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MISCELLANEOUS PAPERS.

Issued March 1, 1913.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

BUREAU OF PLANT INDUSTRY.

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TWO TYPES OF PROLIFERATION IN ALFALFA.[1]

By R. A. Oakley, *Agronomist*, and Samuel Garver, *Scientific Assistant, Office of Forage-Crop Investigations.*

INTRODUCTION.

The production of rhizomes and underground shoots in alfalfa was observed many years ago, and brief, more or less indefinite, mention made of them in literature. It may be that Jethro Tull had in mind something of this nature in making the following statement in his "Horse-Hoing Husbandry":

> Though one lucern root be much taper than another toward the upper part of it, 'tis sometimes seen that a single hoed plant of it has many of these perpendicular roots; some of them springing out from the very branches of its crown.[2]

M. Lullin de Chateau-vieux may also have observed underground stems, for in writing to M. Duhamel regarding his experience with transplanted alfalfa plants, he says:

> The stalks seem to rise out of the earth; and from the first time of cutting them, a kind of head forms just above ground, which extends itself every year. * * * These crowns have become of an oval form, having extended themselves on the sides where they met with no resistance.[3]

It is very evident, however, that neither Tull nor Chateau-vieux appreciated the value of the underground stem character, even if they were aware of its existence, since they make no references to it other than those above quoted. It was Thomas Le Blanc who apparently first called definite attention to the branching of alfalfa below the surface of the ground, and not only should credit be given him for calling attention to this character, but also for pointing out its value to the plant. His statement, which follows, quoted in Young's

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[1] Issued Mar. 1, 1913.

Proliferation: This word is derived from *proles* (shoots or offspring) and *fero* (I bear), so that the word literally means bearing offspring. *Definitions.*—Bearing progeny as offshoots.—*Jackson, B. D., Glossary of Botanic Terms,* ed. 2, London, 1905. The development of an organ or a shoot from an organ which is itself normally ultimate.—*Century Dictionary and Cyclopedia.* Botanically it has usually been used in reference to shoots produced abnormally, but there seems to be no reason why the meaning should not be extended to cover shoot production in general.

[2] Tull, Jethro. Horse-Hoing Husbandry, London, 1733, p. 92–102.

[3] Duhamel du Monceau, H. L. A Practical Treatise of Husbandry, London, 1759, p. 358.

Annals of Agriculture, leaves no doubt as to what he observed or of his appreciation of the importance of the character:

My reasons for preferring it [variegated medick or variegated alfalfa] to lucern are that it is hardier in bearing cold; that from its habit of branching below the surface of the ground and the shoots being much more numerous, it is not choked by the natural grasses, and that for the same reason it will not be injured by being fed by sheep.[1]

Credit must also be given Le Blanc for advocating the value of variegated alfalfa and for his efforts along the line of introducing this strain into general use. The history of his experience with "variegated medick," as written by himself, is very interesting and has a very definite bearing on the subject of stem proliferation.[2]

While underground stems are found in what is considered now to be genuine *Medicago sativa*, they are by no means as common or as well developed as in hybrids between *M. sativa* and *M. falcata* or in pure *M. falcata*.

There is, therefore, little wonder that Le Blanc should be among the first to observe and appreciate them, since he was among the first to study carefully from an agronomic standpoint *Medicago falcata* and its natural hybrids. But notwithstanding the definiteness with which Le Blanc wrote, the subterranean stem character was given little attention by subsequent botanists and agriculturists; or, at any rate, it was very soon lost sight of.

A search through literature fails to reveal any mention of underground shoots or rhizomes from the time of the publication of Le Blanc's work in Young's Annals of Agriculture, 1791, up to the publication by Blinn in 1911[3] of a bulletin entitled "Alfalfa: The Relation of Type to Hardiness," and a bulletin by Oliver in 1913[4] on "Some New Alfalfa Varieties for Pastures." These investigators have called attention for the first time in recent literature to the production of rhizomes in certain forms of alfalfa and the important part they play in rendering the plant resistant to severe conditions, especially those of drought and cold.

That certain types of alfalfa have a tendency to produce high crowns, while others have their crowns at or below the surface of the ground, has been a matter of common observation for some time. Moreover, this character has been associated in a rather general way with hardiness. Brand and Waldron, in discussing qualities producing hardiness in different races of alfalfa, make the following statement:

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[1] Le Blanc, Thomas. Experiments on the variegated medick. Annals of Agriculture, v. 15, p. 279, 1791. (Le Blanc's observations were made about 1783.)

[2] Idem, p. 277.

[3] Blinn, P. K. Alfalfa: The relation of type to hardiness. Colorado Agricultural Experiment Station, Bulletin 181, 16 p., illus., 1911.

[4] Oliver, G. W. Some new alfalfa varieties for pastures. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 258, 39 p., 11 pl., 1913.

The Mongolian alfalfa, which proved to be the hardiest under the severe test at Dickinson of any of the newly imported strains, was found both there and at Stockton, Kans., to have crowns more deeply set in the soil than other varieties. It seems likely that this adaptation, if it may be called an adaptation, is of importance in giving the tenderest part of the plant the needed protection.[1]

It is evident that while these investigators take cognizance of the deep-set crowns they fail to find rhizomes or underground stems produced from the plants, or at least to note their presence. In their discussion of the root system of the Grimm variety they recognize only the ability of this strain to recover after the taproot has been broken off 4 to 8 inches below the surface, and state in this connection that "this condition has suggested the possibility that the long endurance of stands of the Grimm strain may be due in some measure to the capacity for putting out new roots and reestablishing itself after the taproot has been broken." This statement is intended in no wise to convey the idea of proliferation, but only of a reestablishment of the original crown. Headden hints of this in mentioning the old method of transplanting mature plants and the continuation of gopher-eaten plants in some soils,[2] but he also did not have in mind the production of new plants vegetatively from stems or roots.

Just why the production of rhizomes and underground stems in alfalfa was lost sight of until the last few years is hard to explain, but the fact that they were observed at about the same date by several investigators working independently is very largely due to the comparatively recent increased interest in breeding and selection and the introduction of *Medicago falcata* and other alfalfas. The growing of plants in rows and hills in connection with breeding furnishes ideal conditions for rhizome development, and the introduction of new alfalfas furnishes forms in which rhizomes are very commonly produced. The practice of growing alfalfa in rows and hills, strongly advocated in Europe in the time of Tull and Harte,[3] afforded Le Blanc and others a condition for study such as exists at the present time.

STEM PROLIFERATION, CHARACTERS, AND FUNCTIONS.

Conclusions of other investigators.—In his study of the relation of type to the hardiness of alfalfa Blinn found some very important differences between the type of crown and the stooling habits in certain hardy and nonhardy strains.[4] He states that certain of the

[1] Brand, C. J. and Waldron, L. R. Cold resistance of alfalfa and some factors influencing it. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 185, p. 68–69, 1910.

