	Sq. cm.	%	Sq. cm.	%
Brome grass	10	10.4	149	27	58	13.0	167	19.0	136	15.5
Mead. fescue.....	6	12.8	133	24	42	11.6	246	27.9	177	20.1
Sl. wheat grass.....	5	6.8	141	25	85	12.3	80	9.1	25	2.8
Ky. blue grass.....	4	52.4	26	5	2	2.2	37	4.2	203	23.1
Y. S. clover.....	3	7.4	64	11	35	5.6	3	0.3	6	.7
White clover.....	2	10.2	45	8	20	3.9	240	27.2	307	35.1
Weeds.....	..	....	591	..	..	51.4	108	12.3	24	2.7
Totals.....	30	100.0	1149	100.0		100.0	881	100.0	878	100.0

*"Weeds ratio" includes weeds as well as seeded species.

There were several purposes in seeding this mixture. Pasturage for dairy cattle was needed as soon as possible. Since there was ample water for irrigation, the plan was that the mixture should develop in a few years into a permanent pasture consisting chiefly of Kentucky blue grass and white clover. Early pasturage, if possible during the first season, was to be furnished especially by yellow sweet clover, and to some extent by meadow

fescue, brome grass and slender wheat grass. It was expected that these three grasses would furnish the bulk of the pasturage for several succeeding years until Kentucky blue grass and white clover would become dominant.

Due to the smallness of the seeds, Kentucky blue grass made up 52 percent of the total number of pure live seeds sown per acre. Slender wheat grass was included chiefly for its ability to grow on the areas that were difficult to irrigate. There was slightly less brome grass used than meadow fescue because the former could spread by rhizomes while the latter could not. Yellow sweet clover was seeded at 3 pounds per acre, or 7.4 percent of the mixture, so that it would not hamper unduly the growth of other plants.

On May 24 of the first year there was a good stand of pasture plants and there were quite a few weeds. Yellow sweet clover had an advantage in leaf area with 3 to 4 leaves per plant. Most of the plants were from 1 to 1.5 inches tall. The plants of brome grass, meadow fescue and slender wheat grass were 2 to 4 inches tall. Seedlings of Kentucky blue grass were not abundant. They were very slender and only 0.5 to 1 inch tall. White clover averaged about 0.5 inch tall and had 2 to 4 leaves per plant. In places there was considerable competition for moisture and where the weeds were thick some of the shorter seedlings seemed to be suffering for lack of light. It appeared that competition in the seedling stage was very important in determining the later composition of the pasture as well as the rate of future succession.

On June 5 further analyses were made of growth features that were important in the competition between the species. Meadow fescue appeared to be most numerous at this time, with brome and slender wheat grass not far behind. White clover was least numerous. Leaf, stem and root measurements are given in Table 3.

Table 3.—Average Growth Measurements of Plants in the Larimer County Farm Pasture on June 5.

Plants	Height cm.	Diam. of Stem at Base mm.	Length of Longest Leaf cm.	Width of Widest Leaf mm.	No. of Leaves per Plant	No. of Stalks per Plant	No. of Pri- mary Roots per Plant
Brome grass	15.6	1.6	11.8	4.4	4.3	2.0	8.1
Mead. fescue	11.8	1.6	8.9	2.6	4.1	1.1	10.5
Sl. wheat grass	13.4	1.0	9.5	2.3	4.8	2.1	7.6
Ky. blue grass	4.2	0.2	4.2	0.2	2.0	1.0	....
Y. S. clover	7.6	1.1	....	24.1	4.8	....	....
White clover	2.4	1.0	....	7.0	2.3	....	....

The measurements recorded in this table indicate that the three grasses, brome, meadow fescue and slender wheat grass, were taller than the other plants. Kentucky blue grass and white clover were distinctly at a disadvantage in height. Brome grass and meadow fescue had much larger stems than any of the others. Kentucky blue grass was very much smaller. Because of its much larger leaf area per plant, yellow sweet clover had a decided advantage over all other species. It had considerable repressive effect upon the other species by shading them. Brome grass and slender wheat grass had more tillers at this time than the other grasses. This would be of advantage by giving larger surfaces for photosynthesis. Meadow fescue had a few more primary roots per plant than brome or slender wheat. This seeming advantage may have been offset by a greater number or greater length of the branch roots. As a whole, the measurements in the table indicate that yellow sweet clover had a great advantage over all of the others and that the three larger grasses, brome, meadow fescue and slender wheat grass, ranked next.

On July 16 measurements were again made of the growth of the pasture plants. At this time the weeds, green foxtail (*Chaetochloa viridis*), tickle grass (*Panicum capillare*) and lamb's quarters (*Chenopodium album*), were most numerous with meadow fescue close behind. Slender wheat grass, brome grass and white clover were fairly numerous. Yellow sweet clover and Kentucky blue grass were least numerous.

Table 4.—Average Growth Measurements of Plants in the Larimer County Farm Pasture on July 16.

Plants	Height cm.	Stem Diam. at 1 in. mm.	Length of Longest Leaf cm.	Width of Widest Leaf mm.	No. of Leaves per Plant	No. of Stalks per Plant
Brome grass	30.4	1.5	19.2	4.7	7.8	1.8
Mead. fescue	34.5	1.7	28.3	3.9	6.9	2.2
Sl. wheat grass	27.0	1.0	19.1	3.2	7.7	2.8
Ky. blue grass	11.5	0.5	8.9	0.9	2.0	1.0
Y. S. clover	37.1	2.4	.....	38.4	70.1	.....
White clover	13.0	1.2	.....	19.9	4.2	.....

At this time yellow sweet clover had a very great advantage over the other species because of its greater height, greater stem diameter and much greater photosynthetic area per plant as indicated by the average width of the widest leaf and by the number of leaves. The leaves averaged 70 per plant for sweet clover and from two to eight for the other species. Kentucky blue grass was at the greatest disadvantage, having but two

small leaves per plant. Meadow fescue led the other forage plants because of its greatest average height and larger photosynthetic area. Because of its size, yellow sweet clover must have exerted considerable repressive effect upon the other species at this time. The weeds were also serious competitors. They were mowed at the height of 4 to 6 inches and the tops removed for hay a few days later. The mowing also eliminated much of the shade cast by the sweet clover plants. The mowing, and the irrigation which followed the mowing, came just at the right time to save many of the smaller plants.

During the summer the pasture received three irrigations. A few areas had become rather dry at times. Very light grazing by eight head of dairy cattle, during the daytime only, had been permitted from July 8 to July 20 and after August 1. No injury was apparent from this light grazing. On October 1 the pasture was in excellent condition. At this time eight quadrats were carefully located with respect to the accessibility of irrigation water. These were then listed, the number of individuals of each species of pasture plant and weed being counted. The summarized results are given in three columns under "Stand, Oct. 1, 1928," in Table 2.

In order to compare the composition of the stand with the composition of the seed mixture, the percentage of each species that was planted in relation to the total number of these species was calculated. This is shown under "Mixture Ratio." The ideal arrangement, perhaps, in seeding pasture mixtures would be to have this ratio identical with the ratio of pure, live seeds. But in the ordinary methods of drilling, where various kinds of seeds are planted at one time, this could hardly happen. In this mixture, Kentucky blue grass made up 52 percent of the seeding mixture but only 5 percent of the stand on October 1. Only about 2 percent of the seeds that were planted survived, as shown in the column indicated "Survival." Most of the stand was made up of brome grass, meadow fescue and slender wheat grass. The survival of each of these species was good, particularly in the case of slender wheat grass with 85 percent.

The composition of the stand was fairly satisfactory for the first year. A large amount of forage had been produced by yellow sweet clover and the three tall grasses (Figs. 2A and 3A). Kentucky blue grass and white clover had survived in sufficient numbers. The number of weeds was rather high, forming 50 percent of the stand when all plants were figured in the composition, as shown in Table 2 in the column "Weeds Ratio." This could have been reduced by more frequent mowing and irriga-

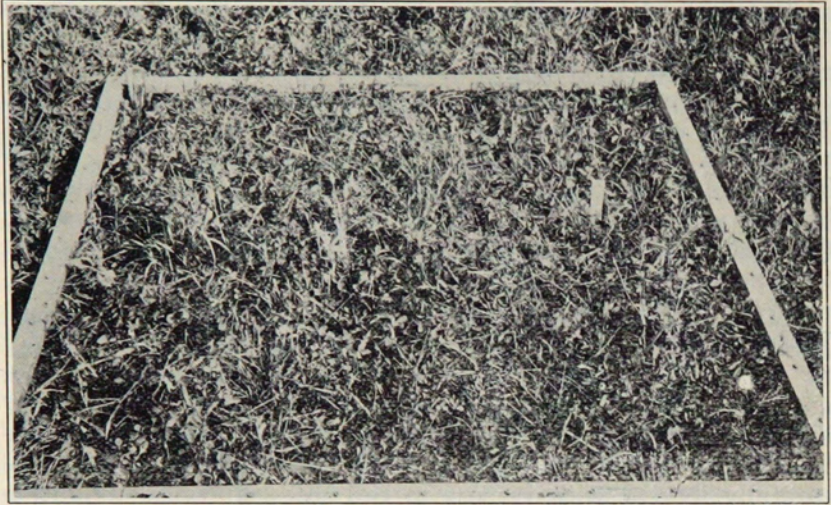


Fig. 2A.—Quadrat No. 3, Larimer County Farm pasture on Sept. 27, 1928. The succession is from yellow sweet clover, foxtail, slender wheat grass, brome and meadow fescue in 1928, to mostly meadow fescue, brome and white clover in 1929 (Fig. 2B), to white clover and Kentucky blue grass in 1930 (Fig. 2C).

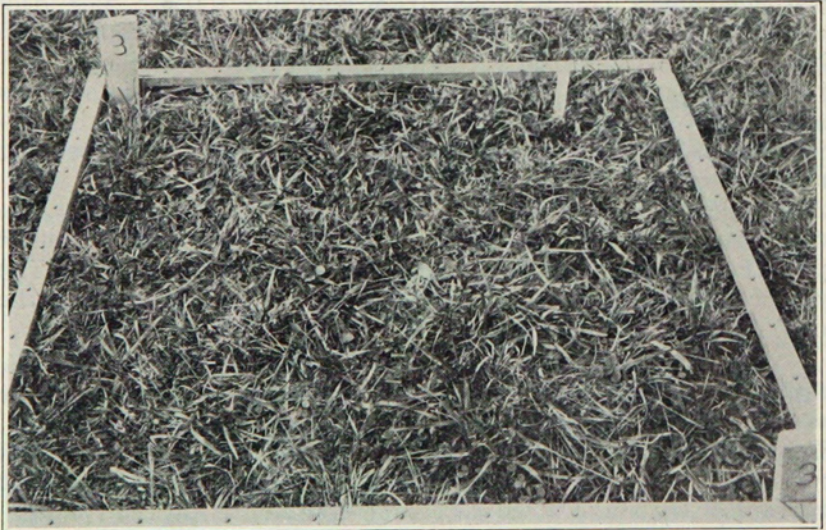


Fig. 2B.—Quadrat No. 3, Larimer County Farm pasture on Sept. 20, 1929. Meadow fescue, brome and white clover are the main plants on the area. Compare with Figs. 2A and 2C.

tion. There were fewer weeds in the better irrigated parts of the pasture than in those parts less well irrigated. There were fewer weeds on the portion of the pasture that had been in sugar beets during the previous year than in that part that had been in winter rye used for pasture. Foxtail and lamb's quarters were the principal weeds. The density of the forage plants would most likely have been greater if the weeds had been mowed oftener and if 2 pounds of seed of yellow sweet clover had been sowed per acre instead of 3 pounds. The larger amount of yellow sweet clover certainly did aid considerably, however, in reducing the growth of the weeds.

