

Bulletin 103.

October, 1905.

# The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

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## The Thorough Tillage System for the Plains of Colorado.

BY W. H. OLIN.

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CORNELL UNIVERSITY

~~Agricultural Experiment Station~~

PUBLISHED BY THE EXPERIMENT STATION

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1905

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# The Thorough Tillage System for the Plains of Colorado.

BY W. H. OLIN.

## I. THE PRINCIPLES OF SEMI-ARID FARMING.

Regions having an annual rainfall of less than twenty and more than eight inches are usually considered as semi-arid. To successfully grow crops in such regions requires a careful study of soil and climatic conditions, with a selection of crops as nearly adapted to these conditions as possible. Even when all requirements are seemingly met, a failure is sometimes the only result. Experience, and experiments already conducted in many parts of our nation's semi-arid belt, demonstrate that the preparation of a soil reservoir of good depth several months before seeding, the thorough culture of this ground before and after seeding, the selection of suitable varieties of crops, the seed of which is grown under dry farming conditions, are essentials which very largely determine success in farming lands in Colorado where irrigation can not be practiced.

The preparation of the soil reservoir and seed bed calls for careful plowing, harrowing and sub-surface packing.

1. PLOWING.—Jethro Tull nearly two centuries ago said "Tillage is manure." Roberts' Fertility says that stirring and mixing the soil is the one fundamental labor of agriculture. The object of plowing should be to pulverize the soil, making it possible to prepare a good seed bed for the reception of the various farm seeds. The depth to plow must depend upon the time of plowing, the character of the soil and the crop to be grown.

Shallow plowing is preferred for shallow soils underlaid by an inferior sub-soil lacking in plant food. Spring plowing for early crops should not be as deep as fall plowing for the same crops. Experiments have shown that deep plowing of stiff or clayey, adobe and in the spring turns up unworked or new soil in which most of the plant food is not available, on account of the mechanical condition of the ground. Crops on lands thus plowed often make an unfavorable growth. It is nearly always desirable to plow sandy and sandy loam soils deep, since the plant food contained in these soils is easily available and the deep plowing brings more plant food to the surface for the tender young plant to feed upon, giving it a sturdy growth at the start.

All deep plowing is best done in the summer or fall. This permits the weathering of the soil, through the fall and winter making its mechanical texture more desirable and the plant food available. Deep plowing assists water to percolate or pass through to lower depths. Hence it increases the water holding capacity of the soil, a most important element in semi-arid farming. The deeper the plowing the greater the soil reservoir. Experiments conducted at the Cornell Experiment Station, New York, by Dr. Roberts show that an acre of average soil in good tilth will hold 20 to 25 per cent of moisture and not be too moist for cultivation. It is estimated that an acre of soil 12 inches deep will weigh 1,800 tons if it contains 20 per cent of moisture, 1,620 tons if it contains 8 per cent of moisture—the amount upon which plants are able to grow and maintain themselves. Dr. Roberts says that an inch of rainfall brings to each acre 113 7-16 tons of water. If this could all be retained in average soil it would mean almost 7 3-5 per cent moisture, nearly enough to maintain plant growth. Well fined soil is capable of taking up two inches of rainfall in the first foot of soil and still be in good condition to cultivate. Suppose that this soil is deeply plowed and contains 15 per cent moisture; an inch or a two inch rain would find the soil reservoir able to hold it. If the ground were shallow plowed, say four inches, an inch rain would saturate the reservoir, while a two-inch rain would overflow the soil reservoir, causing a loss of water and severe washing away of the surface soil. Deep plowing therefore increases the storage capacity of moisture in our soils from which the plant draws as it has need.

Good plowing gives a clean-cut furrow on side and bottom. It turns the inverted furrow slice upon edge in a moderately well pulverized condition with but few air spaces at the bottom edge of the furrow slice. A good coulter lessens draft and aids in making a clean cut furrow. Disking the ground before plowing is advantageous but increases the expense of preparing the seed bed.

A seed bed from one to three inches deep can be prepared without plowing. The young plants may grow sturdily at first, but if the soil is not in a physical condition to store the moisture necessary to dissolve the plant food and render it available for the growing plant, lack of nourishment will bring it to an untimely end and the crop will prove a failure. Very successful crops are grown this way when the moisture is supplied by ditch or sub-irrigation but it is always hazardous to attempt cropping without thorough tillage under semi-arid conditions.

A disc plow will often leave the soil in a good condition before the harrow, when the ground is too hard for a mold board plow to do satisfactory work. The drier the ground the more narrow

should be the furrow, whether the plow be a mold board or a disc plow.

2. **HARROWING THE GROUND.**—Harrowing is the process of stirring the soil by some form of a toothed or circle knife implement. Its purpose is the pulverizing of the soil, reducing it to finer tilth than the plow left it, filling the interstices left by the plow and thus leveling the soil. I believe that the spike toothed harrow is a superior implement for pulverizing after the plow. It should follow as near after the plow as possible so as to prevent loss of moisture by evaporation from the newly plowed earth and the formation of clods. Each half day's plowing should be harrowed that same half day in which it is plowed.

Ground that is harrowed first lengthwise with the plowing will retain its moisture better, since it regularly and evenly fills the interstices or openings at the bottom edge of each furrow slice. Always first harrow lengthwise and later cross harrow if the ground is not in fine enough tilth for the seed. Ground that is inclined to be cloddy should be worked with the disc harrow instead of the spike tooth, double disking or half lapping lengthwise with the furrows. See that your disc is the proper size to do the most effective work in pulverizing the soil. A fourteen to sixteen-inch disc generally pulverizes better than an eighteen or twenty-inch disc, and the draft is correspondingly greater. Experiments seem to indicate that the smaller diameter discs are better adapted for farming conditions on the Colorado plains than the larger diameter discs. Experiments conducted by experiment stations and by Mr. H. W. Campbell of Lincoln, Nebraska, show that disking grain ground after the harvester prevents loss of moisture on stubble ground through too rapid evaporation, and prepares the ground for the ready absorption of rain.

3. **SUB-SURFACE PACKER.**—This tool consists of a series of wedge faced wheels attached to a common axle. These wedge-faced disks are 18 inches in diameter and placed vertically on the shaft 6 inches apart. This machine is better than a smooth roller for a roller firms the surface soil with little or no effect upon the under or sub-surface soil. The packer firms the soil in the lower portion of the furrow slice, restoring the capillarity where plowing had arrested it. This firmed under-surface soil is enabled to draw moisture from below and give good normal root development. In case a sub-surface packer is not obtainable, a corrugated roller can be used. It firms the ground but not to the depth which the sub-surface packer does. These packers should be followed by a smoothing harrow to produce an earth mulch which shall arrest capillarity and thereby check evaporation.

A spike toothed harrow with lever attachments for regulating

the angle of the teeth is a very satisfactory implement for purpose.

4. SUMMER CULTURE. *Fallowing Ground*—leaving the land without a crop for one or more seasons—was a common practice with the ancients. Dr. Roberts in his work on "Fertility of Land," says this was a necessity for them. The imperfect tools then used made but a small proportion of the plant food in the soil available and the demands of the crops grown soon outran the obtainable plant food. Then the only method for renewal was to let the soil "weather out" enough plant food, with the decayed vegetable matter to sustain another crop. Some centuries later the French found that "manoeuvring" the land—causing the particles of earth to change place by tillage—made it more productive. Experiments now show that summer tillage in our semi-arid lands has an added value—it conserves the moisture while it renders more plant food available. Good results have been obtained in Eastern Washington, Eastern Oregon, Utah and many sections of Colorado from summer culture of the land every other season. It has been found that in this way sufficient moisture can be stored from the year's rainfall to mature a crop, in many localities.

After the snows of winter have melted in the spring, plow the ground at least seven to eight inches deep. Level this down with the harrow and packer, following this process with a smoothing harrow, forming an earth mulch to check evaporation. This mulch should not be too fine as the winds of the plains will tend to rattle the soil, or blow the earth mulch *entirely* away. If possible, stir the surface soil from two to four inches every ten to fifteen days throughout the summer. Allow no crust to form after summer showers, as this will increase the evaporation of the soil moisture. Keep the ground clean—free from weeds.

If fall grain is to be sown it is advisable to drill in the grain as this insures getting it below the earth mulch which is really a dry earth blanket used all summer to hold the moisture in the soil below. Get the seed into this moist under-soil where it can have the moisture so essential for germination. It is advisable to sow fall grain not later than the last week in September in the lower altitudes and not later than the first week in September in the higher altitudes; better still, the third or last week in August.

Ground that has been well cultivated for several years will produce two crops in succession and can be given summer culture the third year. In this way it is possible to grow two crops in three years.