[2] Headden, W. P. Alfalfa. Colorado Agricultural Experiment Station, Bulletin 35, p. 6, 1896.

[3] Harte, Walter. An account of some experiments tending to improve the culture of lucern by transplantation. Essay II of his Essays on Husbandry, ed. 2, London, 1770, illus.

[4] Blinn, P. K. Op. cit.

nonhardy types under his observation have "compact, upright-growing crowns, with comparatively few buds or shoots below the surface of the soil"; while certain of the hardy types are "characterized by a more spreading crown, with buds and shoots springing from the crown below the surface of the soil." He has not only observed these underground buds, or shoots, as he calls them, but correlates them with drought resistance and hardiness. Furthermore, he notes the tendency of the rhizomes to take root at some distance from the old crown and produce new plants. No detailed description, however, is given by him of these underground growths or the manner or time of their development.

Oliver, in his work with numerous alfalfas, including natural and artificial hybrids of *Medicago sativa* and *M. falcata*, developed some

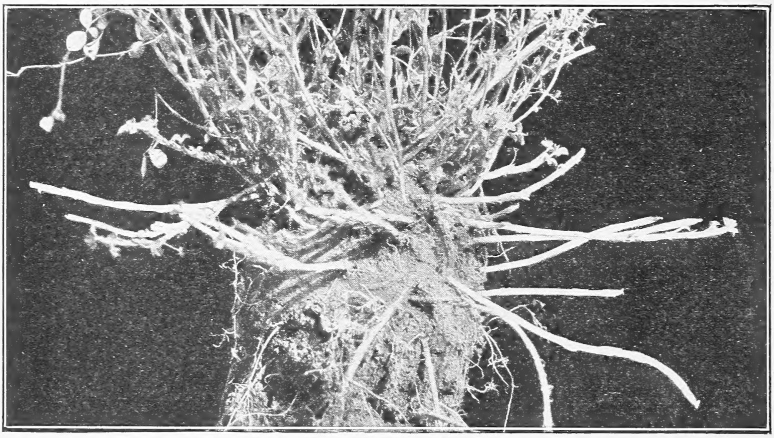

FIG. 1.—A plant of hybrid alfalfa six months from the seedling stage. The prominent growths appearing below the crown are rhizomes; in other words, true stems. (From Bulletin 258 of the Bureau of Plant Industry, by George W. Oliver.)

exceedingly interesting material.[1] He finds that there are two general types of rhizomes produced—rooting and nonrooting—and that during the early stage of their development they appear to be of the same character. He also finds that both types of rhizomes are produced most abundantly during the autumn months and that they originate at or near the crown of the plant, one case only coming under his observation where they were produced below the surface.[2] In this case the rhizome was at least 3 inches below the crown. Oliver gives a rather detailed description of the gross morphology of the rhizomes, their life history, and functions. His descriptions and photographs show positively that the underground growths which he describes are true and modified rhizomes, according to the accepted definition of the term. In other words, they are of stem origin. (Fig. 1.)

[1] Oliver, G. W. Op. cit. [2] Oliver, G. W. Op. cit., p. 22, Pl. X, fig. 2.

In summarizing the observations and conclusions of the various investigators it will be found that certain types of alfalfa, chiefly those which are associated with hardiness and drought resistance, produce underground stems and rhizomes; that these growths are true stems having nodes, scales, and buds; that although sometimes found several inches beneath the surface, they usually originate at or near the crown, seldom below; that the rooting and nonrooting rhizomes may result in new shoots and in some cases ultimately in independent plants; that by virtue of their ability to store up water and produce protected buds they constitute a drought-resistant and hardy character of much value to the plant; and that the rhizomes in their various forms are more abundantly produced in *Medicago falcata* and its natural and artificial hybrids with *M. sativa* than in pure *M. sativa.*

The rediscovery, if such it may be called, of stem proliferation in alfalfa is of vast importance, especially to plant breeders, as it gives them a tangible character with which to work in developing hardy and drought-resistant strains.

Field studies and correlation of characters.—In May, 1912, the writers took up a general study of proliferation in *Medicago falcata* with a view to determining the extent of its prevalence and variation in the different types of that species. Although late spring is probably not the best season of the year in which to study this character, the abundant material in the nurseries at Brookings and Highmore, S. Dak., afforded an excellent opportunity for observation, especially since the plants were growing in cultivated hills and most of them entering into their fourth season of growth.[1]

A careful examination of the numerous forms of *Medicago falcata* showed underground stems or rhizomes to be more prevalent and better developed in the low-spreading, fine-leaved, fine-stemmed types than in those more closely resembling *M. sativa.* However, not all of the forms included in the low-spreading type exhibit tendencies to produce new plants vegetatively. Some spread only over the surface of the ground, the procumbent stems proceeding from fairly compact and high-set crowns without becoming attached to the soil at any point. It was extremely difficult in the case of certain procumbent types to determine whether proliferation was largely the result of an inherent tendency of the plant or was induced to a considerable degree by cultivation. Cultivation unquestionably is in a measure responsible for rooting stems in the erect as well as in the procumbent forms. This point was quite definitely demon-

[1] The plants were grown in the nursery at Brookings and transplanted in hills at Highmore in April, 1910. It is a well-known fact that the pruning incident to transplanting large alfalfa plants affects the development of the taproot. The above-mentioned plants, however, were so small at the time of transplanting that little change in this respect is believed to have been produced.

strated in experiments conducted at the Arlington Experimental Farm during the past season.

In a great many cases where stem proliferation is developed to a considerable degree the center of the plant dies out, leaving that portion of the crown quite devoid of shoots. A similar condition is found in the true grasses, especially in forms of *Festuca rubra* and other fine-leaved fescues. Many explanations of this condition have been based on erroneous conclusions; in other words, it has been argued that underground stems and rhizomes by virtue of their ability to produce new growth keep these old plants alive, even after the original crown has died. As a matter of fact, the barrenness of the old crown is probably due in most cases to unfavorable conditions for the development of buds or new growth in the center of the clump. Where the original plant is grown in a crowded condition or in a condition not conductive to spreading, the center remains productive for an indefinite period. The fescues already referred to behave almost exactly in this manner. Barren centers are found very frequently in procumbent types, while in the semierect or upright plants the tendency is not so common.

ROOT PROLIFERATION.