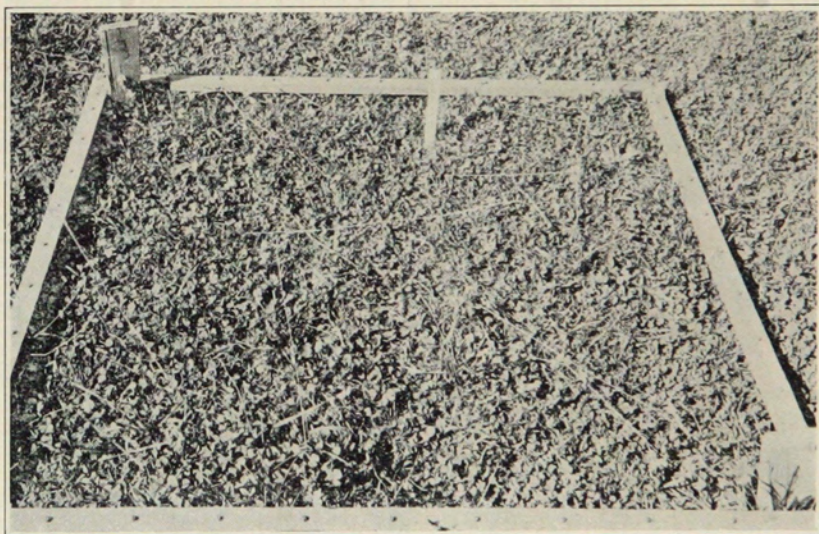


Fig. 2C.—Quadrat No. 3, Larimer County Farm pasture on Sept. 4, 1930. Kentucky blue grass and white clover are the principal plants present. Compare with Figs. 2A and 2B.

Kentucky blue grass continued to spread by rhizomes during the fall so that early in the following spring, February 28, 1929, there were many small patches of sod. It was noted at this time that there were fewer soil cracks in these blue-grass patches than elsewhere in the pasture. Cracks were fairly numerous in areas occupied by the other forage plants but as soon as a dense sod of blue grass was encountered they stopped.

Growth started early in 1929. On February 28, the green growth of blue grass was 2 to 5 inches tall, brome grass growing in small clumps 2 to 4 inches and meadow fescue with only a few stalks in a clump, 2 to 4 inches. White clover had only a few very small green leaves.

On May 21 yellow sweet clover was in excellent condition, 12 to 15 inches tall. Meadow fescue appeared to be most numerous of the grasses, brome next, and blue grass least abundant. Meadow fescue, brome grass and slender wheat were usually 8 to 12 inches tall. It appeared that the dense growth of yellow sweet clover was repressing the other plants. Heavier grazing at this time would have reduced the proportion of sweet clover and may have aided in producing a better stand of the other plants.

On October 4, 1929, the quadrats were listed by the area-list method (6). The summarized results are given in Table 2 under the column designated "Stand, Oct. 4, 1929." Yellow sweet clover

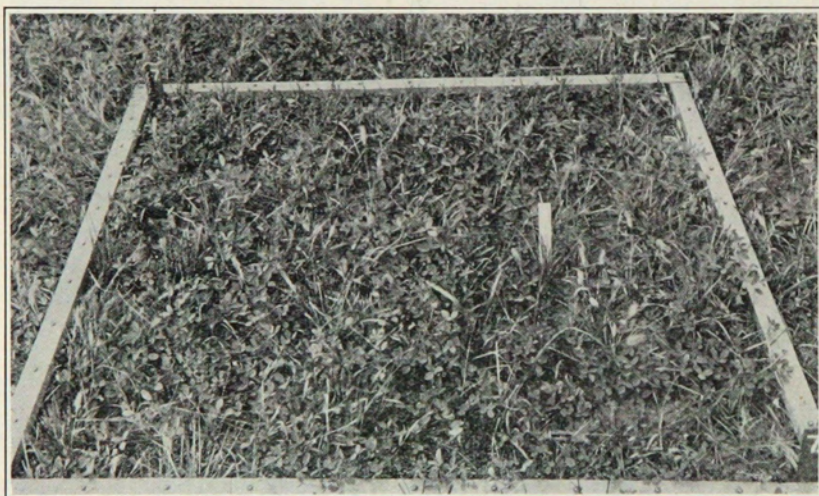


Fig. 3A.—Quadrat No. 7, Larimer County Farm pasture on Sept. 20, 1928, mixture is chiefly brome, slender wheat grass, foxtail, meadow fescue and yellow sweet clover.

had been reduced to 0.3 percent of the stand due to the natural death of the plants at the close of the second season (See Figs. 2B and 3B). White clover had increased from 3.9 percent in 1928 to 27.2 percent. Meadow fescue had also increased considerably. Brome grass and blue grass increased but little and slender wheat grass had decreased. Weeds had been greatly reduced. The weeds and slender wheat grass had not been able to endure the competition of the other forage plants. In the more open and drier parts of the pasture weeds, mostly foxtail, and slender wheat grass were more numerous than in the moister parts.

The pasture had been much undergrazed during the entire season. Heavier grazing would have produced a greater density,

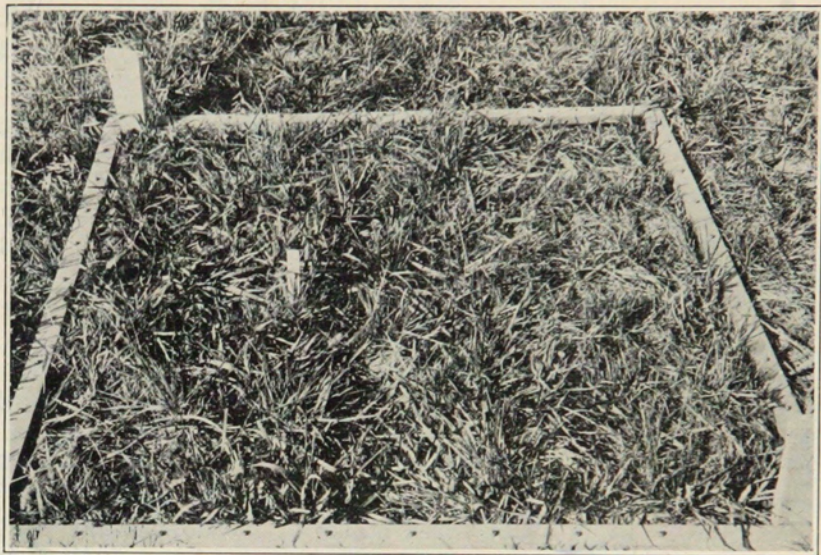


Fig. 3B.—Quadrat No. 7, Larimer County Farm pasture on Sept. 24, 1929. Mixture chiefly brome, meadow fescue and slender wheat grass.

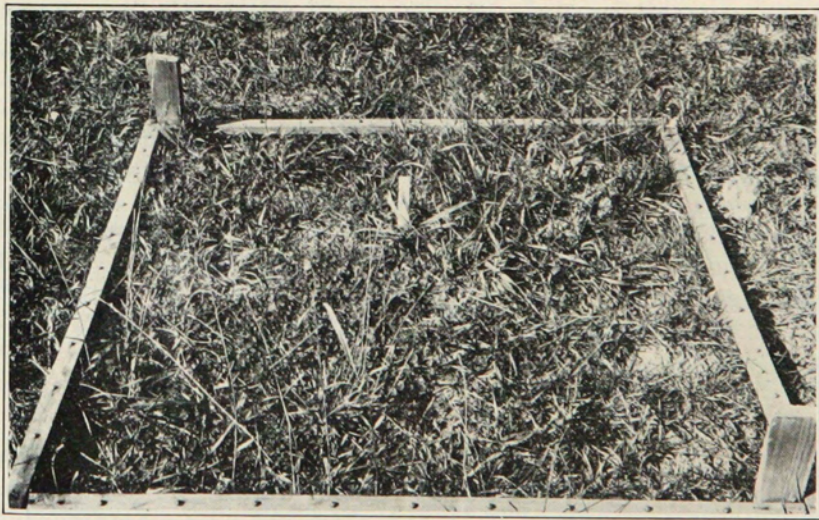


Fig. 3C —Quadrat No. 7, Larimer County Farm pasture on Sept. 4, 1930. Meadow fescue and brome grass are the chief plants present. Note the succession of plants from 1928 to 1930, in Figs. 3A, 3B and 3C. The areas of Kentucky blue grass and white clover have more than doubled from 1928 to 1930.

especially of the rhizome-bearing grasses, brome and blue grass. This would have been of further value in producing a better sod that would withstand trampling and drying out.

During the third season, 1930, the pasture was utilized to a greater extent than before, but it was still undergrazed. On September 4 the quadrats were again area-listed. The summarized results are given in Table 2 under the column "Stand, Sept. 4, 1930." Kentucky blue grass and white clover had increased considerably since the previous fall (see Figs. 2C and 3C). These two species now occupied 58.2 percent of the stand. The average area per square meter had increased from 37 sq. cm. to 203 for blue grass and from 204 to 307 for white clover. The weeds and slender wheat grass had been further reduced so that each of them now occupied but 3 percent of the vegetation. Brome and meadow fescue were less prominent, aggregating 35.6 percent of the stand. The total area of basal cover was about the same in 1930 as in 1929. Seed stalks of meadow fescue were numerous. There was very little yellow sweet clover, indicating that few plants had produced ripe seed the year before. The bulk of the forage was produced this year by meadow fescue, brome grass, white sweet clover and Kentucky blue grass. The chief weeds were foxtail and dandelion.

SUMMARY OF RESULTS FOR THE LARIMER COUNTY FARM PASTURE.—During the first two seasons yellow sweet clover, brome grass and meadow fescue furnished most of the forage. During the third season brome, meadow fescue, white clover and Kentucky blue grass furnished most. Slender wheat grass was good, especially in the drier places, only during the first season. It serves a purpose in the later years, even if it is not abundant, by growing in the dry areas where the other species do not thrive. The weeds, altho very numerous during the first season, showed striking decreases during the two following seasons. In the first season the chief weeds were foxtail, tickle grass and lamb's quarters. In the two following years, foxtail was almost the only weed present. At the close of the third season Kentucky blue grass and white clover were becoming dominant (Fig. 2C).

It appears that the pasture may have been even better than it was at the end of the third season if 2 pounds, instead of 3, of sweet clover had been planted; if there had been more frequent mowing of weeds during the first season, and if the grazing had been heavier during the second and third seasons.



Fig. 4.—Nelson pasture a few days after the barley had been cut. Yellow sweet clover is very abundant, Aug. 6, 1927.

NELSON PASTURE

The Nelson pasture was seeded in the spring of 1927 on a well-prepared seedbed. It was intended for sheep. The soil was a fine sandy loam. About half of the pasture sloped somewhat, just enough to make irrigation rather difficult. The other half was very level and had been drained with tile. There was a small amount of alkali in the level part. As shown in Table 5, the seed mixture consisted of 15 pounds of brome grass per acre, meadow fescue 10, orchard grass 15 and yellow sweet clover 4, totaling 44 pounds. The ratio between the amounts of seed used for each species is shown more exactly by the proportion of pure, live seed.

Table 5.—Seeding Ratio and Resulting Stands on Nelson Pasture, Seeded in Spring of 1927.

Plants	Seed per Acre		Stand Aug. 6, 1927			Stand Oct. 20, 1928		Stand Sept. 17, 1929		Stand Aug. 26, 1930	
	Lbs.	Pure, Live Seeds %	Ave. No. of Plants	Mixture Ratio %	Weeds Ratio %	Ave. Density %	%	sq. cm.	%	sq. cm.	%
Brome grass	15	15	94	14	10	2.7	7.8	104	7.6	102	12.6
Meadow fescue	10	21	188	27	20	10.0	28.9	264	19.4	161	19.9
Orchard grass	15	55	327	47	35	21.5	62.1	964	70.6	504	62.4
Y. S. clover	4	9	83	12	9	0.0	0.0	2	0.1	11	1.4
Weeds . . . . .	..	..	240	..	26	0.4	1.2	31	2.3	30	3.7
Totals	44	100	932	100	100	34.6	100.0	1365	100.0	808	100.0

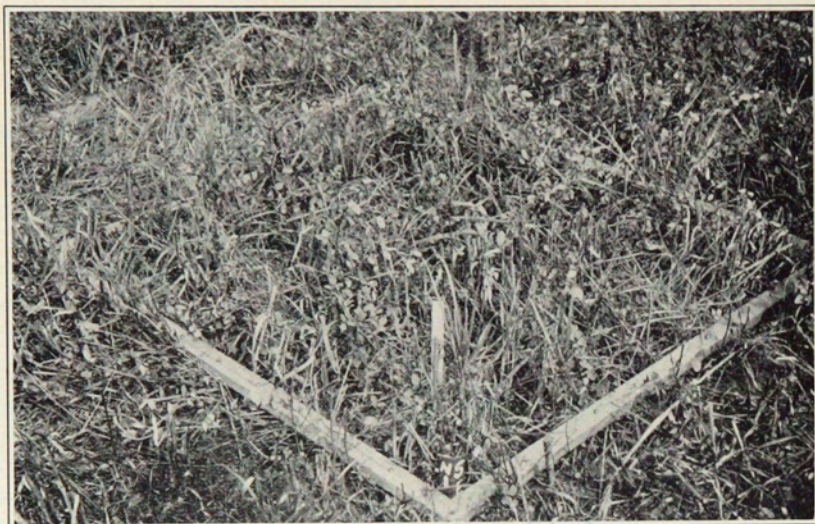


Fig. 5A.—Quadrat No. 1, in moist part of Nelson pasture. On Aug. 6, 1927, it contains chiefly orchard grass, meadow fescue, brome grass, yellow sweet clover and barley stalks.