If a farmer expects to cultivate 80 acres he should divide it into two crop divisions—cropping 40 acres the first year and giving summer culture to the other 40 acres. This gives him a crop

on one half his land each year while he is storing up moisture in the soil reservoir of the other half to make the next year's crop. Farmers in the southern part of Larimer County, Colorado, have been able to raise quite satisfactory wheat, barley and forage crops by following this method of cropping.

Mr. Geo. D. Porter living at Akron, Colorado, near the center of the plains region has used this method of cropping, for a small area, for several years. He reported last fall, when he seeded his winter wheat, a soil reservoir in which there was five feet of moisture. Last season gave us an unusual amount of rainfall but this summer culture has been practiced in some parts of California for more than forty years with satisfactory results. The writer knows of one section of California where it seldom rains from April to September, yet here some of the finest fruit and grain is grown. This region in California has an ample supply of moisture in the rainy season—the winter months. This illustration is simply given to show the value of the earth mulch in holding the moisture which is already in the soil reservoir.

Mr. S. S. Peterman has a cherry orchard near Fort Collins that has never been irrigated. He depends upon rainfall for his moisture in a region that averages scarcely fifteen inches per annum. As soon in the spring as possible he cultivates his orchard and continues to stir the ground until the fruit sets. His trees bear fine flavored cherries in a satisfactory quantity, while his orchard is the cleanest one in his neighborhood. This orchard is eight years old, but has not yet weathered one of our "dry" years.

Summer culture keeps the ground in good tilth, keeps down weeds, renders the plant food easily available for the next year's crop, while it stores up the moisture so necessary to the plant in assimilating its food.

## II. SELECTION OF SEED FOR SEMI-ARID CONDITIONS.

Climatic conditions are believed to have an influence on the development of certain temperaments and characteristics in the breeding of live stock, although the hereditary power of a well-bred horse, cow or sheep to transmit its qualities to its descendents is the major influence and measures the value of a pedigree.

While plants, like live stock, certainly have strong hereditary power, yet it seems true that climate, soil and cultural methods, have an influence on the manner of growth of very many crops grown in our fields.

M. de Candolle, an eminent plant scientist, has succeeded in finding the wild forms of one hundred and ninety-three of the two hundred and seventy species of cultivated plants. Of the remaining seventy-seven, twenty-seven he names as possibly half

wild and the rest he has so far failed to discover in the wild state.

Darwin in his investigation of domesticated plants came to the conclusion that in cases similar to this the cultivated plant either was so changed in its growing habit by its new environment that its wild prototype could not be recognized or that its original parent ceased to exist.

Prof. A. M. Ten Eyck of Kansas in an address on "Plant Adaptation" before the Corn Breeders' Association of that state last March stated:

"From a single, comparatively valueless, primitive wild form have originated in the course of time thousands of valuable varieties of plants, all differing from the original and some to such an extent that they cannot be recognized."

Prof. W. M. Hays, in the Minnesota Experiment Station Bulletin No. 62, speaking of variations in individual wheat plants says:

"Among the four hundred plants of McKendry's Fife for example, plants were found which matured in ninety-seven days, others requiring one hundred twenty-seven days. Among Power's Fife (wheat) plants, the range was from ninety-eight to one hundred seventy-two days; and among Haynes' Blue Stem plants the range was from ninety-nine to one hundred twenty-eight days.

"The ten plants which appeared to the eye as the best yielding plants out of the four hundred of each variety, were harvested and notes taken as to the height of plant, number of spikes, length of spikes and yield of shelled grain. The following table shows the extremes of the variation in each case:

VARIATION AMONG BEST TEN OUT OF FOUR HUNDRED WHEAT PLANTS.

Name of Variety.	Height of Stalks. inches.	Length. of Spikes. inches.	No. of Spikes.	Yield in grams.
Haynes' Blue Stem.....	31 to 39	4 to 4½	19 to 31	15.4 to 19.4
Powers' Fife.....	27 to 33	3½ to 4	18 to 33	3.4 to 13.8
McKendry's Fife.....	30 to 33	3½ to 4	22 to 33	6.8 to 16.7

In breeding corn, the writer has observed that individual plants in the same breed or type of corn, vary widely in producing power, height of ears on the stalk, height of stalk, width and number of leaves and period of maturity of corn. The Iowa Seed Company state their earlist maturing type of dent corn—Farmers' Reliance—was developed by selecting the lowest ear on individual plants, these ears usually ripening first. At the Kansas station a pure bred type of corn known as Reid's Yellow Dent, was planted in the season of 1903—an ear to a row. These ears were carefully selected for uniformity and trueness to the breed characteristics of that type of corn. The resulting harvest from these different rows showed almost as much difference in the character of plants in different rows as in different supposedly fixed types of yellow dent corn, while difference in yield between highest and lowest was nearly four hundred per cent. The very best ears from the best yielding and most desirable mother ears were selected for the mother ears



of 1904 and seeded a row to an ear. Marked differences in growing habit were noted, but differences in yield from lowest to highest was but a trifle more than eighty per cent—one fifth what it was the preceding year.

"Selection is the process by which new varieties are fixed. Artificial crossing may be used to induce variation, with a view to promote the development of new forms, but selection is always the final process by which new varieties are established and maintained.

"Three principal factors largely determine the value of a variety of any cultivated crop, namely, yield, quality and adaptation—and the last named is really the deciding factor which determines whether a variety type may be successfully grown in any locality. In no two countries, perhaps in no two sections of the same country or state, are the plants subject to exactly the same conditions of soil and climate. One section may have a different soil, a little more dry weather, and the plants of this section vary to adapt themselves to these conditions. If the plant is removed from its native habitation and planted in a different part of the world or country, in a different soil, surrounded by different conditions to those to which it has been accustomed, it is placed at a disadvantage, it is exposed to a new environment to which it is not suited. Thus we can understand why a good variety of fruit or grain does not always give as good results in all places, and we should expect a variety of plants originating from the plants of a certain region to be best adapted for growing in that region, or such plants may be adapted for growing in any region having similar conditions of soil and climate.

"We find a demonstration of this principle in the fact that wheat and other grains, brought from the steppes of Russia and Turkey are well adapted for growing in the western plains region of the United States, which has a climate and soil very similar to that of the countries named. The Turkey Red wheat, for instance, has largely replaced all other varieties of winter wheat grown in the West, because of its greater hardiness and productiveness, and that some of the varieties which it has succeeded had been grown in the West for many years and seemed to be fairly well adapted to western climatic and soil conditions. This superior hardiness and adaptation which the Russian and Turkey varieties of grain appear to have in our western country may be largely credited to the centuries of training which these varieties have had in an environment almost identical with that of similar latitudes in the West. While the varieties which the Russian grains succeeded as a rule have been those which have been gradually moved from the Eastern and Middle states farther west, and although many of these varieties have gradually become more or less hardy and fairly well adapted for growing in our western climate, yet, in the comparatively short period during which they have been grown under western conditions, apparently they have not become so hardy and well adapted to those conditions as the Russian and Turkey varieties." (Prof. Ten Eyck's Plant Adaptation.)

For more than ten years Mr. Robert Gauss of Denver, has been growing a certain type of wheat, under drouth conditions with results that are in accord with statements made by Prof. Ten Eyck. Each year Mr. Gauss has made his seed selections looking toward the seeding of wheat for the plains, that has good drouth resisting qualities.

This past season the writer seeded some of this wheat, in May, in the very driest seed bed which he has ever used. It was sown broadcast, and seed covered with a spike toothed harrow. The seeding was done on an experimental plat located on the C. F. & grounds five miles southwest of Pueblo, Colorado. This wheat

matured when barley and oats, seeded at the same time, in the same seed bed, perished from lack of moisture. Mr. Gauss tells me he can trace this wheat as a drouth resistant wheat for at least eighteen years; while his wheat has not been tested for milling qualities, his results would indicate the value of selecting seed grown under *semi-arid conditions, for semi-arid farming*. Persons coming from a lower altitude with a moist climate, often are completely prostrated on being transported to Leadville—Colorado's "Cloud City," nearly two miles above sea level.

In a similar manner, but probably not to so marked a degree, altitude and climate affect our crops and we should try to secure acclimated seed or at least obtain seed from regions with similar climatic and soil conditions. Seed corn from the Mississippi river states cannot be expected to make a sturdy growth in eastern Colorado; seed wheat from near tide water cannot be expected to make a quick, rapid growth at an altitude of 8,000 to 10,000 feet.

Colorado farmers find grain of good quality grown and developed in the region of their farms gives best results and Colorado grown seed should be so selected that it shall take precedence of all other seed on our home markets.

Mr. A. H. Danielson, Asst. Agronomist, a few years ago decided to test selection for hardiness in winter wheat. For this test he selected a number of varieties. The ones which showed the best quality grain and gave the best yields he used as the basis for his work. The first year all were badly winter killed. From the plants which lived through and matured grain, he obtained seed and so continued for four years. This year all of his plots showed a perfect stand, while other plots not thus treated showed from twenty to thirty per cent winter killed.