The brief studies at Brookings and Highmore developed nothing particularly new regarding the type of proliferation heretofore described, but tended only to confirm the conclusions of other investigators. The studies disclosed, however, what is thought to be a type of proliferation heretofore undescribed as occurring in alfalfa—a type wherein new plants are produced from true lateral roots 4 to 12 inches, rarely more, beneath the surface and running almost directly parallel with it.[1] These proliferous roots apparently are given off from any portion of the branching taproot within the limitation of the depths above indicated. At irregular intervals along the lateral roots, swellings occur, usually about twice the diameter of the roots and three-fourths of an inch to $1\frac{1}{4}$ inches in length. (See figs. 2 and 3.) Upon these swellings buds appear, some of which give rise to new plants, while many remain undeveloped.[2] Fibrous roots are rather sparingly produced from the lateral proliferous roots, and in many instances the swellings are devoid of them; in

[1] Hitchcock, A. S., and Clothier, G. L. Fifth report on Kansas weeds—Vegetative propagation of perennial weeds. Kansas Agricultural Experiment Station, Bulletin 76, 23 p., 12 pl., 1898. Clothier, G. L. Root propagation of Ipomoea leptophylla. Botanical Gazette, v. 25, p. 52–53, illus., 1898. These articles discuss vegetative reproduction by true roots in *Rhus glabra, Ambrosia psilostachya, Cnicus undulatus, Convolvulus arvensis,* and *Ipomoea leptophylla*.

[2] In this type of proliferation it will be noted that definite provision is apparently made by the lateral proliferous roots for the production of new plants. There is a material difference in this respect from the case in stem proliferation noted by Oliver, where new shoots arise from the taproot appreciably below the crown.

fact, new aerial shoots reach a considerable degree of development before roots of any importance are sent out from the swellings. There appears to be quite a difference in the plants that arise from

FIG. 2.—A plant of *Medicago falcata* (S. P. I. No. 28071) found at Highmore, S. Dak., May, 1912. The root proliferation is remarkably developed in this plant.

the proliferous roots with respect to root development; some develop a crown and root system of their own at an early date, while others rely for an indefinite period on the proliferating roots for their

FIG. 3.—Sections of proliferating roots of alfalfa, showing swellings upon which the buds that develop new plants appear. The buds are also sometimes produced from other portions of these roots, but so far no shoots have been observed to arise from them.

support. (See figs. 4, 5, 6, and 7.) This point, however, needs a more thorough investigation, as the number of cases thus far found is insufficient for definite conclusions.

The behavior of the proliferous roots with respect to growth in diameter is quite peculiar. In comparatively few cases do they exceed one-fourth of an inch, except at the swellings, the average di-

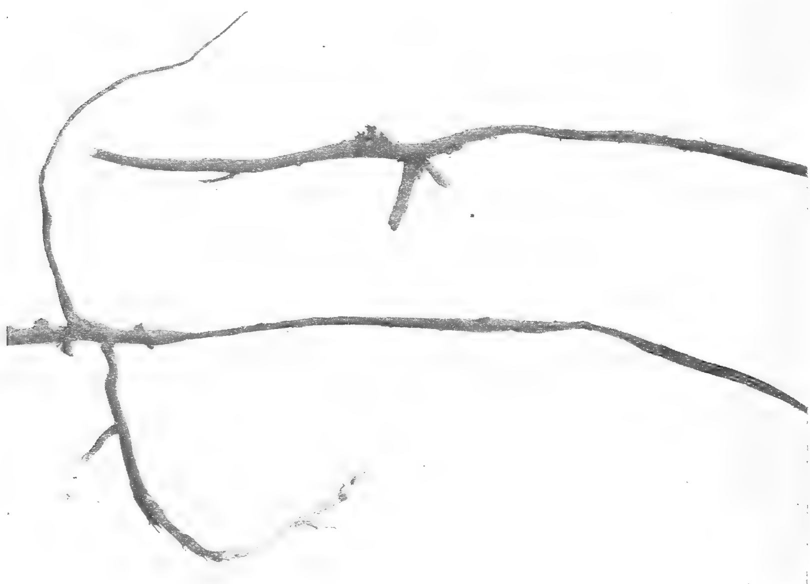

FIG. 4.—Sections of proliferating roots of alfalfa, showing buds of the new shoots in different stages of development.

FIG. 5.—A portion of a plant of *Medicago falcata* (S. P. I. No. 28071), showing the original crown, with new plants that have resulted from proliferating roots. Some of the new plants, it will be noted, have already developed crown and taproot.

ameter being about three-sixteenths of an inch, but it is by no means uniform. At the point of origin the roots may be much smaller than at some distance from this point. At 2 or more feet from the main root they may become reduced in size to one-sixteenth of an inch, enlarging again to a diameter equal to or greater than any previously attained. The greatest length of any proliferating lateral root so

Fig. 6.—Plant of *Medicago falcata* (S. P. I. No. 28071), showing new plants produced from proliferating roots. The character of growth in the diameter of these roots is typified in this illustration. Plants of considerable size are produced in this case without a definite root system of their own.

Fig. 7.—Shoots of alfalfa starting from proliferating roots. These shoots had their origin from 4 to 6 inches beneath the surface and when photographed were depending entirely on the proliferous root for support.

far found is a little over 4 feet, but indications are that their growth in length is limited largely by soil conditions—a loose, loamy soil being conducive to their development (fig. 8). Many of the plants produced from these proliferous roots in time form a new crown and a more or less branching taproot, which in turn is capable of sending out proliferous roots, as does the original plant. No cases have so far been observed of the new plants becoming separated from the mother plant, even after they have become well equipped with a root system of their own, and while no evidence has been noted of the lateral roots disintegrating or becoming atrophied at any point, it is reasonable to assume that at least some of the new plants in time become detached, either through natural process of growth or through accidental causes.

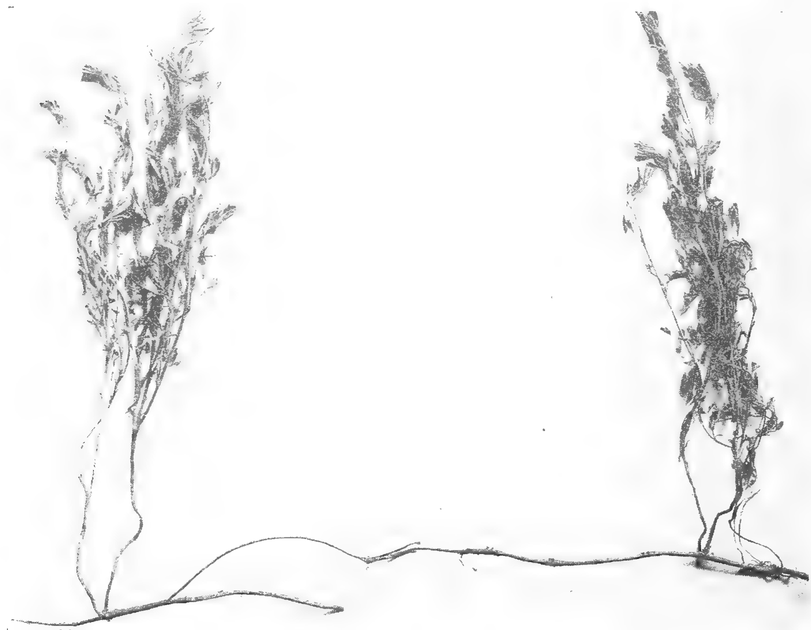

FIG. 8.—Proliferating root of alfalfa, showing branching. While this character is quite common, a single root does not appear to branch more than three or four times at most.