This ratio is brome grass 15 percent, meadow fescue 21, orchard grass 55 and yellow sweet clover 9. In other words, the number of orchard-grass seeds planted was almost four times that of brome and about two and one-half that of meadow fescue. The

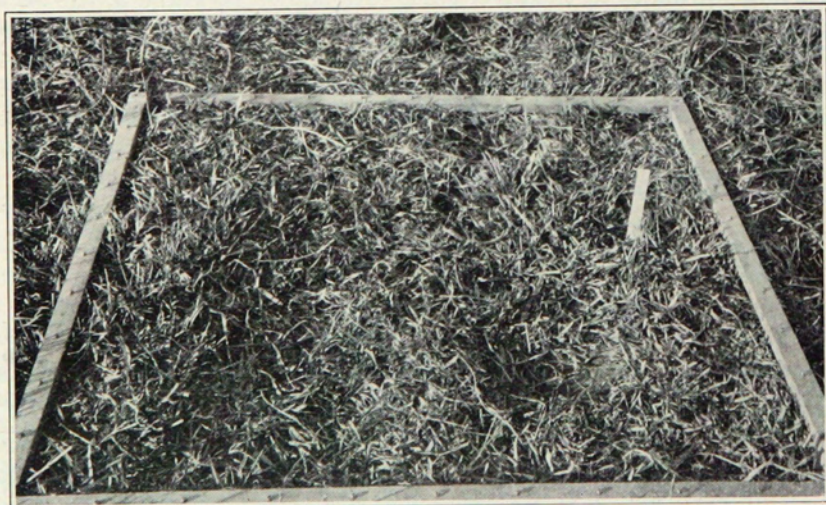


Fig. 5B.—Quadrat No. 1, in moist part of Nelson pasture. Pasture on Oct. 20, 1928, chiefly orchard grass and meadow fescue.



Fig. 5C.—Quadrat No. 1, in moist part of Nelson pasture. Pasture on Sept. 17, 1929, chiefly orchard grass and meadow fescue.

reason for this is that there are many more seeds of orchard grass in a pound than of brome or meadow fescue (see Table 1). In addition 1 peck of barley per acre was also sowed with the seed of the pasture plants. The seed was drilled in.

On August 6, four quadrats were carefully located, two in the moist part of the pasture and two in the dry part. The barley

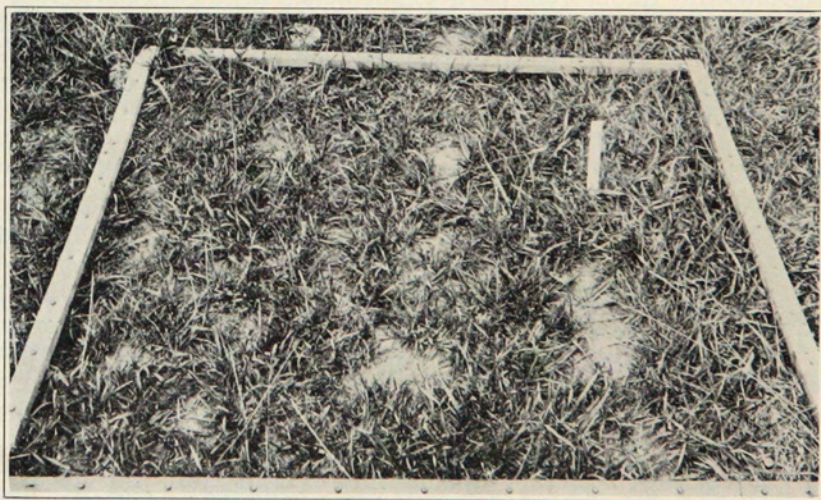


Fig. 5D.—Quadrat No. 1, in moist part of Nelson pasture. Pasture on Aug. 26, 1930, chiefly orchard grass, meadow fescue and brome grass.

had been cut for grain a few days before (Fig. 4). There had been about 6 irrigations so that over most of the pasture the barley crop and the pasture seedlings, especially sweet clover, were in good condition. In the moist parts of the pasture the grasses averaged about 10 inches tall; in the dry parts, about 7 inches. Sweet clover was usually 16 to 18 inches where it had not been cut and about 8 inches where the top had been removed with the grain. The count-list method was used in determining the composition of the vegetation in each quadrat. The summarized results are given in Table 5.

The ratio of the forage seedlings was unusually close to the ratio of pure, live seeds. Meadow fescue and yellow sweet clover were a trifle above and brome and orchard grass a little below. From this it appears that meadow fescue and yellow sweet clover can endure the competition with barley better than the others. Due to the very high proportion of orchard-grass seed that was used, the seedlings of this species were about equal in number to the seedlings of all of the other forage plants. When the weeds are considered in the ratio (see column "Weeds Ratio" in Table 5), it appears that the proportion of weeds (26 percent) was higher than was to be expected in view of the large amount of seed of forage plants and barley that was sowed. The chief weeds were wild buckwheat (*Polygonum convolvulus*), lamb's quarters (*Chenopodium album*) and pigweed (*Amaranthus retroflexus*). As shown in Figs. 5A and 6A the vegetation varied considerably in different parts of the field. In the dry parts there were fewer seedlings of forage plants. For example, in Quadrat 1 (Fig. 5A) there was a total of 898 seedlings of forage plants and 172 barley stalks, and in Quadrat 3 (Fig. 6A) there were 399 and 115, respectively. Yellow sweet clover, brome grass and weeds constituted a greater proportion of the stand in the dry parts than in the moist parts of the pasture.

There appeared to be an excessive amount of sweet clover in the pasture, but this plant was held in check by placing 25 head of sheep on the pasture about September 1. After the sheep had been on the pasture for a month, inspection showed no evident damage to the pasture. The plants in the dry parts, however, were suffering for lack of sufficient water. This lack of moisture was again evident on April 13 of the next year when it was very noticeable that the vegetation was not nearly so dense on the drier, sloping portion as on the moist, level area.

On October 20, 1928, the quadrats were listed by the density-list method (6). The summarized results are given in Table 5 in the column "Stand, Oct. 20, 1928." The pasture was in good

condition. The density was high, averaging 34.6 percent. It showed no signs of having been too closely grazed. Meadow fescue had produced much seed and seedlings were found. This species appears to produce seed very easily under pasture conditions. All of the grasses appeared to be about equally grazed by the sheep. Outstanding changes (compare Figs. 5A with 5B, and 6A with 6B) that occurred during the year were that yellow sweet clover had died, weeds were reduced from 26 to 1.2 percent, and orchard grass (62.1 percent) and meadow fescue (28.9 percent) now made up most of the vegetation. The decrease in weeds was due partly to grazing by sheep. Differences between the dry and moist parts of the pasture (see Figs. 5B and 6B) were that the stand was thinner and there was a greater proportion of brome grass and weeds, as *Bromus tectorum*, in the dry part than in the moist.

On September 17, 1929, the quadrats were again listed, this time by the area-list method, in combination with the count-list method. The method was changed because the area-list method had been demonstrated to be more accurate and time-saving than the other methods (6). Since the method was changed, the data of the 2 years as given in Table 5 are not strictly comparable, but general deductions may be made.

Most of the grazing during this year had been by sheep, and some by cattle and horses. There were numerous seed stalks of orchard grass and meadow fescue on September 17. The stand appeared somewhat less dense in 1929 than in 1928 (Compare Fig. 5B with 5C, and 6B with 6C). The proportions of orchard grass and of weeds had increased somewhat while meadow fescue and brome had decreased.

Another listing by the same method was made on August 26, 1930. The summarized results are presented in Table 5. Seed heads of meadow fescue and orchard grass were numerous. The pasture appeared to be in fairly good condition except for dryness in some parts. Horses and cows, as well as sheep, had grazed on it during the past year. There had been a decrease in density (basal cover) from an average of 1365 sq. cm. per quadrat in 1929 to 808 in 1930 (see Figs. 5D and 6D). The areas occupied by brome grass and weeds remained about the same, yellow sweet clover increased slightly while meadow fescue and orchard grass decreased considerably.

SUMMARY OF THE NELSON PASTURE.—The heavy proportion of seed of orchard grass in the seed mixture produced a pasture consisting chiefly of this grass. During the first 2 years there was considerable yellow sweet clover; after that it

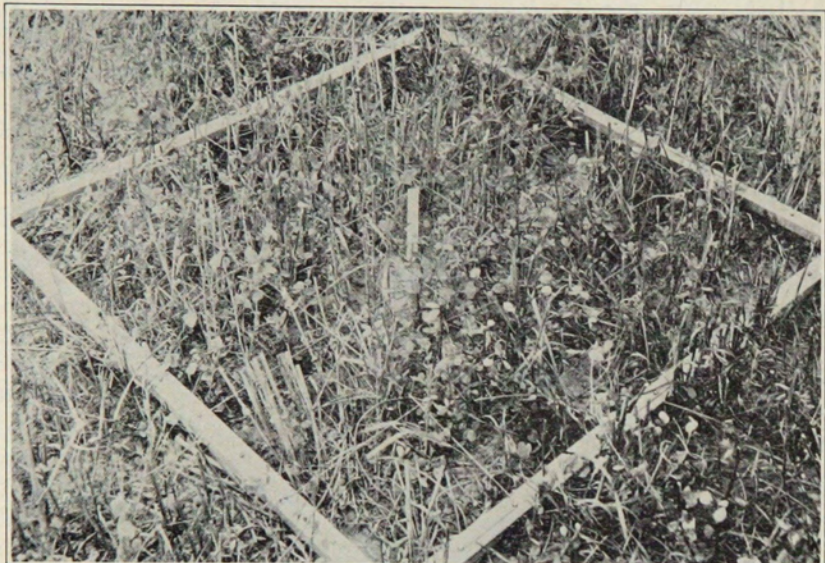


Fig. 6A.—Quadrat No. 3, in dry part of Nelson pasture, on Aug. 6, 1927, chiefly orchard grass, barley stalks, meadow fescue, yellow sweet clover, brome grass and lamb's quarters.

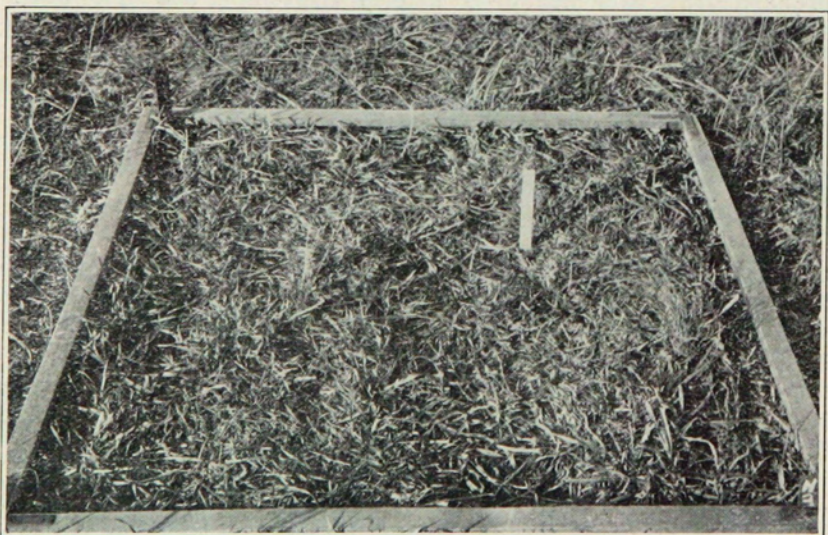


Fig. 6B.—Quadrat No. 3, in dry part of Nelson pasture, on Oct. 20, 1928. Pasture contains chiefly orchard grass and meadow fescue.