The value of good vital seed is shown in an experiment conducted by Professor R. A. Moore of the Wisconsin Experiment Station with oats. He selected from two pecks of seed oats sent to him by the U. S. Department of Agriculture, 33 especially fine, large, plump kernels and planted them in a choice plot by themselves in 1899. From these plants he received sufficient seed to plant a good sized bed. The next year he began sending out seed to members of the Wisconsin Experiment Station, asking that a record of harvest and sales be kept so he could trace the progeny of his 33 oat kernels; last year (1904.) he found the harvest of the oats with a pedigree tracing back to the 33 kernels of 1899, numbered 500,000 bushels. Hardiness, quality and productiveness are to be sought for in our field crops if we would farm profitably in any region. Because of the struggle for existence in our semi-arid fields, our farm seeds should be chosen with great care and with these three essentials always in mind.

*Rate of Seeding.*—Because of the limited amount of moisture in the soil a limited amount of seed should be used in seeding all crops grown on semi-arid lands which can not be irrigated. If seeded too heavily there is not sufficient moisture in the soil to mature all plants and the entire crop in a very dry year is liable to “fire”—ripen prematurely. It is better to under seed rather than over seed. The rate of seeding depends so much upon the size of seed, mechanical condition of the seed bed, method of seeding and moisture—conditions that it is impossible to give the exact amount of seed which should be used in seeding the various field crops. The writer this past season carried on a co-operative experiment with a farmer testing two varieties of drouth resistant wheats on sod. One was seeded nearly twice as heavy as the other one, yet the field having the lightest seeding had equally as good a stand as the field seeded the heavier, because there were nearly twice as many kernels in a bushel and each kernel made a plant. Below is a suggestive table which may prove helpful to persons who are seeding crops for the first time on semi-arid lands. The amount of seed required is usually from one half to two thirds that which is used for the irrigated lands.

## RATE OF SEEDING FOR NON-IRRIGATED LANDS.

Name.	Lbs. per Bushel.	Lbs. per Acre,
<b>GRAIN CROPS.</b>		
Wheat .....	60	45 to 60
Barley .....	48	50 to 60
Oats .....	32	40 to 60
Rye .....	56	35 to 50
Emmer, or Speltz.....	40	45 to 60
Field Corn (in hills)... (shelled)...	56	4 to 6
Field Corn (in drills or lister rows).		5 to 7
Sweet Corn (in hills).....		6 to 8
Sweet Corn (in drills).....		10 to 15
Kafir Corn .....	56	4 to 5
Broom Corn .....	46 to 55	2 to 4
Field Peas .....	60	30 to 50
Field Beans .....	60	15 to 25
Proso .....	60	6 to 12
Millett .....	60	5 to 10
Buckwheat .....	50	20 to 30
Flax .....	56	20 to 30
<b>FORAGE CROPS:</b>		
Sorghum or Cane.....	50	8 to 25 (varies with method of seeding.)
Alfalfa .....	60	20 to 25
Meadow Fescue .....	24	15 to 25
Brome Grasses .....	14	15 to 25
Vetches .....		20 to 30
<b>ROOT CROPS:</b>		
Sugar Beets .....		10 to 15
Mangel Wurzel .....		8 to 12
Carrots .....		3 to 5
Stock Turnips .....		1½ to 4 (manner of seeding.)

### III. CROPS FOR THE SEMI-ARID LANDS.

The amount of water required by growing crops is shown by experiments to vary with the soil, climatic conditions and the nature of the crop grown. Crops having a large percentage of water in their composition will necessarily require more moisture to produce a healthy, vigorous growth than crops with a low percentage of moisture in their composition.

Experiments to determine the best grain, forage and root crops for drouth resistant power and productiveness are now being conducted at the experiment stations in the semi-arid states. Conclusive results have not yet been obtained but the following crops are worthy of consideration for semi-arid farming. All of these have been successfully grown in some portion of the semi-arid West, but probably none of these crops would do well in all regions of Colorado where semi-arid farming is being practiced.

#### I. GRAIN CROPS.

1. *Corn*—Early maturing types of dent and flint varieties are chosen. Cool nights, high altitudes and short summers are not adapted to this cereal since corn is a semi-tropical plant. When the seed bed is well prepared and the crop thoroughly tilled, eastern Colorado farmers have been able to obtain from 10 to 25 bushels per acre with the average season.

Favorable seasons a greater yield is reported in a few individual cases. In raising corn in Colorado it is highly important to grow an acclimated variety. Obtain seed grown as nearly as possible under the same climatic conditions which prevail in the region where you wish to plant it. Select seed of good vital power. It is especially important in all semi-arid regions to give the crops a good start, for they usually have a hard struggle for existence, even under the thorough tillage system of farming. Hence the use of good, strong, vital seed grown under drouth resistant conditions is very important.

2. *Kafir Corn*. This is an important crop both for grain and forage. It is a non-saccharine sorghum. The seed is borne in a head at the top of the stalk and seems to be relished by all classes of stock. In tests conducted at the Kansas Experiment Station the feeding value of Kafir corn for fattening hogs was found to be 90 per cent of the feeding value of corn (Kans. Bulletin No. 128). This crop may appear almost dried up, favorable conditions return and it revives in a remarkably short space of time. It seems to withstand dry and windy periods to a remarkable degree, if these periods do not last too long.

The Fort Hays Sub-Station in Kansas, gives the following plan of seeding for grain and for forage:

"Kafir corn grown for seed does best when planted with a lister in rows from 3 to 3½ feet apart, and cultivated enough to about level the ridges. If seed alone is desired, a special plate should be used in the drill that will put a stalk every 4 to 6 inches apart. If the fodder is also sought, the seed should be much thicker. A common practice is to use the regular corn plate set to drop 12 to 16 inches apart. This will drop a dozen or more grains at a place. When planted in rows the corn harvester should be used for cutting the crop, and the bundles set up in good sized shocks. When the heads are dry they may be threshed with the ordinary thresher. The most satisfactory method of harvesting the heads is to take a low wagon with a tight rack and a good sized chunk laid across the back end, with two stakes set in it, about six inches apart at the bottom and one foot at the top, 18 inches from the chunk. One man with a heavy broadax stands on the wagon and chops the heads off, as two or three others pick up the bundles and lay them on the chunk.

"With two wagons and five men this is a very rapid way of obtaining seed. The bundles may easily be reshocked or laid in piles. The threshing of the entire stalk is not satisfactory, if the stalks are of any size. It is very hard on a machine, and the fodder does not keep so well when cut up. It also dries out, which is undesirable. The practice would be similar to cutting bread for the table a month or so beforehand. It is not palatable.

"For roughage alone, the general practice is to plant with the grain drill at the rate of a half to a bushel per acre, depending upon the land. This is cut with a mowing machine, raked, and put in large cocks. A great deal of labor can be saved by using a buck-rake or "go-devil," to bunch the windrows."

The White Kafir with a black hull or chaff is the earliest variety and so far seems to be the hardiest grower and best yielding variety.

3. *Wheat.* (A) SPRING WHEAT.—The best spring wheat variety for semi-arid conditions seems to be a durum wheat known as Kubanka durum—U. S. Cerealist, M. A. Carleton, introduced some 15 variety types of durum from a part of Russia with soil and climatic conditions quite similar to eastern Colorado. The type which seems best adapted to Colorado conditions is the Kubanka durum. This is a spring wheat in our latitude and should be seeded as early in the spring as ground and weather conditions will permit.

The durum wheat, having been grown for many generations in a semi-arid climate in Russia, withstands drouth conditions better than our common spring wheats. It must be remembered, however, that no wheat can be matured without some moisture. Kubanka durum has good drouth resistant power, but one must not expect this wheat to mature a satisfactory crop without several inches of rainfall during the growing season. While durum wheat has been tested this past season in thirty counties in Colorado, experiments have not been conducted long enough to tell us the minimum amount of moisture required to produce a crop under our differing conditions of soil and climate.

This wheat has the heaviest and coarsest beards found on any wheat. The kernel is very hard and most millers feel that this wheat requires special machinery for milling. For this reason but few local millers in the state are buying durum wheat. Mr.