The type of proliferation described in this paper was found at Highmore, S. Dak., in a fairly upright plant of *Medicago falcata*, seed of which was secured from Orenburg Government, Russia, and introduced under S. P. I. No. 28071. The mother plant was perfectly normal in the appearance of its growth above ground, and attention was attracted to it only by the fact that smaller plants of the same general appearance surrounded it, coming up even from the portions of the row that had been cultivated frequently the season before. The plants were so large that they could be readily distinguished from seedlings and were arranged in such manner as to indicate vegetative propagation. Later in the season other plants were found at Highmore having root proliferation remarkably developed, but they were all from seed bearing the S. P. I. number mentioned, and all conform in a general way to the same type with respect to growth aboveground. There is no definite evidence regarding the period in the plant's life in which proliferous roots are first developed. There are some data, however, to indicate that these roots are not produced until the plant is at least 2 years old.

The production of proliferating roots in alfalfa seemed so abnormal as to indicate a possible pathogenic condition such as might be caused by crown-gall. The external symptoms of this disease, however, are not visible, and a careful microscopic examination of live material failed to disclose the presence of pathogenic organisms of any kind.[1]

Critical studies are now under way to determine as fully as possible the conditions which induce the roots to produce new plants. In this connection the point of origin of the later roots, the swellings on the roots, and the buds on the swellings and other portions of the roots are being given careful consideration. Field studies are also being made to determine the life history of these shoot-bearing roots, the conditions favorable to their development, and the possibility of utilizing the character which they represent in the development of strains of alfalfa particularly adapted to severe conditions. No prediction is ventured regarding the agronomic value of the proliferous root character, especially since it is not known to what extent this character is transmitted or whether cultural conditions influence its development. Close and open fertilized seed has been secured from plants possessing proliferous roots and will be sown in the spring of 1913. New plants have already been produced from stem and root cuttings, so that abundant material should soon be available for use in determining many of the points that are now unsettled.

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[1] Dr. Erwin F. Smith, of the Bureau of Plant Industry, examined the material for crown-gall and other disease-producing organisms. He found nothing to indicate that the production of proliferous roots in the specimens which he examined was in any way pathological.

A NEW SYSTEM OF COTTON CULTURE.[1]

By O. F. Cook, *Bionomist in Charge of Crop Acclimatization and Adaptation Investigations.*

INTRODUCTION.

The way to secure an early short-season crop of cotton is to thin the plants later and leave them closer together in the rows than is now customary. Neither of these policies is advisable if used alone, but they give a real advantage when properly combined. Keeping the plants closer together during the early stages of growth restricts the formation of vegetative branches and induces an earlier development of fruiting branches. The new system is based on the principle of controlling the formation of the branches, as explained in previous reports and publications of the Bureau of Plant Industry.[2]

CONTROLLING THE FORMATION OF BRANCHES.

The principle of branch control is more likely to be understood if studied as the basis of a new cultural system. Application of the principle will involve a reconsideration of all current opinions regarding such questions as distances between rows, times of planting, methods of cultivation, and the values of different varieties. The spacing of the plants and the stages at which thinning should be done will depend upon the local conditions and the habits of the varieties that are being grown, so that it will not be possible to give

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[1] Issued Mar. 1, 1913.

[2] Cook, O. F. Weevil-resisting adaptations of the cotton plant. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 88, 87 p., 10 pl., 1906.

——— Cotton selection on the farm by the characters of the stalks, leaves, and bolls. U. S. Department of Agriculture, Bureau of Plant Industry, Circular 66, 23 p., 1910.

——— Dimorphic branches in tropical crop plants: Cotton, coffee, cacao, the Central American rubber tree, and the banana. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 198, 64 p., 9 fig., 7 pl., 1911.

——— and Meade, R. M. Arrangement of parts in the cotton plant. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 222, 26 p., 9 fig., 1911.

——— Cotton improvement under weevil conditions. U. S. Department of Agriculture, Farmers' Bulletin 501, 22 p., 1912.

——— Results of cotton experiments in 1911. U. S. Department of Agriculture, Bureau of Plant Industry, Circular 96, 21 p., 1912.

——— Morphology of cotton branches. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 256, 113 p., 19 fig., 6 pl., 1913.

——— Heredity and cotton breeding. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 256, 113 p., 19 fig., 6 pl., 1913.

specific directions that can be used everywhere without discrimination. In agriculture, as in other arts, every new application of a scientific principle makes an additional demand for intelligence and insight into the problems of production. The contrasts with prevalent theories and practices of cotton culture are so great that careful consideration of the habits of the cotton plant is needed before the full possibilities of cultural improvement can be appreciated.

The first step toward permanent progress in the new direction is to secure the attention of the intelligent farmer to the principle itself, so that he can begin to observe and experiment on his own account with rows of cotton thinned to different distances and at different stages of growth and thus see for himself the relation of the habits of the plants to the cultural problems. In this case no special equipment of books or instruments is necessary to enable the farmer to study the plant and learn what he needs to know regarding its habits of branching. It is true that these habits are somewhat peculiar from the botanical and biological standpoint, as already pointed out in preceding papers on the subject, but there are no technicalities that interfere in any way with direct observations of the behavior of the plants under the usual farm conditions.

APPLICATION OF IMPROVED METHODS.

Unless the farmer can understand the underlying reasons he is not likely to adapt a new method or to apply it properly, any more than he can use a new machine to advantage without knowing how it works. This requirement of intelligence may limit the application of an improved method, just as it restricts the use of high-grade machines to those who have the ability to handle them properly and understand their construction. But it is generally agreed that larger rewards for more intelligent and skillful farming are in the interest of agricultural progress, and this is especially true in relation to the cotton industry. To make it seem worth while for intelligent men to remain on the farm would soon counteract the urban tendencies now so much deplored.

That cotton has been considered a "sure crop" even with the most careless farming is one of the chief reasons for the backward state of the industry. But the need of improvement is now recognized as never before, as a result of the many changes that are being enforced by the invasion of the boll weevil. With the continued advance of the boll weevil the period of sure-crop cotton is drawing to a close, and the rapid expansion of cotton culture in foreign countries shows that a new test of competition in the production of this crop must be met in a few years. In the mean time any improvement that promises increased efficiency of production is worthy of careful consideration.

IMPORTANCE OF STIMULATING EARLINESS.

The chief advantage of the new system of cotton culture, based on the improved method of thinning, is the increased earliness of the crop; or, in other words, the production of more cotton in a shorter period of time. The need of shortening the growing season of cotton has been recognized as the best solution of the problem of securing protection against injury from the boll weevil, but is no less important in regions where the crop is limited by drought or by short seasons, as in the northern districts of the cotton belt.[1]

CONFLICTING OPINIONS ON SPACING COTTON ROWS.