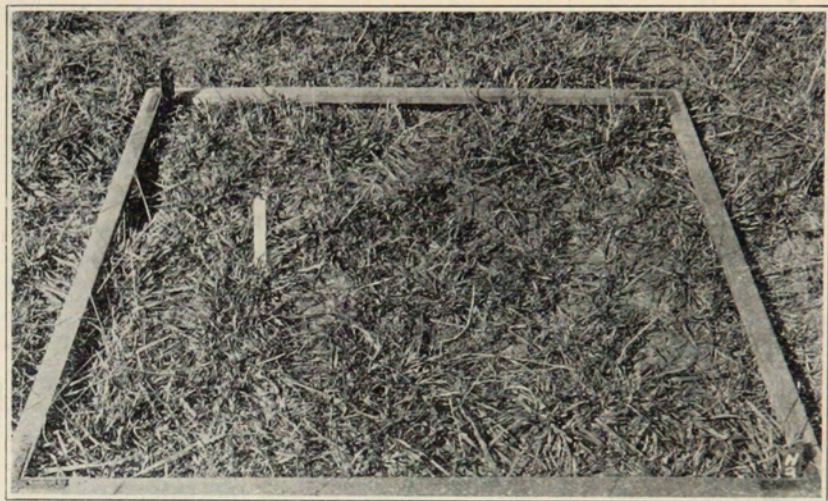


Fig. 6C.—Quadrat No. 3, in dry part of Nelson pasture. Sept. 17, 1929. Pasture contains chiefly orchard grass, meadow fescue and brome grass.

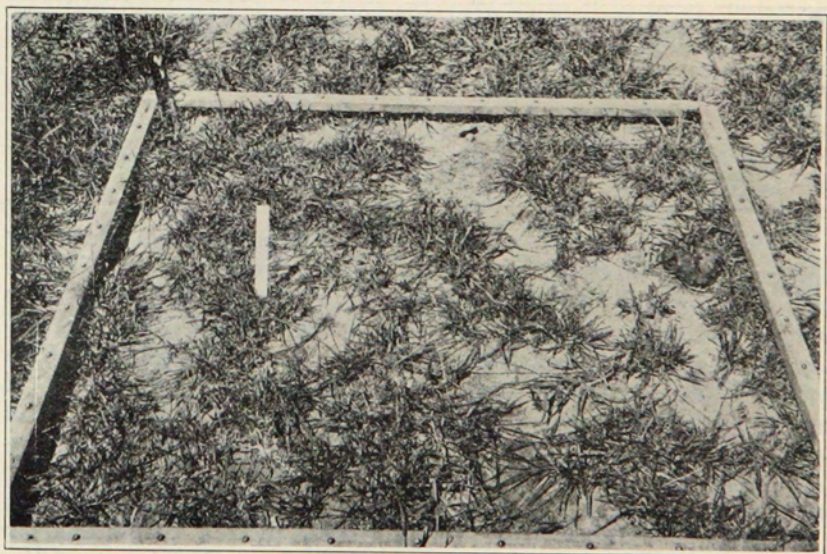


Fig. 6D.—Quadrat No. 3, in dry part of Nelson pasture. Aug. 26, 1930. Pasture contains chiefly orchard grass, meadow fescue and brome grass.

was very scarce. Meadow fescue was more abundant than brome grass but at the end of the fourth season the latter occupied a more prominent position in the stand, due to its rhizome habit of spreading and its resistance to drought and heavy grazing. Weeds were more abundant than was to be expected during the first year, but after that they were rapidly reduced by grazing and competition. By the close of the fourth season, however, they were increasing, due partly to insufficient irrigation in certain parts of the pasture and partly to too close grazing at times.

The danger of having a pasture consisting largely of orchard grass, coupled with too close grazing in the fall, is illustrated by another pasture on this ranch. This had been seeded in 1924 to a mixture of brome grass, meadow fescue, orchard grass, yellow sweet clover and timothy in the proportions as given in Table 6. The number of pure live seeds of orchard grass and timothy was very high in proportion to the numbers of other kinds of seeds. Brome grass seed was only 9 percent of the total number.

Table 6.—Seeding Ratio of Pasture Seeded in 1924 and the Stand in 1927, Grazed by Sheep.

Plants	Seed per Acre		Stand, Aug. 6, 1927			
	Lbs.	Pure, Live Seeds %	No. of Plants	Mixture Ratio %	Survival %	Weeds Ratio %
Brome grass	15	9	8	5	2	5
Meadow fescue	10	13	31	20	6	18
Orchard grass	15	34	101	65	7	60
Y. S. clover	4	6	15	10	6	9
Timothy	6	38	0	0	0	0
Weeds . . . . .	..	..	14	..	..	8
Totals	50	100	169	100		100

On August 6, 1927, a carefully located quadrat was listed by the count-list method. Individual plants were counted. There was a total of only 169 plants in the square meter and these were very small clumps. As shown in Table 6 (Fig. 7), the vegetation consisted of about three-fifths orchard grass and one-fifth meadow fescue. There was no timothy and only 5 percent of brome grass. The stand was very open and the plants had been grazed very closely. At this time the few leaves of orchard grass and meadow fescue that were more than 2 inches long were usually growing flat on the ground. During the fall of 1927, the pasture continued to be very closely grazed. Examination the following spring, April 13, 1928, revealed that most of the orchard grass had died during the winter. Meadow fescue and



Fig. 7.—Nelson pasture seeded in 1924. On Aug. 6, 1927, when photographed, it consisted of about three-fifths orchard grass, one-fifth meadow fescue and one-fifth weeds, brome grass and yellow sweet clover. Due to the heavy proportion of orchard grass and excessively close grazing by sheep, this pasture was ruined by winter-killing early in 1928.

brome grass had survived the winter in good condition. Due to the very thin stand of these grasses, however, the pasture was plowed. Had there been less orchard grass and more brome and meadow fescue in the seeding mixture as well as in the pasture, in 1927, it might not have been necessary to plow it.

GETTMAN PASTURE

About March 1, 1928, 4 acres that had previously been in sugar beets were seeded to a mixture presumably as shown in Table 7. The land had a very slight slope, making it ideal for

Table 7.—Seeding Ratio and Resulting Stands on Gettman Pasture, Seeded in Spring of 1928.

Plants	Seed per Acre		Stand, Sept. 22, 1928		Stand, Oct. 8, 1929		Stand, Aug. 29, 1930	
	Lbs.	Good Seed Ratio %	Ave. Density %	%	Sq. cm.	%	Sq. cm.	%
Brome grass	10	17.9	5.2	18.2	103	9.5	84	13.0
Meadow fescue	6	21.9	5.2	18.2	254	23.5	133	20.6
Sl. wheat grass	4	9.2	1.4	4.9	34	3.1	21	3.1
Orchard grass	4	25.8	15.1	52.8	669	61.9	391	60.6
Y. S. clover	6	25.2	1.2	4.1	2	0.2	1	0.1
Weeds . . . . .	..	..	0.5	1.8	19	1.8	17	2.6
Totals	30	100.0	28.6	100.0	1081	100.0	647	100.0



Fig. 8A.—View of Gettman 1928 pasture on Sept. 22, 1928. Weeds had been mowed in background but not in foreground. No effect resulting from this was in evidence in 1929.

irrigation. The soil was a sandy loam. The seed was drilled in one direction without a nurse crop. A heavy snow-storm came a few days after seeding. By May 29 the stand was in excellent condition. The grasses were 6 to 12 inches long and had started



Fig. 8B.—View of Gettman 1928 pasture on Oct. 8, 1929. Weeds had almost disappeared in 1929, due to close grazing by sheep.

to tiller. Yellow sweet clover was 3 to 5 inches tall. There was quite a little tall black mustard in the drill rows, due to impure seed. The pasture received excellent care during the summer. It was irrigated 4 times up to September 22.

The south half was mowed once to eliminate the mustard. Sheep grazed moderately on it after July 1. On September 22 two carefully located quadrats were listed by the density-list method. The summarized results are given in Table 7. The uniformly good stand at this time (Figs. 8A and 9A) was due to a number of factors, such as the good seedbed, favorable conditions following seeding, timely irrigation and judicious grazing.

It was hoped that by reducing the amount of orchard grass in the seed mixture to 4 pounds per acre that a lower proportion of this grass would be secured in the vegetation. It appears very probable that more than 4 pounds per acre of orchard grass and less than 6 pounds of yellow sweet clover were seeded per acre. The stand on September 22 of the first season was composed of more than half orchard grass, with brome and meadow fescue constituting 36 percent more. The unusually low weed percentage, 1.8 percent, was due to the clean cultivation that had been practiced in previous years when the area was in beets, to grazing by sheep and to the excellent growth of the forage plants. The stand at the close of the first season consisted of too great a proportion of orchard grass and it appears that slender wheat grass could have been omitted (Fig. 9A).

During 1929 the pasture was grazed mostly by sheep and by a few head of Holstein cattle. Three irrigations were given. On October 8 the quadrats were listed by the area-list method. The summarized results are given in Table 7. The condition of the pasture was hardly as good as the year before, due to the death of yellow sweet clover and somewhat of a shortage of irrigation water. Orchard grass had increased from 53 to 62 percent of the total composition, meadow fescue increased slightly, while brome and slender wheat grass had decreased. The weeds remained about the same (Fig. 9B).

During 1930 the pasture was irrigated only once. It was closely grazed by sheep, cows and horses. On September 29, it was again area-listed, giving results shown in Table 7. There was little change in the composition as compared with the previous year, but in area occupied all decreased more or less. The areas of orchard grass and meadow fescue decreased most; brome, slender wheat and weeds least. The total basal cover per quadrat decreased from 1081 sq. cm. to 647. Less close grazing

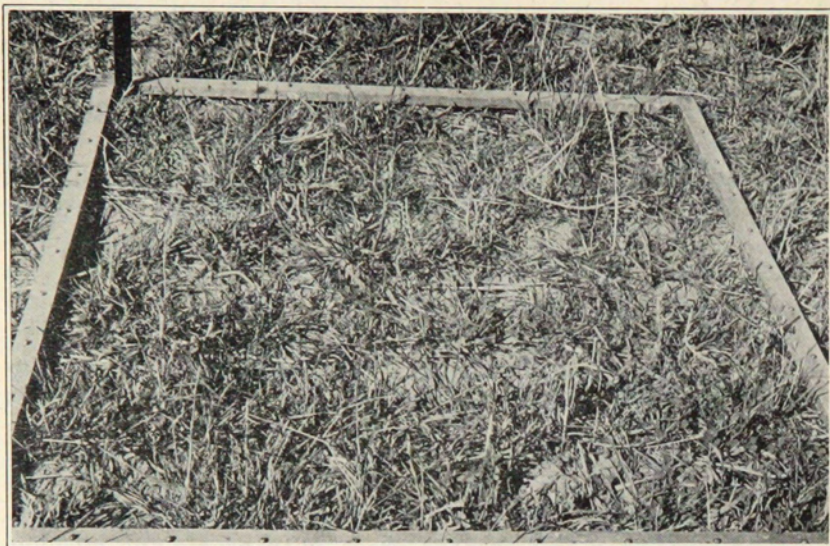


Fig. 9A.—Quadrat No. 1, in Gettman pasture, seeded about March 1, 1928. On Sept. 22, 1928, orchard grass is the most abundant and meadow fescue next in abundance. Brome grass, yellow sweet clover and slender wheat grass are much less abundant.

