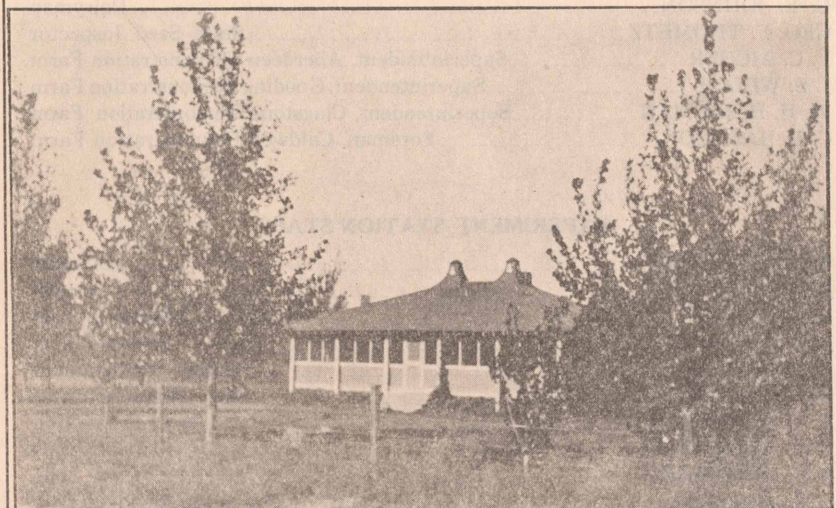
IDAHO AGRICULTURAL EXPERIMENT STATION
MOSCOW, IDAHO

DEPARTMENT OF AGRICULTURAL EXTENSION

IRRIGATION PRACTICE

A REPORT OF FOUR YEARS INVESTIGATION AT THE GOODING SUB-STATION



STATION HOUSE AND YARD

BY

J. S. WELCH, Superintendent.

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EXTENSION DIVISION

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The regular bulletins of this station are sent free to persons residing in Idaho who request them.

FOREWORD

The purpose of the Gooding Station is to help the irrigation farmer solve as many of his soil, crop and water problems in farm management, as possible. The experimental work is planned and agreed upon each season, before work at the Station begins, by the resident engineer of the Office of Experiment Stations of the U. S. Department of Agriculture in charge of the work in Idaho, the Director of Agricultural Extension work for this State, and the Station Superintendent. This bulletin gives in concrete form, the character of work done along the line of irrigation practice with such conclusions as the various experiments, in determining the duty of water on that particular kind of soil, would seem to justify. The soil moisture tests and irrigation experiments have been under the direct supervision of Supt. J. S. Welch and he has personally taken the agronomic or field notes on all crops herein discussed. This bulletin collaborates the findings of the moisture tests, irrigation experiments and the crop field notes.

It is written in a clear manner, well understood terms have been used in explanations throughout and it has been prepared primarily to be of value and of service to farmers engaged in diversified farming on irrigated lands in Idaho.

It is a progress bulletin on such work of the Gooding Sub-Station as pertains to irrigation practice. Forage and pasture work, grain, root and other crop investigations at this sub-station will be summarized in later bulletins.

W. H. Olin,
Director Agricultural Extension.

INTRODUCTION.

The Gooding Sub-Station is located on the Idaho Southern Railway, two miles south of the city of Gooding, Gooding County, Idaho.

The Station was established in May, 1909, at which time Ex-- Gov. F. R. Gooding granted a ten year lease on forty acres of land and $4000.00 for improvements. The Idaho Experiment Station and the office of Experiment Stations, U. S. Department of Agriculture conduct the experimental work and bear the expense.

The Station work was begun under the direction of Mr. Don H. Bark, Engineer in charge of Irrigation Investigations for the State of Idaho, office of Experiment Stations, U. S. Department of Agriculture and Prof. F. D. Farrell, Director of Agricultural Extension Department, University of Idaho. In July, 1911 Prof. Farrell resigned and was succeeded by Prof. W. H. Olin, who has continued joint direction with Mr. Bark.

The experimental work was under the immediate supervision of Mr. John Krall, Jr. from the establishment in May, 1909, until March, 1911, at which time the writer was placed in charge.