Many intelligent farmers are aware of the fact that rows of cotton accidentally left without thinning are sometimes much more productive than rows that were thinned in the usual manner and have reflected on the possibility of securing larger crops by closer planting, but the underlying biological principle has not been understood. The behavior of cotton in different seasons or under different conditions is so extremely variable that any intelligent farmer might well hesitate to adopt a method of culture suggested by an occasional occurrence like the production of a larger crop on an unthinned row.

In each cotton-growing community there are usually some farmers who believe that cotton should be left closer together in the rows, but the tendency in recent years has been toward wider spacing, owing to a general recognition of the evil effects of having the plants too close together, especially under conditions that favor luxuriant growth. Those who use narrow spacing may boast of phenomenal yields in some seasons, but in other years they appear at a disadvantage with their neighbors. The possibility of making a safe combination of the two conflicting methods seems not to have been suggested. The same conflict is shown in the results of formal experiments to determine the best planting distances as in the popular opinions on the subject. Wide spacing in the rows seemed better in some cases and narrow spacing in others, so that no definite conclusions could be reached.[2]

LARGE PLANTS PRODUCE LATE CROPS.

When the habits of the cotton plant are taken into account it becomes apparent that the theory of wider planting has its limitations, as well as the theory of closer planting. To reduce the number of plants by wider spacing in the rows means that a longer period

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[1] Cook, O. F. Relation of drought to weevil resistance in cotton. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 220, 30 p., 1911.

[2] Redding, R. J. Essential steps in securing an early crop of cotton. U. S. Department of Agriculture, Farmers' Bulletin 217, 16 p., 1905.

of time is required to produce a crop, for the reason that large luxuriant plants do not begin to produce flowers and bolls as early as plants of more restricted growth. This is not in accord with what might be considered as the most logical view of the subject. Most people are ready to argue that the plants making the most rapid growth must produce the earliest and largest crop, but the actual behavior of the cotton plant is otherwise. In such cases the biological facts have to be taken into account instead of relying upon the logical deductions.

The biological fact in the present case is that the large luxuriant plants are later in setting and maturing a crop. This is because the young plants in a condition of luxuriant growth develop vegetative limbs at the expense of the lower fruiting branches that are necessary to the production of an early crop. The cotton plant has two different kinds of branches—vegetative branches, sometimes called "wood limbs," which correspond to the main stalk of the plant, and fruiting branches, which produce the flowers and bolls.

When the habits of branching are understood it becomes apparent that the idea of the largest plants producing the earliest and largest crops does not apply to cotton. Spreading, treelike plants, with numerous vegetative branches, do not represent a favorable condition for earliness or for large yields in short seasons. In the interest of correct thinking on cultural problems the row rather than the individual plant should be considered as the unit. The advantages of the new method are gained by improving the form of the rows. More plants are left in the rows, and yet injurious crowding is avoided. Plants that have numerous vegetative branches are more crowded at 2 or 3 feet than plants with single stalks at 8 or 10 inches. With the vegetative branches controlled, the spacing is no longer a question of feet, but of inches. Rows spaced at 6 inches have usually given better results than those at 12 inches or any greater distance.

EXPOSURE OF FRUITING BRANCHES TO LIGHT.

By avoiding the development of the large wood limbs the rows are kept narrower and more hedgelike, so that the fruiting branches receive sunlight throughout the season. This provides much more favorable conditions for the ripening of the crop. When the vegetative branches are allowed to shut off the light by growing up between the rows, most of the bolls on the lower fruiting branches fail to reach normal maturity. Fields of large luxuriant plants often produce very small crops because only the upright growing ends of the stalks and vegetative branches have access to the light. This undesirable condition is avoided by restricting the development of the vegetative branches in the earlier stages of growth.

Numerous experiments have demonstrated the fact that the usual custom of giving the seedlings full exposure by thinning them to wide distances in the rows is a means of inducing the development of large numbers of vegetative limbs. Too much exposure for the young plants results in too little exposure for the adults by increasing the number of vegetative branches. The effect of exposure at wide distances is influenced, of course, by temperature and fertility of soil, larger numbers of vegetative limbs being produced under conditions that favor the luxuriant growth of the plants. But it does not appear that the production of vegetative branches is desirable under any condition. The improved method of thinning restricts the development of vegetative limbs or avoids their formation altogether. This permits a better development of the fruiting branches of the lower part of the main stalk. The plants are induced to fruit earlier and the crop is made larger because more of the early plants can be grown on the same area.

COMPETITION BETWEEN TWO KINDS OF BRANCHES.

The reason this possibility of cultural improvement has not received adequate consideration in the past is doubtless to be found in the fact that the distinctness of the two kinds of branches has not been recognized, nor the relation of this specialization to the method of thinning. When the plants are thinned too young, so as to stand more than 6 inches apart, they put forth a full quota of vegetative limbs, and the subsequent competition and crowding of these limbs with each other and with the main stalks interfere with the development of normal fruiting branches. As it is the low joints of the stalk that produce the undesirable vegetative branches, the plants must be allowed to grow beyond these joints before thinning. Exposure of the stalk to the light in the early stages of growth is one of the factors that lead to the putting forth of the vegetative branches.

EFFECTS OF EXTERNAL CONDITIONS ON BRANCH FORMATION.

The number of vegetative branches is also influenced by temperature and soil conditions. If the weather remains cool, or if the soil is very dry, not many vegetative branches will develop, even when the young plants are widely separated. But if the conditions favor a luxuriant development of the young plants, early thinning will result in the development of a large number of vegetative branches, and the subsequent crowding will be great. Even in the absence of any disease or insect pests the crop may be ruined by crowding alone. Thus, the extent of the injury from crowding depends very largely on the conditions that obtain during the early development of the plant when the formation of vegetative branches is determined.

Until the habits of branching are taken into account it seems impossible to explain the widely different results that are often secured when the same experiments are repeated in different places or in the same place in different seasons. From the present point of view it is easy to understand that merely statistical experiments made without recognizing the effects of different methods of thinning upon the formation of branches would be likely to reach only ambiguous results. The development of the branches, though very easily influenced in the early stages of growth, completely alters the subsequent behavior of the plants. The effect seems out of all proportion to the exciting cause, like touching off a charge of powder or pulling the trigger of a gun.

Wider spacing appears as the only alternative as long as the young plants are led to put forth a full equipment of vegetative limbs by too much exposure in the early stages of growth. That the development of these limbs may be avoided by a later and more gradual thinning of the young plants must be recognized before it is possible to understand the advantages of the new system. When good crops are produced on rows that are not thinned at all, it is because the plants remain so close together that no vegetative limbs are developed. The new system provides for a more regular and effective application of the same principle of suppression of vegetable branches.

THINNING EXPERIMENTS WITH DURANGO COTTON.