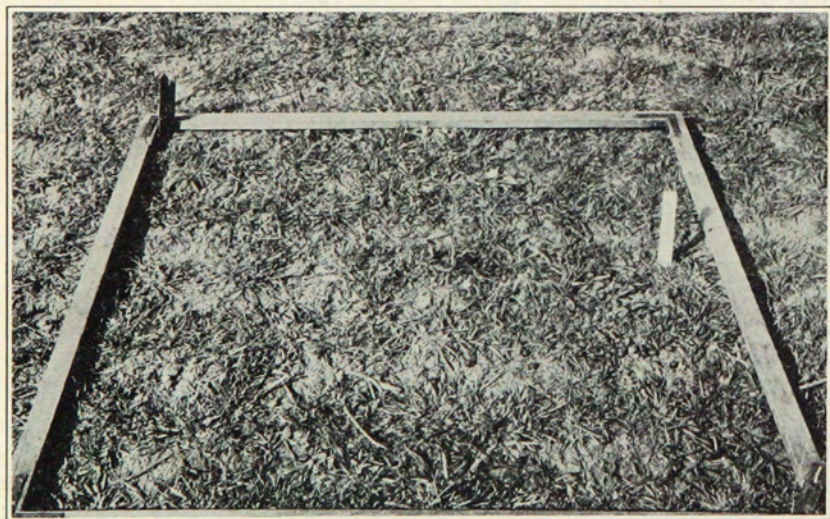


Fig. 9B.—Quadrat No. 1, in Gettman pasture, seeded about March 1, 1928. On Oct. 8, 1929, orchard grass is the most abundant and meadow fescue next in abundance. Brome grass, yellow sweet clover and slender wheat grass are much less abundant.

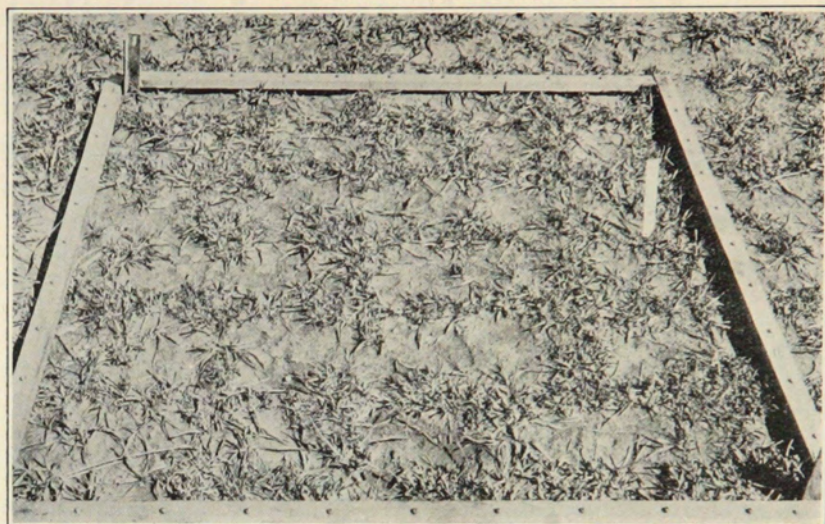


Fig. 9C.—Quadrat No. 1, in Gettman pasture, seeded about March 1, 1928. On Aug. 29, 1930, the same plants still showed the same abundance. Orchard grass and meadow fescue are the most abundant. Brome grass, yellow sweet clover and slender wheat grass are still least abundant.

and frequent irrigation would have prevented the decrease in density (Fig. 9C).

Another 9 acres was seeded in the spring of 1929. Orchard grass was left out of the mixture and by mistake an excessive amount of yellow sweet clover was seeded per acre (10 pounds). The seeding ratio, as well as the summarized results of listing 4 quadrats in 1929 and 1930, are shown in Table 8.

The exceedingly high proportion of yellow sweet clover in the seed mixture, 46 percent of the total number of good seed,

Table 8.—Seeding Ratio and Resulting Stands on Gettman Pasture, Seeded in Spring of 1929.

Plants	Seed per Acre		Stand Oct. 11, 1929.		Stand Aug. 29, 1930.	
	Lbs.	Good Seed Ratio %	Ave. No. of Stalks	%	sq. cm.	%
Brome grass	10	19.6	290	22.0	164	54.3
Meadow fescue	6	24.1	572	43.5	68	22.5
Sl. wheat grass	4	10.2	121	9.2	52	17.2
Y. S. clover	10	46.1	299	22.7	2	0.7
Weeds . . . . .	..	....	34	2.6	16	5.3
Totals	30	100.0	1316	100.0	302	100.0



Fig. 10.—Gettman 1929 pasture near end of second summer, Aug. 29, 1930. Brome grass and old stalks of yellow sweet clover are prominent.

resulted in a stand (Fig. 11A) that was dominated by yellow sweet clover. It made up 22.7 percent of the stand on October 11, 1929. The very thick stand of yellow sweet clover caused the death of many grass seedlings. It also produced bloating in the sheep. When the sweet clover died the following summer, the stand was more open than it would have been otherwise (Fig. 11B). The pasture was in excellent condition (Fig. 10) on August 29, 1930, in spite of the heavy seeding of yellow sweet clover the previous year. Brome grass was the most abundant of the forage plants at the close of the second summer.

SUMMARY OF GETTMAN PASTURES.—A greater number of orchard-grass seed in the seeding mixture led to a heavy proportion of orchard grass in the pasture seeded in 1928. The large amount of orchard grass appeared to prevent brome grass from spreading. It seemed that orchard grass might have had a depressing effect upon brome. When orchard grass was left out of the mixture, on the same kind of soil, in the pasture seeded in 1929, brome grass grew much better (Figs. 10 and 11B). The excessive amount of yellow sweet clover seed planted in the 1929 pasture led to such a dense growth of this plant that many grass seedlings died and there was much bloating in the sheep. If there is any danger of bloat it is important to reduce the amount

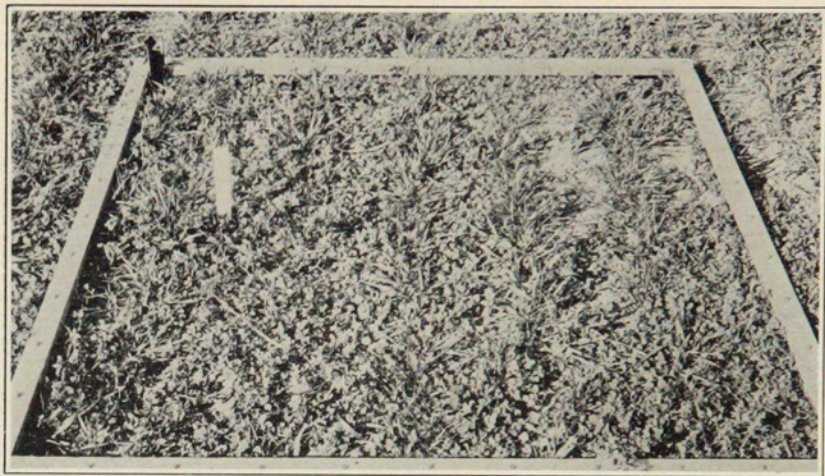


Fig. 11A.—Quadrat No. 4, in Gettman 1929 pasture. On Oct. 11, 1929, yellow sweet clover, meadow fescue and brome grass are most abundant.

of yellow sweet clover to 2, or perhaps 3, pounds per acre so that the grasses will produce most of the forage. Too thick a stand of yellow sweet clover leaves open spots in the pasture after the yellow sweet clover has died in the second summer, due to its suppressive effect upon the grass seedlings (compare Figs. 11A and 11B).

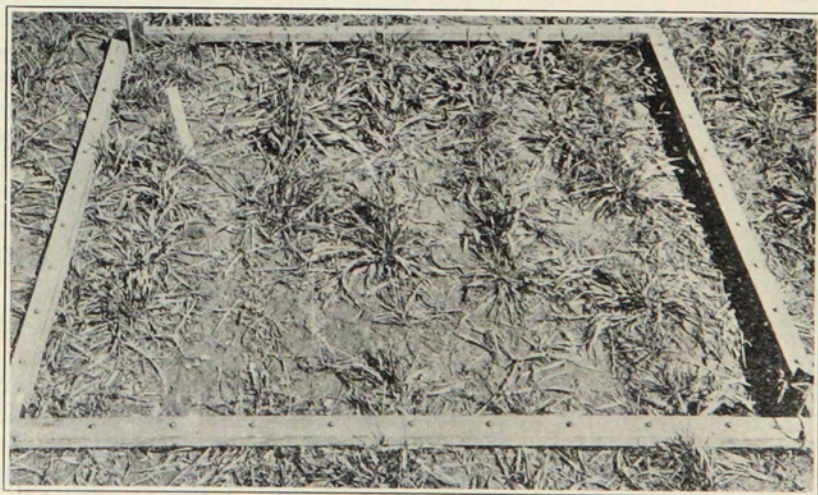


Fig. 11B.—Quadrat No. 4, in Gettman 1929 pasture. On Aug. 29, 1930, brome grass is most abundant.



Fig. 12.—Hice pasture on Sept. 6, 1927, seeded the preceding spring. The wheat crop greatly suppressed the seedlings of the pasture plants.

HICE PASTURE

An irregular area of about 6 acres, lying between two large irrigation ditches, was plowed in the fall of 1926, and seeded about April 1, 1927, to the mixture shown in Table 9. In addition to the 30 pounds per acre of seed of pasture plants, 5 pecks of wheat were also planted per acre. This mixture produced an excellent crop of wheat. On July 8, when the wheat kernels were beginning to harden, the wheat was in splendid condition, but the forage plant seedlings were very small and scarce. Meadow fescue and brome were most abundant; all of the others were hard to find. The surface soil was very dry and cracks were numerous. The seedlings of the pasture plants were finding it very difficult to remain alive.

On September 6, five quadrats were carefully located so that dry and moist areas would be represented in about their approximate proportions. The wheat had been cut for some time but the shocks were still on the pasture. The soil was hard, dry and cracked. The pasture plants looked much better than could be expected (Figs. 12 and 13A). Under the shocks, however, most of them had died. The quadrats were listed by the count-list method and the results are given in Table 9.

Table 9.—Seeding Ratio and Stands in 4 Successive Years on Hice Pasture, Planted About April 1, 1927.

Plants	Seed per Acre		Stand, Sept. 6, 1927			Stand, Sept. 18, 1928 %	Stand, Sept. 10, 1929		Stand, Aug. 27, 1930	
	Lbs.	Good Seed Ratio %	Ave. No. of Plants	Mix- ture Ratio %	Weeds Ratio %		sq. cm.	%	sq. cm.	%
Brome grass	8	5	99	29	25	26	203	14.9	184	28.1
Ky. blue grass	5	40	35	10	9	1	2	0.2	27	4.1
Meadow fescue	8	10	160	47	41	52	758	55.7	370	56.5
Timothy	5	32	31	9	8	5	114	8.3	22	3.4
White clover	4	13	17	5	4	6	229	16.8	8	1.2
Y. S. clover .....	..	..	2	..	1	..	..	..	7	1.1
Weeds .....	..	..	50	..	12	10	56	4.1	37	5.6
Totals	30	100	394	100	100	100	1362	100.0	655	100.0

The vegetation at the close of the first summer consisted chiefly of meadow fescue (41 percent) and brome grass (25 percent). Weeds, chiefly lamb's quarters, pigweed and fetid marigold (*Dysodia papposa*), were numerous, constituting 12 percent of the vegetation. Timothy, Kentucky blue grass and white clover were scarce. The pasture plants were less numerous in most of the quadrats than the wheat stalks (Fig. 13A). More of the brome grass germinated and produced seedlings that survived the first summer than of any other species.

On April 19, 1928, the pasture appeared fairly good, especially in the lower places. Brome and meadow fescue seemed about equally abundant. Both were very leafy and in excellent condition. Brome grass was 3 to 7 inches tall with leaves about 0.25 inch wide. Meadow fescue was 3 to 5 inches tall with leaves about 0.12 inch wide. The clumps of both were mostly 1 to 3 inches in diameter at the base. Timothy, Kentucky blue grass and white clover were scarce but were spreading somewhat, forming small clumps. During the second season grazing by horses was light but very spotted. The care given the pasture was not good as shown by the dryness and hardness of the soil, deep cracks, and hoof marks caused by slipping of the horses when the soil was wet. In spite of the poor treatment, brome grass and white clover had spread vegetatively and the clumps of meadow fescue had enlarged. Seed was produced by these plants as well as by timothy. Meadow fescue seedlings were rather numerous in the areas that were more favorable, due to seepage. Barnyard grass (*Echinochloa crus-galli*) and black medic (*Medicago lupulina*) had seeded profusely.