B. F. Hottel of the Lindell Mills, Fort Collins, Colorado, ground 1,500 bushels of Kubanka durum last fall. He put up five pound sample sacks of this flour and the Agronomy Department assisted in placing these sacks in more than fifty families to be tested in both light bread and biscuits. The reports sent in from this test showed that light bread or biscuits made from Mr. Hottel's durum flour compared very favorably with the patent flour in common use, in texture, elasticity (lightness), flavor and moisture. While the bread was possibly a shade darker it was not considered a serious objection. Comparative tests made later, by the Domestic Science Department, Mrs. A. M. Hawley and Mrs. Winnie E. Olin, confirmed the previous tests, showing the Hottel durum flour made a very satisfactory bread. This wheat is also used in making semolina, a milled product from which our very best French and Italian macaroni is made. A milling firm in Cincinnati, Ohio, is now making from 8,000 to 9,000 pounds of macaroni per day from western grown durum wheat. This wheat when first introduced, was known as macaroni wheat and it was believed that it could not be used for anything else. The milling and baking tests conducted in North and South Dakota, Minnesota and Colorado, demonstrate that durum or macaroni wheat gives a desirable flour for bread or pastry. Prof. J. H. Shepard, Chemist of the South Dakota Station, has found that the importation of wheat known as Kubanka No. 5639, gives the best quality flour of all durum wheats.

This wheat should not be sown on the irrigated lands, as the use of too much water produces starchy kernels, causing the wheat to deteriorate in quality. It should not take the place of any bread wheat now being successfully grown in any region. It is recommended as a spring wheat on lands where other spring wheat does not yield a satisfactory crop, in a region where there is sufficient rainfall to mature a drouth resistant wheat, giving the farmer a semi-arid bread-wheat. Like all new crops, a market must be developed for it.

This wheat has only been grown in our state a few years and farmers are urged to study market conditions and determine their acreage of this new crop by the market demands for this wheat.

(B) WINTER WHEAT.—The variety of wheat has given the most satisfactory yields and shown drouth resistant power is Turkey Red. This wheat has been grown quite successfully in Kansas, Nebraska and portions of Colorado for many seasons. It is the wheat which made Kansas the greatest winter wheat state in the Union and is as good for the irrigated as for the semi-arid lands. The millers of Colorado prefer this to any other wheat for flour production. It has a ready and constant market at any mill in the state. Seed for semi-arid lands should be obtained from

regions where this seed has been kept pure and grown "above ditch."

The sub-stations in Nebraska and Kansas located in the western portions of these states can aid our eastern Colorado farmers to obtain seed and the Monticello sub-station farm in Utah will help our western Colorado farmers to obtain seed wheat, while the writer will also assist anyone desiring this wheat, to obtain as good seed as possible, grown under drouth resistant conditions.

Any winter wheat which has good milling quality and shows drouth resisting power, adapted to the region where grown, can and should be developed by wise seed selection and careful culture treatment.

All semi-arid wheat should be harrowed or run over with a weeder to break up the crust which may form, and thus check too rapid evaporation. Wheat can thus be advantageously cultivated until it is knee high. Often seeding rows sixteen instead of eight inches apart (stop up every other hole in the drill) is advantageous. Then one can use a beet cultivator or other small toothed cultivator and cultivate the crop, keeping the ground well stirred.

Cultivating grain in the semi-arid region lessens evaporation and thereby holds more moisture for the growing crop.

4. *B rley*.—This grain has not been generally sown as a drouth resisting crop. Bald barleys can be grown in the higher altitudes and in the northern and north central portions of the state, with a fair degree of success. Bald barley when ripe has a very hard kernel and most feeders find it best to crush or grind it before feeding to stock. Cut in the soft dough or before ripening, it is fed in the straw without threshing. A bearded feed barley is grown in some sections of the state. Obtain seed grown on non-irrigated lands.

5. *Emmer*. This grain belongs to the wheat group and is sometimes called speltz by our farmers. Both emmer and speltz have a hull which clings to the kernel and does not come off when threshed.

Speltz and emmer differ in size of head and arrangement of spiklets on the spike or head. Emmer is the more preferable grain of the two for our conditions. This is a spring grain and should be seeded the same as barley. It is used as a feed grain for nearly all kinds of stock. It is being grown more extensively in the South Platte and on The Divide east of Colorado Springs, than in any other portion of the state.

6. *Oats*. This grain is not well adapted for non-irrigated lands. Only the earlier maturing types should be grown. It is often sown for a hay crop in eastern Colorado and in higher altitudes above the ditches.

7. *Rye*. Winter rye or early varieties of spring rye are sown for hay and for grain crops as well. Choose a market type of rye and seed a small acreage at first.

## II. FORAGE CROPS.

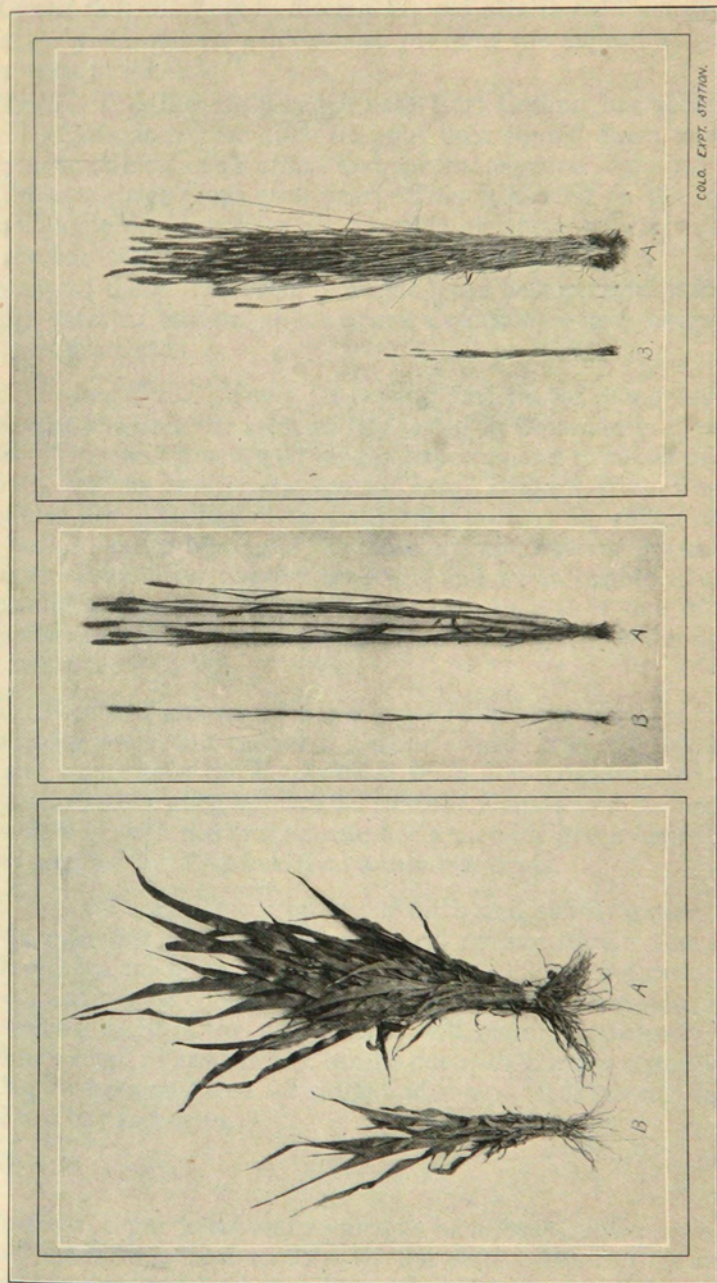
1. *Cane or Sorghum*. This is grown for feed to supplement the range in winter. Grow early maturing types. Drilled sorghum is a more certain crop than when sown broadcast.

2. *Proso*. This is a drouth resistant millet, imported within recent years by the U. S. Cerealist, Prof. M. A. Carleton, from the driest regions of Europe. This crop grows a wealth of seed in a close paniced head, while it affords considerable forage in its broad leaved foliage. It is a spring crop, but should not be seeded until all danger of frost is passed. There are several varieties but the white proso furnishes the most foliage and fully as much grain as any other type of proso.

3. *Millet*. Mr. J. E. Payne in Bulletin No. 77 of this station reports this as a widely grown crop with a yield varying from one quarter to one half a ton, according to season and locality. The German millet has proven one of the more desirable types to grow on account of its yield of grain.

4. *Alfalfa*. This crop is being tested in many parts of our semi-arid land. Results differ with methods of seeding, soil and the seasons. Experiments already conducted are not convincing. This is our most important perennial forage crop and the writer would ask that the following suggestions, given in Bulletin No. 90, by Mr. J. E. Payne, be noted by all who contemplate seeding alfalfa on non-irrigated land: "The important factor in getting a stand of alfalfa is getting a good seed bed for it. My experience has taught me to plow the ground early in the season five to eight inches deep, harrow until it is thoroughly packed and then wait until the ground is thoroughly wet before planting the seed. If this occurs before the middle of July go on the ground with a light drag harrow as soon after the rain as the surface appears to be dry and break the crust thoroughly." Then sow the seed with a press drill and follow with the harrow. A good stand has been obtained every time I have followed this rule. "Some have been successful with the hoe drill and some have used the press drill. One man seeded his alfalfa with a lister, taking off the shares and running the seed in behind the subsoiler part of the machine. The time to sow alfalfa may be any time when the ground is in good condition, between the 1st of May and the 1st of July. Having a stand of alfalfa, the next question is how shall it be maintained against its enemies, the drought and the grasshoppers? It has been demonstrated in west-





COLO. EXP. STATION.