The behavior of the Durango cotton at Norfolk, Va., in the season of 1912 affords an excellent illustration of the application of the principle of controlling the formation of branches as a means of securing earlier and larger crops of cotton under short-season conditions. Planted in a row test with other varieties and thinned in the usual manner to the ordinary distances, the Durango cotton, which is unusually productive for a long-staple variety, yielded at the rate of about 1,175 pounds of seed cotton per acre, though considerably exceeded by the Trice, an extra-early short-staple variety, which produced at the rate of 1,756 pounds per acre. In a field planting on lighter and less fertile soil the rows of the Durango cotton that were thinned in the usual manner to ordinary distances yielded at an average rate of 909 pounds of seed cotton per acre, while alternate rows that were thinned late and left with the plants closer together yielded at a rate of 1,391 pounds, or about 53 per cent higher than the others. Table I shows some of the figures obtained from the Norfolk experiment by Mr. G. S. Meloy.

Table I.—*Results of a thinning experiment with Durango cotton at Norfolk, Va., in 1912.*

Row No.	Number of plants in row.	Average daily flowering based on counts for 10 days.	Gross yield of seed cotton, in grams.	Yield of seed cotton per acre, in pounds.	
				Ordinary wide-spaced rows.	Hedge-formed rows.
1	176	97.9	6,276.7		1,379
2	65	79.3	4,601	1,012	
3	203	87.7	6,230		1,371
4	66	79.9	4,816.5	1,050	
5	229	87.8	6,777		1,491
6	61	68.6	3,384	744	
7	215	93.4	6,524.5		1,435
8	63	75.9	4,191.5	922	
9	211	101.3	6,796.5		1,495
10	60	68.1	4,054	892	
11	159	75	5,985.5		1,317
12	64	70.8	4,282	942	
13	166	62.5	5,679.1		1,249
14	61	50.8	3,659.5	805	
Average				909	1,391
Percentage of increase in hedge-formed rows					53

The rate of flowering, which also serves as a measure of earliness, showed an advantage of 42 per cent in favor of the hedge-formed rows. Though the proportion of 5-locked bolls was less in the hedge-formed rows, a census on the basis of locks showed a difference of 48 per cent in favor of the hedge-formed rows.

Many of the plants in the hedge-formed rows had no vegetative branches—29 out of 52 in a series that was counted. An equal distance in the next wide-spaced row was occupied by 16 plants, all but one of which produced vegetative branches, most of them three or four. The average amount of vegetative branch development on the widely spaced plants was 38.6 inches; on the hedgerow plants only 6.9 inches.

BRANCHING HABITS OF UPLAND AND EGYPTIAN COTTON.

The results obtained at Norfolk are in general agreement with those obtained from other experiments with the Durango and other varieties of Upland and Egyptian cotton in Texas and southern California. The idea of controlling the formation of the branches through cultural methods was first developed through a study of the behavior of the Egyptian cotton in Arizona and southern California. But it has now become evident that the principle has a vastly greater practical importance in connection with Upland cotton. Though the tendency to overdevelopment of vegetative branches is not so strong in the Upland cotton as in the Egyptian, the results are often worse, on account of the heavier foliage of the Upland cotton and the greater tendency to shedding the buds and young bolls.

NORTHWARD EXTENSION OF LONG-STAPLE COTTON.

The Norfolk experiment is significant, not only as an example of the beneficial effects of controlling the formation of the vegetative branches, but also as an indication of the possibility of extending the cultivation of the Durango cotton and perhaps of other long-staple varieties along the northern border of the cotton belt and even beyond the present limits of cotton cultivation. At any such rate of production as that shown at Norfolk, the Durango cotton is a very profitable crop, for the fiber attains a length of $1\frac{1}{4}$ inches under favorable conditions, is of high quality, and sells, when properly handled, at a premium of 5 cents or more a pound above corresponding grades of short-staple cotton. Such a premium means an addition of about $25 per bale to the farmer's profits. Though it has long been known that fiber of good quality could be produced in the northern rim of the cotton belt, the late-maturing habits of the older long-staple varieties rendered the crop small and precarious. But with the new varieties and new cultural methods that have now become available the outlook is entirely changed.

CONCLUSIONS.

The new system of cotton culture is based on the application of a principle not hitherto recognized in cultural experiments—the control of the vegetative branches by improved methods of thinning. The formation of vegetative branches can be controlled by leaving the plants closer together during the early stages, until the stalks have grown beyond the stage where vegetative branches are produced.

The essential feature of the new system is later or more gradual thinning. This makes it possible to leave more plants in the rows than is now customary, and yet injurious crowding is avoided through suppression of the vegetative branches.

The control or suppression of the vegetative branches also permits an earlier development of fruiting branches and leads to the production of an earlier crop. In regions where the period of crop production is limited, either by short seasons or by the presence of the boll weevil, increased earliness is a means of securing larger yields.

GRASSES FOR CANAL BANKS IN WESTERN SOUTH DAKOTA.[1]

By Arthur C. Dillman,[2] *Assistant Physiologist, Office of Alkali and Drought Resistant Plant Investigations.*

INTRODUCTION.

In the construction of canals and ditches for the purpose of irrigation, the area of soil exposed and left bare of vegetation is very large in the aggregate. Experiments have been conducted on the canal banks of the Bellefourche Irrigation Project in western South Dakota to determine what grass or combination of grasses will establish a satisfactory sod on such banks. This circular describes the experimental work and gives such recommendations for seeding canal banks on this project as are justified by the results thus far obtained.

THE NEED OF A GRASS COVERING.

The advantages of a grass sod on the canal and ditch banks are, chiefly, to prevent erosion of the soil, to prevent the growth and spread of weeds, and to furnish pasture for live stock.

The erosion of the loose soil on the steep slopes of the ditch banks is often serious. Most of the soils of this region are composed of fine particles and therefore wash more readily than soils of a coarser character. The amount of erosion on any short section of ditch bank might not be considered serious, but the quantity of soil washed down into the canals and ditches from over 300 miles of canal banks must be enormous.[3] Any covering of sod which will prevent or lessen this erosion will mean a real economy in the maintenance of the project.

One of the chief uses of a grass covering is to exclude the growth of annual weeds which usually infest ditch banks. Unless a perma-

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[1] Issued Mar. 1, 1913.

[2] The investigations here reported have been conducted by the writer, representing the Office of Alkali and Drought Resistant Plant Investigations, in cooperation with Prof. C. V. Piper, of the Office of Forage-Crop Investigations, who has furnished useful suggestions, as well as most of the seed required.

[3] Mr. F. C. Magruder, project engineer, writes that there are 50 miles of main canal, 85 miles of main laterals, and 314 miles of small laterals on the Bellefourche Project. These canal banks have a total area of about 1,200 acres.

nent sod is established, the banks become covered with Russian thistles, buffalo bur (*Solanum rostratum*), wild oats, sweet clover, and other troublesome weeds. The seeds of these weeds are freely carried by the canal water and are scattered far and wide over the fields. The resulting growth of weeds greatly increases the expense and labor of cultivation. It is practically impossible to produce pure seed crops of grain and alfalfa if weeds are allowed to multiply along the banks of canals and ditches which cut through the fields. The best check to the growth of weeds is a good grass sod.