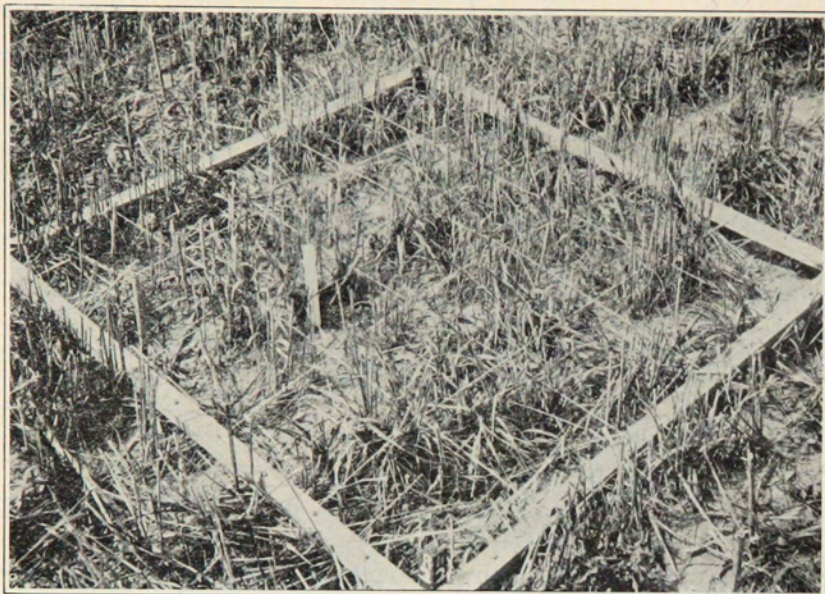


Fig. 13A.—Quadrat No. 2, in Hice pasture, seeded in spring of 1927. On Sept. 6, 1927, meadow fescue and brome grass are the principal plants. Wheat stalks abundant in 1927.

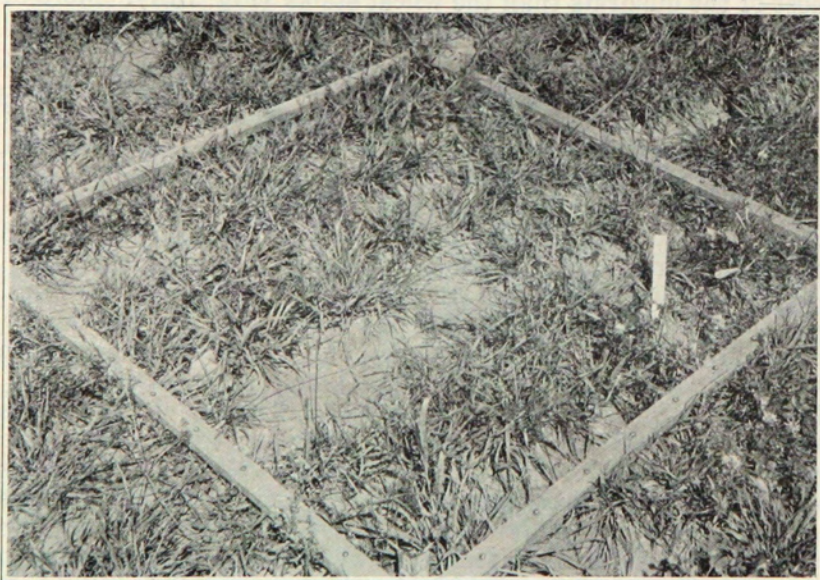


Fig. 13B.—Quadrat No. 2, in Hice pasture, seeded in spring of 1927. On Aug. 11, 1928, meadow fescue and brome grass are the principal plants.

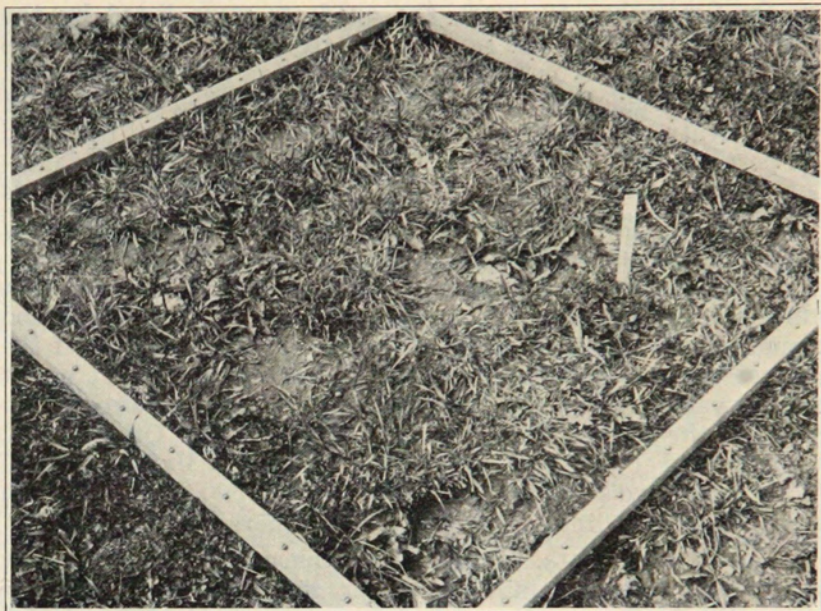


Fig. 13C.—Quadrat No. 3, in Hice pasture, seeded in spring of 1927. On Sept. 10, 1929, meadow fescue and brome grass are the principal plants. Dandelion is coming in and is noticeable.

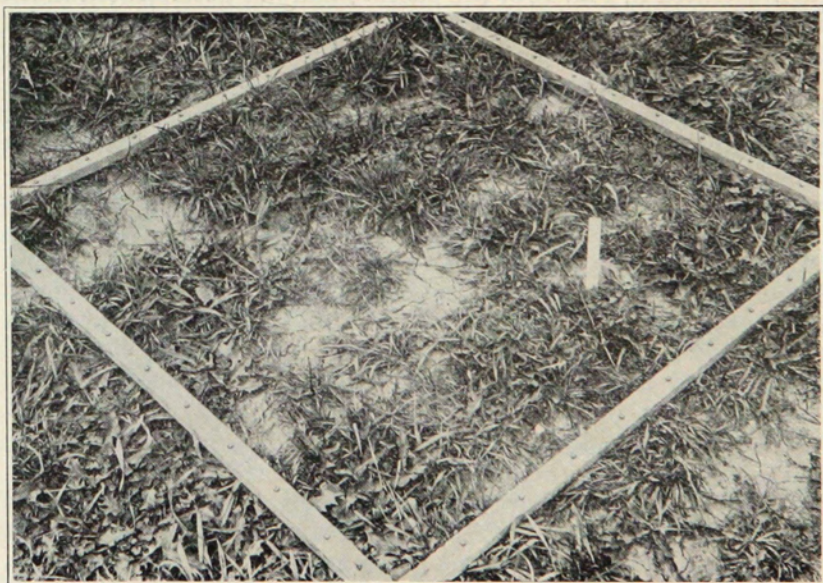


Fig. 13D.—Quadrat No. 3, in Hice pasture, seeded in spring of 1927. On Aug. 27, 1930, meadow fescue and brome grass are still the principal plants. Dandelion is abundant. This quadrat illustrates the bad effect of a heavy nurse crop in the first season and the lack of sufficient water and proper management in later years.

On September 18, 1928, the quadrats were listed by the density-list method. The summarized results are given in Table 9. The pasture was in much better condition at this time (Fig. 13B) than could have been expected considering the lack of proper treatment. Meadow fescue occupied over half of the stand (52 percent) and brome grass 26 percent. Weeds, chiefly dandelion, fetid marigold, sage (*Salvia lanceolata*), barnyard grass and foxtail were more abundant (10 percent) than is usual where better care is given.

Examination the following spring, May 14, 1929, showed that white clover was spreading rapidly and that meadow fescue and brome grass were in excellent condition. It appeared that if the pasture were irrigated sufficiently and grazed properly it might become very good, but at this date the grazing was already too close and the soil was becoming hard and cracking. Other weeds, as gumweed (*Grindelia squarrosa*), mallow (*Malva rotundifolia*), shepherd's purse (*Bursa bursa-pastoris*) and dandelion were either invading or becoming much more numerous.

The quadrat data, taken on September 10, 1929 (see Table 9), indicate increases in white clover, meadow fescue and timothy. White clover and meadow fescue occupied 16.8 and 55.7 percent, respectively, of the vegetation, while brome grass occupied 14.9 percent. Weeds had decreased from 10 to 4.1 percent. As illustrated in Fig. 13C, the pasture had not deteriorated much during the past year, but it had not improved as it could under proper management.

During 1930 the pasture deteriorated considerably (Fig. 13D). The density especially, was much lower. In 1929 the average basal cover per quadrat was 1362 sq. cm., in 1930 it was 655. White clover and meadow fescue showed the greatest decreases in the area occupied. There had been no irrigation up to August 27. Dandelion and gumweed increased decidedly in number, but other weeds had died. The quadrat data taken on August 27, as summarized in Table 9, show that brome grass occupied a larger proportion of the stand than in the previous year, meadow fescue remained about the same, white clover and timothy decreased, and blue grass and weeds increased.

SUMMARY OF THE HICE PASTURE.—A mixture, consisting of brome, meadow fescue, Kentucky blue grass, timothy and white clover, was seeded on an area that varied considerably in moisture conditions. Parts of it were moist due to seepage from a large irrigation ditch; other parts became very dry due to lack of sufficient irrigation. Brome grass grew best on the dry parts, meadow fescue and white clover on the moist ones. Due to a

heavy nurse crop, deficient soil moisture, cracking of the soil, and overgrazing at times, the pasture plants at the close of the fourth season were not dense enough, and weeds (dandelion and gumweed especially) were too numerous. The pasture was not producing nearly the amount of forage that it could. A better mixture for these conditions would have included yellow sweet clover with brome and meadow fescue, omitting timothy, blue grass and white clover. It is remarkable, however, that under the poor treatment given this pasture, the forage plants grew as well as they did. At the close of the fourth summer the weeds were beginning to succeed the forage plants.

DAVIS PASTURE

The results of seeding only one pasture grass, brome, are illustrated by the Davis pasture. This area was located near the Poudre River. The soil was heavy and poorly drained. After preparing a good seedbed, 15 pounds of brome grass and 60 pounds of oats per acre were planted by drilling, in the spring of 1927. The oats were cut for grain on August 6. Three irrigations had been given the crop. On September 20, two quadrats were listed. There were 346 seedlings in one quadrat and 234 in the other. This indicates germination and survival of



Fig. 14.—A 1-year-old brome grass pasture (Davis) seeded at rate of 15 pounds per acre with a nurse crop of oats at 60 pounds per acre. Seeded in spring of 1927, photographed on April 19, 1928.

about 90 percent of the good seed in the former and about 61 percent in the latter. Early the following spring, April 19, 1928, the pasture was in excellent condition as illustrated in Figure 14. The tufts were large for plants only about 1 year old and the density was excellent. The plants were beginning to spread by rhizomes. Further observations were discontinued because the field was used for seed production instead of for pasture.

This pasture demonstrates the growth of brome grass when it is not handicapped by the competition of other species, especially orchard grass.

WELTY PASTURE

The Welty pasture is one of the oldest irrigated pastures in Northern Colorado (Fig. 15). It was seeded about 1899, to a variety of pasture plants, such as Kentucky blue grass, alsike clover, brome grass, orchard grass, rye grasses, etc., but no record was made of the exact proportions. Since other old pastures in the region were similar to this one, it appeared desirable to determine its composition. On November 12, 1928, five quadrats



Fig. 15.—Welty pasture on July 14, 1927. It was seeded about 1899. Kentucky blue grass and white clover, which is in full bloom, are the main constituents. Brome grass, orchard grass, timothy, false quackgrass and alsike clover are in smaller proportions.

were located in typical parts of the pasture and listed by the density-list method. The average composition of the pasture was found to be Kentucky blue grass 80 percent, false quackgrass (*Agropyron pseudorepens*) 3, white clover 13, brome grass 1, orchard grass 1, weeds (almost entirely dandelion) 2. As seen in Figure 15, this was an excellent pasture. The top soil was a mass of decaying stems and leaves with a network of rhizomes and roots. It had required many years to build up the large amount of organic matter that was present. The average carrying capacity was about 2 cows per acre from early in the spring until late in the fall. It was difficult to determine accurately the carrying capacity because some cattle were on it during the entire year and because the number of cattle in the pasture varied.