FIG. 1. One Hill Corn.  
A. (In each Fig.) On well prepared soil.  
In each case the plants are from the same seed and same field.

FIG. 2. One Wheat Plant.  
B. (In each Fig.) On poorly prepared soil.

FIG. 3. Ten Wheat Plants.  
B. (In each Fig.) On poorly prepared soil.



ern Kansas that thoroughly discing the old alfalfa field usually increases the yield of hay, while it also prevents the deposit of grasshopper eggs in the field."

Mr. H. T. Miller on a ranch near Fort Collins, has some ten acres of alfalfa above the ditch that has been seeded down twenty-eight years. He cuts two crops, and favorable years, like 1904 and 1905, he cuts three crops each year. This is located on the lower level and some years receives considerable moisture, which runs off from the higher ground surrounding the field.

Many of these "favorable locations," can be successfully found in many parts of eastern and western Colorado, where irrigation can not be practiced.

5. *Brome Grass*. There are several varieties of this grass but the one that has been the most widely tested in Colorado is *Bromus inermis*. This was first tested on the experimental grounds of the California station, being imported by Prof. Hilgard from Europe and offered for distribution to California farmers in 1884. This grass has proven to be one of our best drouth resistant grasses in Colorado. It requires a good seed bed and a reasonable amount of moisture for germination and early growth. It is one of the first grasses to appear in the spring and the last grass to die down in the fall.

6. *Meadow Fescue*. This is a grass resembling our blue grass in habit of growth, but carries a heavier sward. It is English blue grass and where seed can be obtained from non-irrigated land has made a reasonably good growth in western Kansas and Nebraska. It is of slow growth the first season, has a metallic green lustre and is better adapted for a pasture than a meadow grass.

7. *Field Peas*. This crop under ditch and sub-irrigation has made an excellent growth in many parts of our state. But few tests have been made on non-irrigated lands. These indicate that field peas can not be counted as a sure crop every season, but very often seeding early in the spring, peas will mature sufficiently for a good hay crop. Peas for hay can be cut with a mower, and well cured hay makes good feed for cattle and sheep. It is not advisable to feed this hay to horses.

### III. ROOT CROPS.

Potatoes, sugar beets and rutabagas have been grown on non-irrigated lands in a few sections of the state. Root crops need considerable moisture and it will require experiments for several seasons to determine to what extent these crops can be grown on semi-arid lands in the various sections of our state.

## IV. NATIVE PASTURES AND MEADOWS.

Colorado has some most nutritious native grasses. While the grass is short and sparse in many parts of our ranges, when not overstocked, it keeps the stock in excellent condition.

The hay made from native grass commands a premium in the market. Much of our very best quality hay grows above the irrigation ditches. One of our most hardy and best native hay grasses is the Western Wheat Grass (*Agropyrum occidentale*), known locally as Colorado Blue Stem. This is a leafy grass, forms an even sod, and experiments show it can be sown the same as brome grass or meadow fescue, with good success.

A farmer near Fort Collins sowed three acres of Blue Stem with a nurse crop this spring, and has a good stand of grass on cultivated ground. He sold the Blue Stem hay from a native grass meadow for five to six dollars a ton more than he could have obtained for his alfalfa hay. His native hay is always of good quality and sells from \$12 to \$16 per ton in the market.

Native meadows may be made profitable when good native hay grasses are carefully chosen. The underground stems of many of these grasses give them good drouth resisting power and causes them to thicken rapidly, making finer and therefore superior quality hay, yielding from one and one half to two and one half tons per acre. Many arroyas or lower level areas furnish favorable locations for Blue Stem meadows.

The writer will be glad to assist anyone who wishes to start a Blue Stem or Grama Grass meadow.

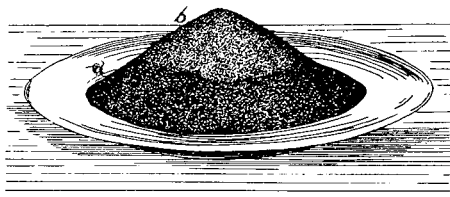
## IV. PRINCIPLE OF CAPILLARITY.

Water in the soil used in the plant economy is known as capillary water. The water found in the bottom of postholes dug in the wet ground or standing on the surface of the ground is called ground water or free water. This free water flows under the force of gravity, as does the water in our irrigation ditches. When the ground becomes thoroughly saturated all the spaces between the grains of soil become filled with water. This cuts off all air from plants and they drown or suffocate.

Ground or free water is not in that particular form available to the plant. When it sinks into the soil and later comes up in small quantities in the capillary tubes of the soil, it is the essential capillary water which aids in dissolving plant food in the soil so the root hairs can utilize said food. Plants get all the water they use *through their roots*. When the texture of the soil is just right and the amount of moisture ample, the soil grains and granules will be surrounded by this water as a thin sheet or film. This is continuous

where the grains or granules are in contact or nearly so and seeks to extend in all directions. If a dish be filled with soil composed of grains and this soil be rounded up into a cone, one can get some conception of this capillary action of the water in the soils of our fields.

Pour water slowly into the dish and it will be observed that soon this water is drawn quite a distance upward from the base of the cone, as shown in diagram. Place two rectangular pieces of window glass in a basin of water so that two edges of the glass plates touch. It will be observed that where the edges are in contact with each other is where the water rises higher than anywhere else on the plates.



COLO. AG. EXPT. STA.

FIGURE 4.  
(From First Book of Farming.)

- a. Saturated soil-water drawn up by capillary action from bottom of basin.
- b. Dry soil.

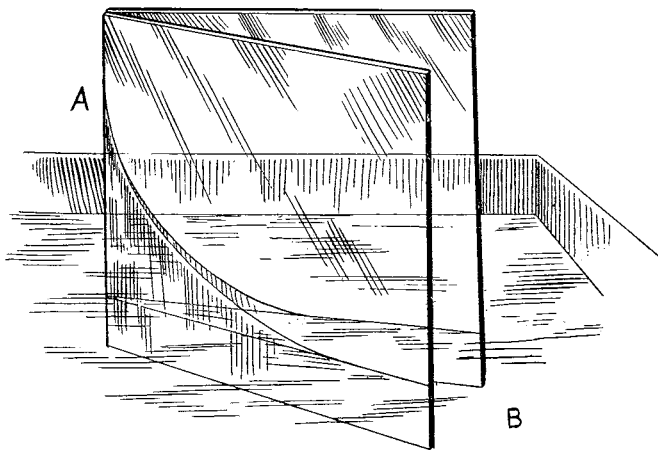


FIGURE 5.

- a-b. Water line between glass plates.

This action is also clearly shown by the diagram used by many text books in physics. Place several glass tubes varying in size from a quarter of an inch in diameter to as small a tube as you can obtain, with one end of each tube in a basin of water. It will

be noticed that the water on the sides of the tubes is above the height of the water in the basin and the smaller the tube the higher will be the water on the sides of the tube.

"The force which causes the water to rise in these tubes is called capillary force, from an old Latin word *capillum*, (a hair) because it is most marked in hairlike tubes, the smaller the tube the higher the water will rise. The water which rises in the tube is called 'capillary water.'" (Goodrich's First Book of Farming).

This book of Mr. C. L. Goodrich (formerly instructor in Agriculture in Agricultural Institute, Hampton, Va.,) shows that, for their best development and growth, roots of plants must have a firm, mellow soil, a ventilated soil, a warm soil, a soil supplied with plant food and a moist soil. The following interesting diagram teaches the relative amounts of film moisture held by coarse and fine soils. Here are two tumblers, one with a half pound of coarse soil, the other with a half pound of fine, sandy loam. In a small phial is shown the amount of water necessary to cover each half pound with a film of moisture. It requires more than five times as much water for the sand as it does for the coarse soil.

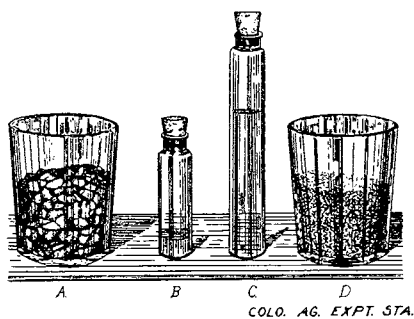


FIGURE 6.

- A. Coarse soil.
- B. Phial containing amount of water necessary to cover the coarse soil with a thin film of moisture.
- C. Phial containing the amount of water necessary to cover the fine sandy loam with a thin film of moisture.
- D. Fine sandy loam.

This shows that fining the soil increases the capillarity of the soil, its power to hold capillary water.