Another advantage of the grass covering is to furnish pasturage for live stock. The area occupied by ditch banks can not be utilized for the production of cultivated crops, but can be made to yield some return when used for grazing. On many of the larger farms the aggregate area that may be made use of in this way is considerable. A half mile of canal bank of medium size has an area of 1 to 2 acres. Moisture is usually abundant on the lower slope of the banks, and a good growth of grass can be secured, which will furnish a fair return for the trouble and expense of seeding.

NATURE OF THE SOIL.

The soils of the Bellefourche Project are of two principal types. In the northern part of the area the soils are mostly of the heavy clay loam, known locally as "gumbo." These soils are formed by the weathering of the Pierre shale which underlies the whole area. In the southern part of the project the soils are somewhat lighter on account of the silt and sand which they contain. The unweathered shale which is turned up in many places in building the canal banks is very unfavorable for the growth of grasses, but after a year or two of weathering it is possible to get grass started even in the partly decomposed shale.

OBSTACLES TO SECURING A STAND.

Alkali salts are present, although usually in small quantity, in many of the soils of the project. Over the greater part of the area, especially north of the Belle Fourche River, the alkali content ranges from 0.2 to 0.6 of 1 per cent in the first 6 feet of soil. South of the river there is generally less than 0.2 of 1 per cent. The alkali is of a relatively harmless type, consisting mostly of sulphates of calcium, magnesium, and sodium. Fortunately no black alkali (sodium carbonate) is present. Alkali is especially likely to accumulate along ditch banks because of the high water content of the soil and the high rate of evaporation from the loose surface. This accumulation is especially noticeable in large fills, for in such places some water often seeps through the canal banks. Wherever more than 1 per cent of alkali is present it will be difficult to start even the most resistant grasses.

Drought is an even more serious obstacle in starting grasses on the ditch banks and is the general cause of failure to secure a good sod. The upper part of the canal banks is often very dry, since the steep slope is unfavorable to the penetration of rain water and since the seepage or capillary water does not rise to this height. After the more drought-resistant grasses are once well started they will be able to survive any ordinary period of drought. On the smaller ditch banks and on the lower slopes of the larger canal banks moisture is generally so abundant that there should be no difficulty in establishing a good growth of grass.

The growth of annual weeds, especially Russian thistle, hinders the growth of grass during the first season. If, however, the canal bank is harrowed at frequent intervals during one summer, especially after each rain, this treatment will destroy the growth of weeds and conserve moisture, which will put the soil in good condition for seeding early the following spring.

Live stock should not be allowed to graze on the newly seeded canal banks until the grass is well established. The trampling of stock, cattle especially, kills out many of the young plants on the steep slopes, and close grazing also is injurious to the new growth of grass until a sod is obtained.

It is not probable that all of these adverse conditions—alkali, drought, the competition of weeds, and close grazing—will be encountered in every part of the area, but a combination of grasses should be planted which will endure any of these conditions as well as possible. Some of the experiments with the different grasses described in this paper were made under very adverse conditions, while others were made under more favorable conditions.

OUTLINE OF THE EXPERIMENTS.

The first planting was made in 1907 on the south canal near the storage dam. Three plantings were made in 1908: One on the surface of the storage dam, one on the south canal near the present town of Nisland, and one on the Indian Creek lateral on the farm of Mr. George Maass. Duplicate plantings were made again in 1909 and 1910 on the farm of Mr. Maass. Each species was seeded on a section of the canal bank about 20 feet wide, the plat extending from the water line on the inner surface over the bank to the ground level on the outside. The time of the different seedings ranged from the first of April to the middle of June.

GRASSES AND OTHER PLANTS TESTED.

Several of the common hay and pasture grasses have been tested for the purpose of soil binding. The list includes brome-grass, western wheat-grass, slender wheat-grass, meadow fescue, tall fescue, red fescue, redtop, orchard grass, Canadian bluegrass, and alfalfa, both singly and in various mixtures. A few species have given good results in pure stands, though the best results have come from certain mixtures. The value of the different species is discussed in the following pages.[1]

BROME-GRASS.

Brome-grass (*Bromus inermis*) has been used with good success, whether planted alone or in mixture with other species. This grass is well adapted to the climatic conditions of the Northwest, and on

FIG. 1.—A canal bank, showing western wheat-grass in the foreground and brome-grass and western wheat-grass in the middle of the picture.

account of its habits of growth it is well adapted to the particular purpose of soil binding. The initial growth is fairly rapid, so that the grass gets well established the first season. It endures drought well and is quite resistant to alkali.

The growth of brome-grass is unhindered where the alkali is of the medium grade (0.5 per cent). In fact, this grass can make excellent growth and seed production where the alkali is medium strong (0.7 per cent), and it has been observed to ripen some seed in the presence of very strong alkali (1.5 per cent).[2]

[1] It should be understood, however, that the results here reported apply only to the conditions under which the experiments were made and do not necessarily indicate that the same species would behave similarly in other parts of the country.

[2] Kearney, T. H. The choice of crops for alkali land. U. S. Department of Agriculture, Farmers' Bulletin 446, p. 19, 1911.

Brome-grass will not endure as severe drought as will western wheat-grass, but is more drought resistant than any of the other grasses tested. In certain plats on the ditch banks it maintained a good stand during the extremely dry seasons of 1910 and 1911. Its habit of spreading by means of underground rootstocks enables it to form a good sod and makes it one of the best grasses for soil binding. (See fig. 1.)

WESTERN WHEAT-GRASS.

Western wheat-grass (*Agropyron smithii*) is native to western South Dakota and is the most valuable pasture and hay grass of the region. On the dry plains it forms, with buffalo grass, the chief forage for the range stock, and in the creek valleys, where it is sometimes watered by overflow from the streams, it makes a thick growth and is the chief native hay grass. It is extremely drought resistant and yet will endure a great amount of flooding. It is the most resistant to alkali of the grasses mentioned in this paper. In the field experiments of Mr. T. H. Kearney[1] it proved to be the most resistant to alkali of any of the grasses tested. On the dry ditch banks it is slow in starting growth, but when once established it makes a tough, permanent sod. The seed can not be obtained commercially, but can usually be harvested in favorably situated places along the creek bottoms. In 1909 the writer thrashed 100 pounds of seed from a few bundles which were cut in an hour's time with a common grain binder. The germination of the seed is often rather poor, so that a large quantity, about 30 or 40 pounds per acre, should be used. The chief objection to western wheat-grass is its slow early growth which makes it long in establishing itself. Its valuable characters—drought endurance, alkali resistance, ability to endure flooding, and good sod-producing habit—make western wheat-grass one of the best of soil binders. In places where a native sod is cut through in making the ditches, the surviving plants of western wheat-grass at the edge of the cut will extend their growth up the canal bank, so that in a few years a good covering is naturally produced. This, however, will only occur where the grass is already present at the edge of the bank and not in cultivated fields where the native sod has been destroyed.