Judging by this pasture and by several other nearly as old pastures, the final stage usually consists of chiefly Kentucky blue grass and white clover, with a small mixture of other species such as brome grass, orchard grass, timothy, alsike clover, red clover and black medic (*Medicago lupulina*). Usually the most common and abundant weed in the old pastures is dandelion. Other weeds that may occur are, in low moist spots, western ragweed (*Ambrosia psilostachya*), poverty weed (*Franseria tomentosa*), downy brome (*Bromus tectorum*), squirrel-tail grass or wild barley (*Hordeum jubatum*); in dry areas, field bindweed (*Convolvulus arvensis*), sage (*Salvia lanceolata*) and gumweed (*Grindelia squarrosa*).

MEREDITH PASTURE

The Meredith pasture, consisting of about 6 acres, was planted in the spring of 1927 to a mixture consisting of brome grass, meadow fescue, orchard grass, timothy and yellow sweet clover. The proportion in which these were planted was not determined. No nurse crop was used. The seedbed was well prepared. The soil was a sandy loam. Water was usually not available to irrigate the pasture sufficiently. The seedling stand, early the first season, was not very good due to the dryness of the soil. The pasture was grazed by dairy cattle. Four quadrats were carefully located and quadratted in late summer or fall for 4 consecutive years. The summarized results are given in Table 10.

Due to insufficient irrigation and to overgrazing at times, the pasture was never very good. During the first 3 years, orchard grass and meadow fescue were most abundant, but during the summer of 1930, when even less water was applied, these

Table 10.—Composition of the Vegetation in the Meredith Pasture for 4 Successive Years. The Figures Represent Averages of Four Permanent Quadrats.

Plants	Stand, Sept. 12, 1927		Stand, Oct. 27, 1928		Stand, Sept. 27, 1929		Stand, Aug. 25, 1930	
	Ave. No. of Plants	%	Area sq. cm.	%	Area sq. cm.	%	Area sq. cm.	%
Brome grass	63	6.1	110	7.7	150	12.0	136	26.8
Meadow fescue.....	333	31.9	472	32.9	403	32.3	140	27.5
Orchard grass.....	429	41.1	518	36.0	490	39.3	168	33.1
Timothy.....	83	7.9	206	14.3	182	14.7	57	11.2
Y. S. clover.....	76	7.3	Tr.	Tr.	7	0.6	2	0.4
Weeds.....	59	5.7	131	9.1	14	1.1	5	1.0
Totals.....	1043	100.0	1437	100.0	1246	100.0	508	100.0

two species decreased much more than brome grass, so that in the late summer of 1930 brome grass occupied almost as much area as either of the other two. Yellow sweet clover was abundant only during the first two seasons. Timothy occupied from 8 to 14 percent of the stand during the first three seasons and then fell to 11 percent. The chief weeds were pigweed, fetid marigold, tickle grass, foxtail, barnyard grass and sage (*Salvia lanceolata*). In the fourth season some perennials, as gaura (*Gaura coccinea*) and buffalo grass (*Bulbils dactyloides*) were beginning to invade.

This pasture again illustrates that the lack of adequate water and careful management results in a poor stand of vegetation. Even if good treatment is given after poor treatment the first year, the pasture will never be as good as it could have been under good treatment from the beginning. Brome grass withstood the unfavorable conditions best. If there had been more seed of brome grass in the seeding mixture and less of orchard grass, and no timothy, the pasture would most likely have been much better at the end of the fourth season than it was, because the percentage of brome grass in the stand increased from 6.1 in the first year to 26.8 in the fourth.

DISCUSSION

The successful establishment of an irrigated pasture usually depends upon how carefully the management of the pasture has been directed in view of the controlling factors. The pasture plants, especially in the seedling stage, are quickly and directly affected by a large number of factors. Efficient pasture management includes not only consideration of all possible factors, but

also the adaptation of management methods to the most important factors and the control of factors as far as possible. Findlay in Scotland (4), Volkart in Switzerland (22), and Stapledon and Davies in Wales (16) have considered a number of factors that determine the success or failure of seed mixtures. The principles upon which pasture mixtures should be based are also treated. Brown and Slate (2) discussed several factors that are involved in the maintenance and improvement of permanent pastures in humid sections. The more important factors that influence the establishment of irrigated pastures are listed and briefly discussed below:

1. Purposes of the pasture
2. Topography
3. Soil conditions
4. Climate
5. Supply of irrigation water
6. Preparation of the seedbed
7. Selection of the seed mixture and competition between species
8. The "nurse crop" and its treatment, if planted
9. Time and method of sowing
10. Weeds
11. Grazing and mowing
12. Management

1.—PURPOSES OF THE PASTURE.—The class or classes of stock to be grazed are probably a first consideration. The composition of the vegetation should meet the needs of the kind of stock grazing thereon as far as possible. The characteristics of various available species will be discussed under "Selection of the Seed Mixture." It is well known that sheep prefer forbs and the leaf blades of grasses, and that cattle and horses eat fewer species of forbs and are less selective in grazing grass. Mixed grazing, as sheep and cattle at the same time, successive, or rotation grazing may be practiced. The species of forage plants to sow depends upon whether the pasture is temporary, as part of a rotation plan, or permanent. The season during which the pasture is to be most heavily used influences the choice of plants to seed. Perhaps the pasture is needed chiefly in spring and fall. If it is needed for as long a season as possible, species should be selected that will grow well at various times so as to give the longest grazing period. Crested wheat, brome and Kentucky blue grass are the earliest species and they grow well late in the season. Brome, slender wheat and yellow sweet clover appear to do best in midseason if soil moisture is low.

The best pastures studied in this investigation appear to be the Welty and the County Farm. Both of these show a number of characteristics of good pastures such as high yield of concentrated forage; dense, uniform sod capable of withstanding much trampling when wet or frozen; freedom from soil cracks; a long grazing season; and few weeds.

2.—TOPOGRAPHY.—The area chosen for an irrigated pasture should, as much as possible, have a uniformly gentle slope so that all parts of it may be easily irrigated, as in the Gettman pasture. If the slope is very great, the run-off will be high. If the surface is irregular, as in the County Farm and Nelson pastures, it may be impossible to irrigate some parts properly. Careful leveling before planting and well-planned ditches in the pasture aid considerably in distributing the water. On exposed slopes facing south or west, that dry out rapidly, the more drought-enduring plants should be seeded.

3.—SOIL CONDITIONS.—Each species of pasture plant can usually grow best in a particular kind of soil. When the soil conditions are known, the species may be selected that can grow best under the particular conditions. On alkali seepage areas, as in part of the Nelson pasture, slender wheat grass, brome grass and yellow sweet clover did best. Brome grass probably grows better than other species on dry, sandy areas. Results that have been secured on pastures in humid climates indicate that the fertility, especially the phosphate and lime content, would probably play a very important part in the establishment of the irrigated pasture.

4.—CLIMATE.—Some of the factors of the environment that may play an important part in the establishment of an irrigated pasture are the duration of the frostless season, the intensity of temperatures in summer and in winter, duration of favorable and unfavorable temperatures, humidity, wind and precipitation. A heavy snow falling and melting soon after the seeding of the first Gettman pasture was of considerable benefit in securing a good stand. Since on most ranches the amount of irrigation water is limited, rains coming at opportune times may conserve the supply of water. The dry summer of 1930 caused greater mortality in meadow fescue and orchard grass than it did in brome grass. Winter-killing produces more loss in orchard grass than in brome grass. This was strikingly illustrated on one of the Nelson pastures which was ruined due to heavy winter-killing of orchard grass early in 1928. This grass appears to be near its northern as well as its altitudinal limit in Northern Colorado. Perennial ryegrass (*Lolium perenne*), at best a short-lived

grass, has been recommended as a constituent of pasture mixtures in Southern Colorado, but it is not recommended for Northern Colorado (9). Stapledon, *et al.* (17) state that at temperatures of 44° F. and lower, germination is retarded and that grasses are slower to germinate than clovers. Some of the smaller grasses are more affected than larger ones. In this way clovers and larger grasses may secure an advantage over grasses in young stands.

5.—SUPPLY OF IRRIGATION WATER.—The water available for irrigation varies from ranch to ranch depending upon water rights. The pasture mixture should, as far as possible, be adjusted to the amount of water that is available at various times. The mixture on the Hice pasture was not suited to the insufficient irrigations. The Meredith pasture failed to start properly because not enough water was supplied after seeding and the soil became too dry for the survival of seedlings. Welch (20) emphasizes the importance of keeping the seedbed moist during germination and early growth of the seedling. He stated that most of the failure in securing good stands is because the young plants dry out. As with most other plants the most critical time in the life of pasture plants, and in the successful establishment of pasture, is during the seedling stage. Welch states that experiments have shown that "it is absolutely necessary" that early irrigations be made by the corrugation method with furrows about 24 to 30 inches apart. Jayne (7) recommends that the pasture should be irrigated quickly, if possible by flooding between borders.

6.—PREPARATION OF THE SEEDBED.—It is generally recognized that the preparation of the seedbed is of great importance. It should be fine and firm, of uniform surface, in good tilth and containing ample moisture. Freedom from as many weed seeds as possible is highly desirable. A crop of sugar beets, kept clean, as on part of the County Farm pasture and on the first Gettman pasture, makes almost an ideal crop preceding sowing to pasture. It is due chiefly to difficulties that young, tender seedlings encounter in even the best of seedbeds that the establishment percentage of seeds is far below the germination percentage. Stapledon and Davies (18) report that the percentage of viable seeds that became established as seedlings ranged from 9 in small-seeded species, as smooth-stalked meadow grass, to 56 in large-seeded species, as perennial ryegrass.

7.—SELECTION OF THE SEED MIXTURE.—The determination of the species and the proportions in which to seed them should

be based upon as full an appraisal as possible of the purpose for which the pasture is intended and of the factors that will influence the establishment and maintenance of the pasture on each specific ranch. The list of species from which selections may be made includes those species that appear best adapted to conditions in Northern Colorado. These are: Smooth brome grass, orchard grass, meadow fescue, timothy, Kentucky blue grass, slender wheat grass, crested wheat grass, red top, yellow sweet clover, white sweet clover, white clover, alsike clover, red clover and black medic. Since the plants are chosen because of their characteristics, a brief statement of the characteristics of each is given.

Smooth or Hungarian brome grass is a long-lived perennial propagating by root-stocks. Because of this vegetative method of propagating, it will increase the density of a pasture if given a chance. The sod that is formed is rather open. The herbage consists of a high proportion of leaves compared to stems. It starts growth very early in the season and grows well late in the season. It is less retarded by droughts in midsummer than most other species. In alkali tolerance it ranks next to slender wheat grass and yellow sweet clover. Smooth brome grass is very winter hardy and withstands close grazing. It is highly palatable to both cattle and sheep.

Meadow fescue is a perennial but it appears to be somewhat short-lived in pastures. It does not propagate by rootstocks, but grows in small tufts. When a pasture is not grazed closely it readily produces seed that germinates soon after falling. In drought and alkali tolerance it does not rank as high as brome grass but under moist conditions it is very leafy and palatable to all classes of stock. Like brome grass it is winter hardy and grows well in mixtures with it.

Orchard grass is a long-lived, rather coarse bunch grass. It is not particularly drought resistant and tolerates very little alkali. In early spring and late fall it does not grow as well as brome grass. It tends to winterkill in Northern Colorado, especially when closely grazed. This grass produces a large amount of forage but it becomes fibrous and loses in palatability shortly after the flower stalks appear. The young leafy shoots are readily eaten by all classes of stock. Because of its vigorous growth it hinders and often prevents the establishment of other species. This has been noted by several investigators in other regions (15, 14).

Timothy appears to be rather long-lived in irrigated pastures where it becomes established. It usually forms small bunches

with curious enlargements at the base of the stems called haplo-corms by which it propogates. It is not noted for drought nor alkali resistance, but it is winter hardy. Usually very few plants become established in a pasture, even when quite a little seed is planted. The stems are not as leafy as in the preceding species and they become woody and unpalatable rather early. The young shoots are grazed by all classes of stock.