It has been estimated by careful agriculturists that the film surface of a cubic foot of clay loam spread out would cover three fourths of an acre. When these capillary tubes of the soil extend to the surface the hot sun of our semi-arid lands pumps the water from them which is seemingly wasted in the dry air of these regions. The earth mulch is the dry blanket which breaks capillary connection between the under surface soil tubes and the hot outer surface.

face, checking this seriously rapid evaporation. Of course the finer the mulch the more perfect its action. Were it not for the winds on our plains, we could make a *dust* mulch and thus get the most perfect earth mulch for checking evaporation of moisture from the soil. The danger from wind blowing soil and seed from the field is too great and farmers are cautioned not to make the earth mulch too fine. Leave the soil as loose as possible on top, so as to prevent this capillary action reaching to the surface, but *do not* make it of *dust-like fineness*.

The blanket-like action of this earth mulch and the difficulty the water has in getting through it, is well illustrated by loaf sugar and granulated sugar. Place one of these hard squares of loaf sugar in a teaspoon and lower it so it is partly submerged in a cup of coffee. How soon it is saturated. Place the same amount of granulated sugar in the teaspoon and lower as before in the coffee and observe how much longer it takes to saturate the finely ground sugar than it did the loaf sugar. The finer flour sugar used by confectioners takes still longer for water to saturate it. A thoroughly fine, dry, dust blanket requires more moisture to wet through it, to the soil you want to reach with moisture, since the dust is so much finer and has therefore a greater film surface than the under soil. On the other hand, when moisture seeks to come up, it has the same difficulty to get to the surface of the dust blanket and be lost in the hot, dry air above, which it experiences in getting down.

For this reason our earth mulch should be kept as fine as the action of prevailing winds will permit.

Remember, capillary force will carry *down* as well as *up*, and we can deepen the root growing power of our farm crops by deep plowing and summer culture, which stores and conserves soil moisture.

## 7. EXPERIMENTS AND EXPERIENCE IN SEMI-ARID FARMING IN OTHER STATES.

The following questions were sent to the experiment stations in each of the western states in the semi-arid regions, where crops are being grown without irrigation.

### QUESTIONS.

1. To what extent is semi-arid farming, without irrigation, practiced in your State.
2. With what success?
3. Do your best farmers under this system of farming try to obtain a crop each year from a given field, or only every other year?
4. Will you tell me what preparation you think makes the most satisfactory seed bed for semi-arid farming conditions?
5. What is your average rainfall in localities where semi-arid farming is practiced?

6. How do your farmers conserve this moisture?
7. What tools are used in doing this work?
8. What crops have proven most successful for you?
9. What yields are obtained?
10. What literature can you cite me to for information on thorough tillage system of farming under semi-arid conditions?

The answers received from these questions show that semi-arid farming, where irrigation cannot be practiced, is now being carried on with some degree of success in eastern Washington and certain portions of Oregon, Idaho, Montana, Wyoming, California, Nevada, Utah, Colorado and New Mexico.

The reply letter from Prof. E. E. Elliott, Agriculturist at the Washington Experiment Station, located at Pullman, Washington, gives us the farm system which eastern Washington farmers have followed for several seasons quite successfully.

Pullman, Washington, June 14, 1905.

Dear Sir:

Replying to the questions in your letter of June 8th, I will make the following answers: (1.) One-third of the State of Washington is available for dry farming and a very large part of it is now under cultivation. In using the word "dry farming," I refer to agricultural operations outside of irrigation. (2.) This part of Washington is by far the most fertile and produces the largest crops in the State except those under irrigation. It is largely devoted to the culture of the different grains and embraces the famous wheat region of eastern Washington. (3.) It is the general practice to summer fallow for fall grain, a crop being produced by this means every other year. Many of our progressive farmers are trying to introduce other crops to take the place of the summer fallow in the alternate years. (4.) Probably the best preparation of the ground under the summer fallow system is to plow it in June and cultivate thoroughly throughout the season. By this means the moisture is conserved and the seeding can begin much earlier in the fall. (5.) The average rain fall throughout the semi-arid regions of this State where farming is practiced, runs from 12 to 23 inches. You will understand, however, that through part of this region the conditions for conserving this moisture are very favorable, owing to the nature of the soil. Successful crops of grain are being produced where the rain fall is as low as ten inches. Since much of our wheat is grown from fall sown crop and the greater amount of the moisture is precipitated during the winter and spring months, there is little difficulty in conserving a sufficient amount of the moisture to produce a crop, and it is rare that a failure occurs from the lack of moisture. (7.) The tools employed for cultivating the plowed ground are the common harrow used everywhere, although specially designed tools intended to destroy wild oats are coming into general use. (8.) This question is answered by question one. (9.) The yields of wheat range from 20 to 50 bushels. Oats, from 15 to 30, and barley slightly less, while rye is grown almost entirely for hay and that in the extremely dry sections. (10.) I regret that we have no literature that would be of much service to you on this subject.

Thanking you for this inquiry, I am,

Very truly yours,

E. E. ELLIOTT.

Mr. F. M. Gum and Mr. W. L. Putnam, special students in Agronomy for spring term of 1905, assisted me in preparing the questions and carrying on the correspondence. The replies which they received are hereby acknowledged:

Prof. J. H. Sheperd, Dean of Agriculture, North Dakota.



Prof. F. B. Linfield, Director State Experiment Station, Montana.  
 Prof. B. C. Buffum, Professor of Agriculture, State University, Wyo.  
 Prof. Luther Foster, Director Experiment Station, New Mexico.  
 Prof. Lewis A. Merrill, Agronomist, Utah Experiment Station.  
 Prof. T. L. Lyon, Agriculturist, Nebraska Experiment Station.  
 Prof. A. M. Ten Eyck, Agriculturist, Kansas Experiment Station.  
 Prof. Jas. Withycombe, Oregon Experiment Station.  
 Prof. G. A. Crosthwait, Idaho Experiment Station.  
 Prof. M. A. Carleton, United States Cerealist, Department of Agriculture, Washington, D. C.

These answers show that summer culture is being practiced with considerable success. This plan contemplates making the soil a reservoir to hold sufficient moisture to grow a crop every other year. The rain fall in those portions of the western states where this system of farming is practiced varies from 10 to 25 inches. Successful crops are being produced in both Utah and eastern Washington with the average rainfall near the minimum. It must be remembered that soil as well as climatic conditions quite largely determine the success of any system of farming.

Director Linfield of the Montana Experiment Station says:

"In certain sections of this State farming without irrigation is practiced quite extensively. This is particularly the case in Gallatin Valley, where from 75,000 to 100,000 acres are farmed in this way. Probably a larger area than this is farmed near Great Falls and in the Flathead country around Kallspell. There is also quite a large area cropped without irrigation in other sections and very successfully indeed. We are at present trying to encourage the extension of this method of farming in other parts of the State. Conditions look very favorable in the Bitter Root Valley, in the Judith Basin, and in the higher districts back from the Yellowstone river, both north and south. In the drier portions of the State the practice is to crop the land every second year only. In the Gallatin Valley this is particularly the case, fall wheat and fall rye being the crops. Around Great Falls and Flathead spring crops are grown and the cropping is usually every year. It will depend of course to a certain extent upon the rainfall and climatic conditions which vary considerably in the different valleys of the State.

"We have not experimented long enough to determine just exactly what preparation of the ground makes the best seed bed for dry land farming conditions. I am inclined to think that with many of our farmers their practice is not the best. Where crops are grown every year, the land must be plowed in the fall and plowed deep, then cultivated in the spring just as early as possible or as soon as the land gets dry enough to work. This working is continued until the weather is warm enough to sow the crop. The time of sowing varies from the latter part of March to the first of May, depending, of course, on the climatic conditions in the lower and higher valleys. For fall crops, the land is usually plowed in the spring and then worked down immediately with the disc and drag harrow, and cultivated frequently during the summer to conserve the moisture and then fall wheat is sown usually about the first week in September. Some sow the latter part of August. Some do not sow until the early part of October, but the earlier sowing gives the best results as a rule. The average rainfall in our best dry farm districts is about 16 to 18 inches, varying of course with the different years. In this State no special tools have been introduced for the work of cultivating. The disc and spring tooth harrow and the drag harrow are the only tools used in the cultivation of the ground.

"In the Gallatin Valley, fall wheat and fall rye are the principal crops grown on the land. Around Great Falls spring crops are more generally grown, wheat, early oats, bald barley, and spring rye. Timothy hay and

brome grass are also grown to a considerable extent, particularly the former, and alfalfa is being tried with considerable success. It seems to do well once it is well started in the ground. In the Flathead country also, spring crops are grown, but here the clover seems to do a little better than the alfalfa, although it is not a permanent crop. In the Gallatin Valley the fall wheat will usually yield from 20 to 25 bushels per acre on the average and I believe around Great Falls somewhat similar crops are obtained as the conditions are a little more favorable."