SLENDER WHEAT-GRASS.

Slender wheat-grass (*Agropyron tenerum*) makes a comparatively rapid growth and is valuable to give quick results in a mixture. This grass, unlike western wheat-grass, is a bunch grass and does not form a continuous sod unless planted very thickly. It is not nearly as drought resistant as either brome-grass or western wheat-grass.

[1] Loc. cit.

Its chief value for the purpose here desired is its early, vigorous growth. In a pure stand, however, it has maintained a fair growth since it was planted in 1909.

ALFALFA.

Alfalfa has proved very satisfactory as a covering for canal banks, especially when planted in mixtures with some species of grass. The growth during the first season is fairly rapid, the roots strike deep and soon reach the seepage water present in the lower depths of the soil, and the forage produced is of first-rate value. Alfalfa does not

FIG. 2.—Alfalfa on a canal bank, with western wheat-grass crowding in near the water's edge.

stand close grazing and excessive trampling so well as do some of the grasses, but when planted with a vigorous grass, such as brome-grass, it makes a good covering. Pocket gophers have given some trouble by eating off the roots of alfalfa plants, but this is not likely to prove a serious drawback to the use of alfalfa on the ditch banks. Where seed of a hardy strain can be obtained, alfalfa may be recommended for use in a mixture with grasses (fig. 2).

REDTOP.

Redtop (*Agrostis alba*) makes a good growth where an abundance of moisture is available, but is not at all drought resistant. It may be seeded near the water's edge and where seepage water occurs, or, if included in a mixture with other grasses, it will make a good growth on all moist parts of the bank.

THE FESCUES.

The three species of Festuca tested, meadow fescue, tall fescue, and red fescue, have not shown any particular value as soil binders in this region. None of them are able to endure the dry conditions of the higher part of the banks, nor do they make a permanent sod, even under more favorable conditions.

OTHER GRASSES.

The other grasses tested, namely, orchard grass, Italian rye-grass, creeping bent-grass, and Canadian bluegrass, have not shown any value for soil binding in this region. They are unable to endure the trying conditions, nor can they compete with the more resistant grasses when used in mixtures.

MIXTURES TESTED.

Several mixtures of grasses have been tested to determine if any combination could be found which is better adapted to the purpose than a single species.

The following mixtures (by weight) have been used:

Mixture No. 1:

Brome-grass	4 parts.
Western wheat-grass	4 parts.
Meadow fescue	1 part.
Italian rye-grass	1 part.

Mixture No. 2:

Brome-grass	4 parts.
Canadian bluegrass	2 parts.
Italian rye-grass	1 part.
White clover	1 part.

Mixture No. 3:

Western wheat-grass	4 parts.
Red fescue	2 parts.
Alfalfa	1 part.
Italian rye-grass	1 part.

Mixture No. 4:

Slender wheat-grass	2 parts.
Tall fescue	2 parts.
Redtop	1 part.
Orchard grass	2 parts.

Mixture No. 1 combines two hardy and permanent but rather slow-growing grasses with others which quickly form a cover. The brome-grass and western wheat-grass have survived since planting in 1909 and now form a good cover. The other species made a fair growth during the first season and may be desirable to use in a lawn where quick results are desired, but they have no permanent place on a canal bank.

In mixture No. 2 brome-grass is the only species that has survived. The Canadian bluegrass did not do well at any time in this mixture.

As it was not used in a pure seeding, it is uncertain whether its failure was due to the nature of the soil or to the competition with the more vigorously growing brome-grass.

In mixture No. 3 western wheat-grass and alfalfa have done well and show a good covering three years after planting. No doubt brome-grass would do as well as western wheat-grass in mixtures with alfalfa under most conditions; and it can be used more extensively, since the seed is more easily obtained.

Mixture No. 4 made a good showing during the first and second years, but has not proved permanent. The redtop, however, still survives near the water's edge.

PREPARATION OF SOIL AND SEEDING.

In order to insure a successful growth of grass it is necessary to have the soil in as favorable a condition as possible. There must be a well-prepared seed bed—the soil should be fine, firm, and moist—in order to insure a quick and continuous growth of the grass. A good preparation is to harrow the canal bank at frequent intervals during one summer, so as to prevent the growth of weeds and conserve as much moisture as possible. This will put the soil in good condition for seeding early the following spring.

The seed may be sown broadcast by hand, or, in case a large area is to be seeded, a hand seeder may be used to advantage. The soil should be harrowed before seeding and the seed covered by harrowing again after seeding. In covering the seed, the harrow teeth should be set at a slight angle, so as not to dig too deeply. A common 2-horse steel harrow is convenient for this work.

From 15 to 30 pounds of seed per acre, depending upon the kind of seed and the condition of the seed bed, should be enough to secure a good stand of grass. Any heavier rate of seeding will hardly compensate for poor soil conditions. The smaller seeds, such as redtop, need not be sown as heavily as the larger seeded grasses. A heavy growth of grass can not be expected on the drier parts of the canal banks, and yet on account of the less favorable conditions there a liberal quantity of seed should be used.

It is very important that the planting should be done early, in order to give the young grass the benefit of the cooler growing weather and the early summer rains. Competition from weeds, especially Russian thistle, is also less during the early summer. The best results have been obtained by seeding in April rather than later. Live stock should not be allowed on the banks after seeding until a sod is well established. Even then, close grazing should not be allowed if a permanent sod is to be maintained.

RECOMMENDATIONS.

From the results thus far obtained it seems safe to recommend brome-grass, western wheat-grass, and alfalfa as the best plants for covering the canal banks of the Bellefourche Project. Redtop may be seeded in a mixture with these or seeded alone where an abundance of moisture is available, as is the case near the water line on the inner slope of the canals. Western wheat-grass should not be seeded alone, on account of its slow early growth, but if seed can be obtained it should be included in a mixture with brome-grass or alfalfa. A mixture which can be recommended for all types of soil on the project is the following:

Brome-grass	6 pounds.
Western wheat-grass	6 pounds.
Alfalfa	6 pounds.
Redtop	2 pounds.

This should be enough seed, under ordinary conditions, for planting 1 acre. If all of these species are not available a mixture of equal parts of brome-grass and alfalfa will in most cases give a satisfactory covering. Care should be used to secure a hardy strain of alfalfa seed, preferably one that has been grown in the neighborhood for a number of years.

The seeding should be done early in the spring, during a rainy period if possible, and care should be taken to obtain a firm, moist seed bed, in order to insure rapid early growth.

Grazing on the banks should not be allowed for a year or two after seeding, and close grazing should never be permitted if a good sod is to be maintained.

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