Kentucky blue grass is a long-lived perennial, propogating by rhizomes and forming a dense sod that withstands much trampling even when the soil is wet. The seedlings are very small, but once the plants are established they become very aggressive. They can endure considerable shade, but do not withstand much alkali. During dry periods growth ceases and the plants become dormant, but as soon as the moisture supply is renewed, growth begins again. It grows well late in the fall and early in the spring, yielding the earliest of forage. Cattle have been observed grazing the new growth, mixed with that of the previous year, in early March. The rhizomes are very vigorous, growing at all times when soil moisture is satisfactory and when the soil is not frozen. It is largely because of this active rhizome growth that this species can kill out most other species and, in time, dominate the pasture. The proportion of leaves to stems is very high. The forage is extremely nutritious and more palatable than other species to all classes of stock.

Slender wheat grass, usually called western wheat or rye-grass on the market, is a perennial forming small or medium, erect bunches. When growing in mixture with other species in irrigated pastures it does not appear very long-lived. It has shown greater resistance to alkali and drought than any other species of tame grass in Northern Colorado. Since it is native to this region and much farther north, it is very winter hardy. It does not have as high a proportion of leaves to stems as brome grass, but it grows well very early and late in the season. The forage is extremely nutritious and palatable, especially to cattle. When young it is very palatable and nutritious to all classes of stock, but it does not withstand very close grazing.

Crested wheat grass is a long-lived perennial bunch grass that has just recently been placed on the market. The merits of this grass are its great drought resistance, winter hardiness, early growth, nutritiousness and palatability. It begins growth and develops herbage for grazing earlier, it appears, than any other tame species and even earlier than most native species. It is adapted particularly for pastures on which little or no irrigation water is available.

Red top is a long-lived perennial grass propogating by rhizomes to form a dense sod. Red top has value as a pasture plant in wet, non-alkaline soils where Kentucky blue grass and meadow fescue cannot grow. It probably should be used in mixture with other wet-land plants as timothy and alsike clover. Red top does not form as nutritious and palatable forage as the other grasses.

Yellow sweet clover is a biennial that is widely used in pastures in Northern Colorado. It is the most drought and alkali resistant of the tame legumes. It furnishes a large amount of forage, but there have been occasional losses of stock by bloating caused by eating yellow sweet clover. Some ranchers prefer to have a heavy proportion of grass and a low proportion of sweet clover in their pastures. This may be secured by planting only about 2 pounds of sweet-clover seed per acre. By the end of the second season practically all of the plants have died and there is little or no natural reseeding, in most irrigated pastures.

White sweet clover is a biennial similar to yellow sweet clover, but it grows taller and forms coarser forage. It is usually not used in Northern Colorado. The growth habits are similar to those of the yellow-flowered species.

White clover is a perennial that propogates by creeping stems to form low, often dense mats, on the soil surface. The white to pink flowers are very attractive. This species requires ample moisture for good growth. It forms an ideal companion to Kentucky blue grass and these two species are usually found as the chief dominants in the older pastures in Northern Colorado. It is very winter hardy and withstands close grazing, but does not tolerate alkali.

Alsike clover and red clover are found occasionally in irrigated pastures but neither of these appear to endure close grazing well enough to make them important constituents of pasture mixtures. The former is especially well adapted to grow in wet soil that is not alkaline.

Black medic is a valuable annual legume that is now found in a large number of the irrigated pastures. It is highly nutritious and palatable. It apparently has invaded the pastures by means of the irrigation water. The plant is not very conspicuous because the stems are usually decumbent on the ground or on the forage plants. The flowers are small and yellow and the small pods are black.

After the species that are best suited to particular conditions have been selected it is necessary to determine the amounts of each kind of seed to sow. A scientific seed mixture is based

upon the kind of a pasture that is desired, upon the approximate percentage of seed of each species that will become established and upon the rôle that each plays in the competition between species. The percentage of establishment and the results of competition vary under different conditions. Slender wheat grass will become dominant under alkaline conditions, while orchard grass will become dominant under more neutral conditions. A large proportion of orchard grass in the mixture, as in the Nelson pastures where over 50 percent of the viable seed in the mixture was orchard grass, gives this species a great advantage over other species as brome grass and meadow fescue. The rapidly growing orchard grass suppresses and kills a large number of the other two so that the proportion of orchard grass plants in the pasture is greater than that in which it was seeded. It is a waste of seed, usually, to sow a small amount of seed of less aggressive species with a large amount of seed of a very aggressive species. The seed of the former may as well be saved and only the seed of the latter planted. This phase of competition has been thoroly studied under Welsh conditions by Stapledon and Davies (16). An abundance of yellow sweet clover also exerts a distinctly suppressive effect upon the grass seedlings even when only 3 pounds per acre are planted, as in the County Farm pasture. Because of its early rapid growth and large number of leaves it soon becomes dominant. On July 16 of the first year on the County Farm pasture, yellow sweet clover had 70 leaves per plant while the grasses had no more than 7 or 8 leaves.

The subject of correct proportions to sow is so very complicated that considerable work remains to be done. It could only be touched upon in this paper. The investigations that are reported here do, however, reveal certain basic principles.

(1) The proportion of seeds of each species in a mixture should be based upon the proportion of individuals that survive the period of establishment and the period of competition between seedlings and young plants. This can usually be determined in the second summer after planting.

(2) Species, as orchard grass and yellow sweet clover, that produce very vigorous seedlings will suppress and kill less vigorous seedlings as those of brome grass and meadow fescue. If both sets of species are desired in a pasture the very vigorous species should be represented by much lower proportions of seeds in the seed mixture than the less vigorous species. If a pasture is desired that contains considerable brome grass and meadow fescue, it appears that instead of sowing a mixture containing over 50 percent of viable seed of orchard grass, as in the Nelson

pasture, it would be desirable to leave out the orchard grass, as in the County Farm pasture, or to reduce it to about 10 percent. If an orchard grass pasture is wanted, then omit from the mixture the species that cannot compete successfully with orchard grass.

(3) The seed should be of high quality and purity. Serious weeds may be introduced with the grass seed. On the Gettman pasture a large number of wild mustard plants appeared, due to impure seed. Stapledon and Davies (15) report that weeds may appear abundantly in a pasture even when they made up less than 1 percent of the total seed.

(4) The rancher should mix his own seed so that he can be certain of securing correct proportions.

(5) A medium amount of seed per acre often produces a better pasture than a very large amount. Amounts from 15 to 30 pounds per acre have produced very satisfactory stands, as on the County Farm and Davis pastures. If the amount is too large the competition between the large number of seedlings weakens all of them and retards growth and establishment. There is more tillering per plant when there are fewer plants (17). There is an optimum effective quantity of seed for each combination of conditions and there also appears to be a maximum effective quantity.

8.—THE "NURSE CROP" AND ITS TREATMENT IF PLANTED.—Welch (20) has stated the case of a "nurse crop" in competition with grasses in irrigated pastures very nicely. He says:

"There can be little doubt that grasses will do much better without the so-called nurse crop. The grain starts quicker and grows faster than the grass and is sure to rob it of most of the available moisture. If there is insufficient moisture the grass and not the grain will die. Even if there is plenty of water for both, the grain will soon cover the grass completely. Instead of stooling out to form a sod it grows a long, slender stalk in its attempt to get a share of the air and sunshine. In the hottest part of the summer when the already weakened grass plant requires plenty of moisture the land is left dry for the grain to ripen and gets no more water until after harvest. By this time a great deal of the grass is dead. Actual practice has shown that this is the case and that the use of a grain crop which is allowed to ripen almost invariably results in a poor stand of grass. There may be special conditions such as a blow-sand soil that will require the use of a grain crop during the early part of the season. In such cases a good deal of water should be applied and the grain should be cut for hay early in the summer."

In the present study the pastures that were seeded without nurse crops usually became established better than those with

nurse crops. The Hice pasture, especially, suffered under the effects of a heavy "nurse crop."

9.—TIME AND METHOD OF SOWING.—For each species there appears to be an optimum time of planting to secure the highest percentage of establishment. The species at whose optimum time the sowing is made thereby secures an advantage in competition. Pasture results may therefore vary due to variation in the time factor alone. Stapledon et al (17) report that early seeding favors clovers, late seeding favors grasses. In Idaho late-spring and early summer seeding is advised (20). Recommendations are also frequently given to allow time for weed seeds to germinate so the weed seedlings may be destroyed by harrowing before seeding. In sowing the seed it is most important to cover the seeds thoroly with the proper depth of soil (21, 22). Drilling is preferred to broadcasting, taking care that most species of seeds are not seeded more than about an inch-and-a-fourth deep (9). Cross drilling is better than drilling in one direction. It leads to denser stands, with wider spacing between the seedlings so that competition is less intense. Soil cracks forming in dry weather will often stop at the drill rows.

10.—WEEDS.—The control of weeds in irrigated pastures should begin with the crop preceding the pasture. A crop which is clean-cultivated, as sugar beets or potatoes, leaves the land in good condition for pasture. Only forage seeds that are free from objectionable weed seeds should be planted. Sometimes in young pasture stands it is advisable to pull weeds out by hand, as in the case of the County Farm pasture where large dandelions were pulled out. Occasional mowings, at a height of 4 to 6 inches, during the first summer will kill large numbers of weeds, as pig-weed and lamb's quarters, giving the forage plants increased opportunity for growth. Mowing also favors the production of tillers in the grasses. How far infertility of certain soils may favor weed growth and handicap the forage plants is not known.

11.—GRAZING DURING THE FIRST SEASON.—A limited degree of grazing during the first season helps to control weed growth, especially when combined with mowing, and stimulates tillering and a more decumbent or spreading type of growth in the forage plants. Leukel and Coleman (10) have clearly demonstrated that when Bahia grass is not grazed or mowed often enough it forms erect tufts, with slow and poor sod formation leaving many bare areas in which weeds invade. Frequent grazing or mowing stimulates horizontal growth of stems, leading to more rapid sod formation with decreasing numbers of

weeds. The Gettman and County Farm pastures were favored by judicious grazing and mowing during the first season. Grazing should be permitted only when the soil is dry and the grazing should not be closer, on the average, than about 4 inches. If the grazing is too close irreparable damage may be done, especially to the most desirable species.

12.—MANAGEMENT.—It has been stated that good management may offset the disadvantages of a pasture composed of inferior species of plants (23). There is no doubt that grassland is responsive to good management. The Hice pasture never had an opportunity to develop; the County Farm pasture received more good management than poor. Rotation grazing is usually recommended for irrigated pastures (7, 8). In order to secure the best possible establishment of a pasture, considerable thought and work are required to secure adjustment of needs and desires to the three groups of variable factors; the livestock, the plants and the environmental factors, including irrigation water.

SUMMARY AND CONCLUSION

1.—The purpose of this paper is to present an ecological analysis of the factors and principles involved in the establishment of irrigated pastures in Northern Colorado.

2.—Experimental data are presented on 10 pastures under farming conditions. On eight of these the seed mixture was analyzed and on all of them the composition of the vegetation was determined by the quadrat method each year that they were under study. Most of the pastures were studied over a period of 3 to 4 years. Methods of management were noted in every case.

3.—The principal tame forage plants from which selections for irrigated pastures may be made in Northern Colorado are: Smooth brome grass, meadow fescue, orchard grass, timothy, Kentucky blue grass, slender wheat grass, crested wheat grass, red top, yellow sweet clover, white sweet clover, white clover, alsike clover, red clover and black medic. The characteristics of each of these species are briefly discussed.

4.—The chief factors that influence the establishment of irrigated pastures are classified as follows:

- 1.—Purposes for which the pasture is intended
- 2.—Topography
- 3.—Soil conditions
- 4.—Climate
- 5.—Supply of irrigation water
- 6.—Preparation of the seedbed

- 7.—Selection of the seed mixture and competition between species
- 8.—The “nurse crop” and its treatment, if planted
- 9.—Time and method of sowing
- 10.—Weeds
- 11.—Grazing and mowing
- 12.—Management

Each of these factors and its application is discussed.

5.—Five basic principles governing the proportion in which to sow the seed of each species are stated. These are: 1.—The proportion of each species to sow should be determined by the number of plants that survive the periods of establishment and competition; 2.—since species with vigorous seedlings and young plants as orchard grass and yellow sweet clover dominate and suppress species with weak seedlings, it is a waste of seed to sow small amounts of weak species with large, or equal, amounts of strong species; 3.—there should be no doubt that the seed is of good quality and purity; 4.—the rancher should mix his own seed in order to be certain of securing correct proportions; 5.—there is an optimum effective quantity of seed of each species as well as of the total amount of seed planted per acre for each combination of conditions. There also appears to be a maximum effective quantity.

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