Prof. A. M. Ten Eyck of Kansas, in speaking of the tools used for preparing the seed bed in western Kansas, says:

"Disk plows are being commonly used now in western Kansas. They appear to be better adapted for plowing dry, hard land, than the moldboard plows. Other tools used are the disk harrow, common harrow and some make use of a sub-surface packer, or corrugated roller."

Prof. James Withcombe of the Oregon Experiment Stations, says:

"Replying to your letter of the 7th, beg to say we have no specific date as to wheat growing under semi-arid conditions without irrigation, in this State. There are, however, several million bushels of wheat grown annually under practically arid conditions and without irrigation.

"Precipitation in several of our wheat growing counties will range from 8 to 14 inches annually and the wheat crop in these sections will range from 15 to 35 or even 40 bushels per acre, some seasons.

"The prevailing system is to summer fallow every alternating year; in this way some of the moisture of the preceding year is conserved for the wheat crop. There is no especial system of culture developed and ordinary agricultural implements are used, such as gang plows of the ordinary moldboard pattern, and the disk plow is used. The better class of farmers endeavor to work their ground down well immediately after plowing; in this way the furrow slice is thoroughly pulverized and made compact, and in this condition it conserves the maximum amount of capillary moisture.

"The soil in these sections is in excellent physical condition, being largely volcanic ash with considerable organic matter. However, the present system of farming is very injurious and in time will doubtless develop very unsatisfactory conditions for wheat production. While from 8 to 12 inches of precipitation may be sufficient to produce a good crop of wheat now, later when the organic matter becomes reduced, a great deal more moisture will be required as the soil will be less capable of retaining moisture.

"Trusting this supplies the desired information and if we can be of further assistance at any time, you will kindly advise us."

## VI. AMOUNT OF MOISTURE REQUIRED BY FARM CROPS.

The amount of moisture required by the various farm crops varies with the character of the crop and the climatic conditions under which they are grown. The experiments already carried on in the agricultural stations of Europe, and the Eastern and Central States, east of the Mississippi river in the United States, show that the leading grain and root crops require from 271 to 576 pounds of water to produce one pound of dry matter under normal conditions, in a normal season.

Hellriegel of Germany and Prof. F. H. King of Wisconsin, give the amount of water to produce one pound of leading crops as follows:

Wheat .....	453	lbs. water.
Barley .....	464.1	" "
Oats .....	503.9	" "
Corn .....	270.9	" "
Clover .....	576.6	" "
Field Peas .....	477.2	" "
Potatoes .....	385.1	" "

The Utah Experiment Station has found that under semi-arid conditions the evaporation is such that wheat requires 750 pounds to mature one pound of dry matter.

Counting the weight of straw necessary to grow 1 bushel of wheat (60 lbs.) as 90 lbs. (1 1-2 times the weight of grain), we find that it requires 56 1-4 tons of water to produce one bushel of wheat in our climate. The moisture required to mature a crop of wheat is believed to indicate the maximum amount required by most any farm crop in the semi-arid lands of Colorado.

VII. ANNUAL RAINFALL FOR COLORADO.

The U. S. Weather Bureau has divided the state into weather districts for convenience in making and recording reports. The average annual and crop season rainfall in these several districts is indicated on the chart given below. These averages are made from the government reports and cover the period observations have been made. The minimum is six and the maximum thirty-seven years. Through the courtesy of Mr. F. H. Brandenburg, District Forecaster for the Rocky Mountain District, we are enabled to give this valuable data on the rainfall by districts.

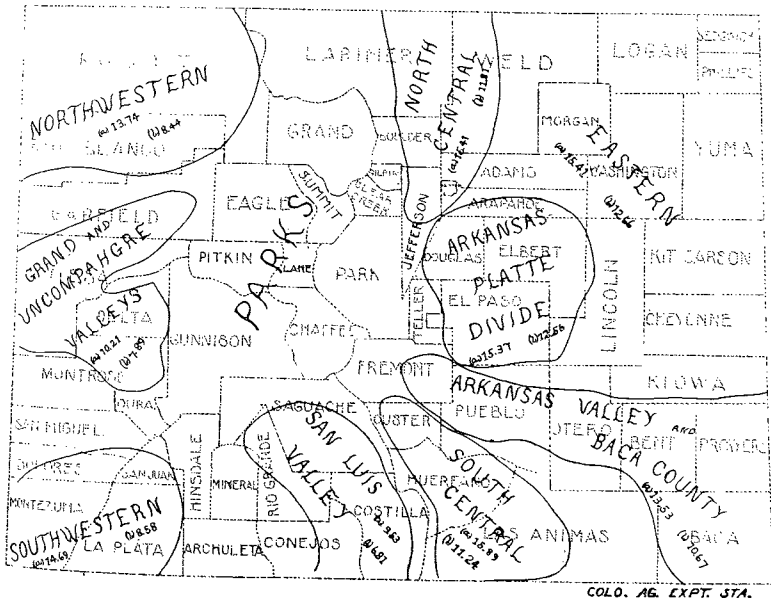


FIGURE 7.

COLO. AG. EXPT. STA.

- a. Average annual moisture precipitation.
- b. Average precipitation February to August.

Weather districts are marked by **full lines** and county limits by **dotted lines** on the chart.

Station normals, with the number of years weather records have been taken, are as follows:

## I—NORTH CENTRAL DISTRICT.

	No. Years.	Average Annual Precipitation Normal
1. Alford .....	10	17.75 inches.
2. Boulder .....	9	17.20 "
3. Boxelder .....	13	17.14 "
4. Denver .....	33	14.49 "
5. Fort Collins .....	25	14.47 "
6. Greeley .....	14	11.76 "
7. Laporte .....	14	14.97 "
8. Waterdale .....	10	15.47 "
District Normal .....	16	15.41 "
Crop Season, Normal for Dis- trict, February to August.		11.81 "

## II—EASTERN DISTRICT.

1. Cheyenne Wells .....	11	15.64 inches.
2. Fort Morgan .....	9	11.53 "
3. Fox .....	13	16.65 "
4. Grover .....	8	11.29 "
5. Holyoke .....	9	15.96 "
6. Le Roy .....	16	15.30 "
7. Wallet .....	10	18.11 "
8. Wray .....	12	17.30 "
9. Yuma .....	14	17.05 "
10. Seibert .....	10	15.21 "
District Normal .....	11	15.41 "
Crop Season, Normal for Dis- trict, February to August.		12.66 "

## III—ARKANSAS-PLATTE DIVIDE.

1. Castle Rock .....	13	17.74 inches.
2. Colorado Springs .....	25	14.32 "
3. Glen Eyrie .....	13	15.35 "
4. Haups (Hugo P. O.).....	12	13.76 "
5. Husted .....	17	15.98 "
District Normal .....	16	15.37 "
Crop Season Normal for Dis- trict, Feb. to August .....		12.56 "

## IV—ARKANSAS VALLEY AND BACA CO.

1. Canon City .....	15	12.33 inches.
2. Holly .....	9	15.16 "
3. Lamar .....	14	15.57 "
4. Las Animas .....	37	11.33 "
5. Pueblo .....	17	12.11 "
6. Rocky Ford .....	15	12.86 "
7. Blaine .....	14	15.89 "
8. Vilas .....	14	14.01 "
District Normal .....	17	13.53 "
Crop Season Normal for Dis- trict, Feb. to Aug.....		10.67 "

## V—SOUTH CENTRAL DISTRICT.

	No. Years.	Average Annual Precipitation Normal.
1. Hoehne .....	14	13.15 inches.
2. Trinidad .....	10	17.10 "
3. Westcliffe .....	11	17.41 "
District Normal .....	12	15.89 "
Crop Season Normal for Dis- trict, Feb. to Aug.....		11.24 "

## VI—SAN LUIS VALLEY.

1. Garnett .....	12	6.38 inches
2. Saguache .....	14	7.22 "
3. San Luis .....	14	11.78 "
4. Fort Garland .....	25	12.74 "
District Normal .....	16	9.53 "
Crop Season Normal for Dis- trict, Feb. to Aug.....		6.81 "

## VII—SOUTHWESTERN DISTRICT.

1. Durango .....	12	16.04 inches.
2. Mancos .....	6	13.72 "
3. Hermosa .....	7	14.30 "
District Normal .....	8	14.69 "
Crop Season Normal for Dis- trict, Feb. to Aug.....		8.58 "

## VIII—GRAND AND UNCOMPAHGRE VALLEYS.

1. Cedaredge .....	12	10.93 inches.
2. Collbran .....	12	13.65 "
3. Delta .....	14	8.04 "
4. Fruita .....	6	8.77 "
5. Grand Junction .....	17	8.50 "
6. Grand Valley .....	13	11.20 "
7. Montrose .....	10	9.11 "
8. Paonia .....	10	9.62 "
9. Silt .....	10	12.04 "
District Normal .....	12	10.21 "
Crop Season Normal for Dis- trict, Feb. to Aug.....		7.89 "

## IX—NORTHWESTERN DISTRICT.

1. Lay .....	12	12.13 inches.
2. Meeker .....	13	15.66 "
3. Pagoda .....	14	18.76 "
4. Rangeley .....	8	8.39 "
District Normal .....	12	13.74 "
Crop Season Normal for Dis- trict, Feb. to Aug.....		8.44 "

RAINFALL BY MONTHS AT THE AGRICULTURAL COLLEGE, FORT COLLINS, COLORADO.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1872	0.25	0.16	0.00	1.20	2.30	1.50	1.30	0.85	0.75	0.42	0.02	0.20	0.20
1873	0.06	0.43	1.29	0.71	0.95	0.65	3.15	0.25	0.00	1.00	0.02	0.00	9.10
1879													10.40
1880	0.72	1.09	0.38	0.94	0.60	0.86	1.80	0.37	1.47	2.07	0.15	0.60	
1881	1.10	0.55	1.45									0.10	
1882													
1883	1.00	1.50	0.68		4.67	3.07	1.76	0.89	2.51	0.82	0.29		
1884	1.10	0.70	1.15		2.51	3.18		1.78	1.00	1.29	T	1.83	
1885	1.77			3.94	4.84					0.10	1.80	0.35	
1889													
1887	0.86	0.23	0.25	1.10	1.23	1.96	3.05	2.12	0.54	0.69	1.18	0.33	
1888	0.29	0.36	0.73	1.23	3.39	0.47	0.60	1.01	0.29	0.43	0.15	0.10	12.12
1889	0.21	0.34	0.65	2.07	3.39	2.06	0.79	0.95	0.42	0.88	0.38	0.16	9.79
1890	0.13	0.21	0.22	3.92	1.19	0.12	1.27	3.14	0.07	3.16	0.43	0.01	14.48
1891	2.32	0.16	1.21	2.14	4.07	1.30	0.17	2.05	1.01	0.70	0.82	0.42	13.58
1892	0.60	1.29	1.52	1.60	4.83	2.42	1.32	0.22	0.14	0.20	0.60	0.46	15.69
1893	0.02	0.54	0.11	1.66	1.92	0.26	0.84	0.82	0.18	0.83	0.23	0.01	15.45
1894	0.25	0.60	0.67	0.86	3.09	0.42	1.72	1.53	2.29	0.16	0.55	0.12	7.11
1895	0.24	1.52	0.64	1.36	3.62	3.65	3.75	1.45	0.47	T	0.14	0.76	12.36
1896	0.43	0.03	1.73	1.26	1.68	3.05	3.05	2.20	1.55	1.06	0.40	0.01	18.07
1897	0.18	0.54	2.15	1.39	2.06	1.69	2.65	1.74	0.75	0.49	0.05	0.24	15.76
1898	0.14	0.08	0.50	1.08	3.65	1.37	0.60	0.98	0.50	0.75	0.67	0.67	15.24
1899	0.66	1.04	1.50	1.10	1.01	1.03	4.95	0.99	0.21	0.82	1.24	0.17	11.03
1900	0.25	1.12	1.07	10.66	1.75	0.82	1.14	0.16	0.21	3.23	T	0.47	16.19
1901	0.19	0.38	1.88	3.82	7.17	2.35	0.71	0.22	1.92	0.24	0.07	0.11	19.21
1902	0.82	0.15	1.50	2.13	2.43	2.43	1.31	0.67	2.10	0.86	0.02	1.37	21.17
1903	0.16	1.60	1.03	1.50	2.53	2.23	1.06	0.28	7.12	1.15	0.27	0.77	18.43
1904	0.04	0.34	0.51	0.89	5.87	1.68	1.99	0.71	0.87	1.70	0.18	0.07	11.31
1905	0.29	0.35	1.75	6.32	4.13	0.64	2.18	1.25	1.09	0.39	0.	0.12	13.13
Average.....	0.52	0.61	0.95	2.22	2.98	1.64	1.78	1.13	1.18	0.65	0.36	0.35	14.75

It is to be observed that the weather station records have not been taken for the same length of time in the different districts nor for the same number of years at the various stations within the districts.

The above record is just as the U. S. Weather Office has received it and indicates the number of years the different stations have reported observations. It may possibly be interesting, in this connection, to look over the rainfall by months and years, as recorded by Mr. R. E. Trimble, in charge of the meteorological observations at the Fort Collins Station, in the North Central District of the state:

It will be seen by this table that the years 1873, 1888 and 1893 had less than 10 inches and the year 1901 more than 20 inches of rainfall. The last ten years show an average of 15.95 inches, while the preceding years, for which there is full record, give an average of but 12.12 inches rainfall. This would seem to suggest that our rainfall has great variations. It was the exceptionally dry years of 1873, 1888 and 1893 which gave the farmers on our eastern plains little or no harvest.

It is these "dry" years which test all systems of crop farming and soil culture. The past few years have been quite favorable for any system of careful farming, but we need to profit by the experiences of the past and not rely too much upon the average rainfall or even the rainfall for some several years back. It is those years with a minimum rainfall which test our systems of crop farming. We have not met these years very successfully in the past and the careful plains' farmer will be conservative in his farming ventures, until he has successfully tided over one or more of the "dry" years, when the rainfall drops below 10 inches per annum.

## Conclusions.

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1. Do not assume that all unoccupied land is good farming land under any system of soil-culture or crop farming.

2. Character of soil, amount of rainfall, method of farming and market conditions, on land where irrigation can not be practiced, must largely determine the success or failure in all farming ventures in Colorado.

3. Methods of farming which (a) conserve the soil moisture, (b) prepare a good seed bed, (c) reduce the evaporation to as near the minimum as possible, (d) use good vital, acclimated seed, (e) employ a crop rotation which has stock foods prominent, contain at least one money crop, (f) and the practice of thorough tillage of the ground, often tide the farmer over bad years and insure his success in good years.

4. With all these conditions met, crop failures or low prices will prove disastrous some years, unless stock raising is combined with crop farming.

5. Most of the crop should be "driven to market," in the stock sold from the farm.

6. Natural conditions must be considered in determining whether lands can be made more profitable for farming than for grazing purposes.

7. The first principles of semi-arid farming was enunciated by the English farmer, Jethro Tull, nearly three centuries ago, who said "Tillage is manure."

8. Present day experiences and experiments demonstrate that fineing the soil has a tendency to render more plant food available.

9. All so-called soil culture systems, are groupings of few or many of the principles of the thorough tillage system, which is the correlated experience of our best farmers of past and present time.

10. The Thorough Tillage System of farming considers:

- (a). Time and manner of plowing the ground.
- (b). Time and manner of harrowing.
- (c). Firming the soil and formation of an earth mulch to arrest evaporation in semi-arid regions.
- (d). Summer culture to fine the soil, conserve moisture and prepare a good seed bed for any crop under drouth conditions.
- (e). Principle of capillarity and how moisture may be conserved.
- (f). Selection of seed and rate of seeding.
- (g). Crops which have shown drouth resistant power.
- (h). Amount of moisture required by plants.
- (i). Average crop season rainfall for a period of years in locality where farming is to be practiced.
- (j). Crop rotations most profitable for the farmer and the land.

11. Small grain, forage crops and potatoes have been successfully grown on the Colorado Divide and in certain sections of eastern Colorado, without irrigation. Thorough tillage will undoubtedly increase the areas where these crops can be successfully grown in our semi-arid lands.

12. Our best native grass—Western Wheat Grass, (Colorado Blue Stem)—Prof. R. A. Oakley of the Agrostology Division of the Department of Agriculture, Washington, D. C., finds will do best on irrigated ground with one early irrigation. More water is a detriment. This would indicate we may yet be able to induce this grass to make a profitable hay crop on cultivated lands where we have ten or more inches of rainfall per annum.



13. Roots of all cultivated plants make their best growth when the following conditions are supplied:

A firm, mellow,  
A warm, mellow,  
A ventilated,  
A moist } soil well supplied with plant food.

14. The earth mulch prevents excessive evaporation and thus conserves moisture.

15. Deep plowing furnishes a soil reservoir of good depth to store moisture and summer culture conserves it.

16. Crops require more moisture to mature them under semi-arid than under humid conditions.

17. Our field crops rank from the lowest to highest in amount of moisture required to mature them as follows: Corn, potatoes, wheat, barley, field peas, oats, alfalfa and red clover.

18. Ten inches of rain furnishes enough moisture to mature more than twice that number of bushels of wheat per acre.

19. The amount of rainfall, together with the selection of drouth resistant crops, must be considered under any system of soil culture—under semi-arid conditions.

20. The total area of land which can be successfully farmed within Colorado's semi-arid belt is yet to be determined.

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