The farm consists of forty acres, all of which, with the exception of three acres of old alfalfa meadow, was cleared of sagebrush in the summer of 1909. The soil is a medium clay loam, underlaid at an average depth of ten to twelve feet by the basaltic lava rock common to Southern Idaho. It is fairly uniform except for occasional "adobe" spots and these are being overcome by cultivation and by the addition of organic matter. Like most sagebrush soil it is lacking in nitrogen and humus but with this deficiency supplied, by the growing of leguminous crops and by the addition of manures, it gives remarkable results in crop production.

The average annual precipitation including rain, hail and melted snow for the years, 1910, 1911, 1912 and 1913 is 9.73 inches. This was distributed throughout the years as follows: from January 1st to April 1st, 2.88 inches; from April 1st to September 1st, 2.75 inches; from September 1st to December 31st 4.09 inches.

The weather is characterized by a prevailing west wind and an unusually large number of clear days. The average evaporation from a free water surface during the period from April 1st to October 1st for the past four seasons 40.13 inches. The altitude of the Station is 3,572 feet.

The work of the Station consists of Irrigation Investigations and general crop tests. The irrigation investigations are three-fold. In the first place, since the farmer on our irrigated lands has very little accurate information regarding the amount of water that should be applied to common crops, the experiments on the duty of water are conducted to furnish such information. The results of these experiments should also prove valuable in the organization of new canal systems and in the adjustment of water rights.

Secondly, it is a matter of common observation that there are certain more or less critical periods in the development of a plant when a greater moisture supply is needed than at other periods. In irrigation farming, it is noted that two fields receiving practically the same total amount of water, but receiving it at different stages of plant growth, often return very different yields. The irrigation farmer can apply the water whenever it is most needed, but it is clearly a serious waste for him to do so when it could be of no benefit and might even be harmful. The experiments in the time of irrigation are for the purpose of supplying accurate data along this line.

Thirdly, the method of applying irrigation water should vary with different crops and soils, and attention has been paid to this phase of irrigation practice so that our work more or less completely covers the field.

In all of these investigations, the water applied to each plat and also the waste water was carefully measured, so that the amounts reported represent the water actually absorbed by the plat.

Very complete agronomic notes were taken on each crop during the entire season, so that any variation, caused by the different treatment, would be noted.

Since the amount of moisture in the soil is a very important factor in determining the amount of irrigation water that must be applied, and in order to, as far as possible, make our results applicable to other types of soils, a study of the moisture content of the various plats was made at the beginning of the irrigation season and at harvest time. During the season of 1910 soil moisture determinations were made to a depth of four feet, and during the succeeding seasons to a depth of six feet.

It should be remembered when studying the soil moisture data in the following tables that the figures given represent the total amount of moisture in the soil. Plants are not able to use this entire amount, however. The proportion of total moisture content that is available for the use of plants varies with the different types of soils. Ordinarily our soil moisture content should be above 13 per cent to furnish a good growing condition. In the Gooding soil, moisture can be used by the crop down to about 10 per cent.

For those who have not used any measuring devices in their irrigation practice it should be stated that on soils similar to ours at Gooding an average irrigation amounts to about three to five tenths of an acre foot per acre.

A question is often raised concerning the accuracy of experimental work because of the very small areas that are often used. It has been our aim to bring our experiments as nearly as possible under ordinary field conditions. The average amount of land used in each season for the alfalfa experiments has been four acres, for spring wheat four acres, for winter wheat, oats, barley and potatoes each two acres.

The general crop tests include experiments on soil management, cultural methods and varieties of all the ordinary forage, grain and root crops.

The purpose of this bulletin is to report the results so far obtained by irrigation investigations, and the results of the experiments on soil management in so far as they have a bearing upon the duty of water.

CLEARING AND LEVELING

The rank growth of sagebrush, which covered most of the farm in the beginning, was grubbed by hand, piled and burned. After clearing, the farm was divided into plats, each being 198 by 220 feet in size.

The land was comparatively level and had a fairly uniform slope, but in order to facilitate a more economic and even distribution of irrigation water, each plat was carefully leveled. The more noticeable high places were scraped off and the depressions filled with a "Fresno" scraper. The land was then plowed, harrowed and was gone over once each way with a rectangular plank float or drag. This implement left the surface smooth so that smaller irregularities in slope were more readily noticed and these were leveled with a "Shuart" land grader. The grader consists of a wood frame attached to three low metal wheels, two steel runners and a curved steel cutting blade five and one-half feet long and thirty-two inches wide. The blade is raised or lowered by means of a hand wheel. When a load has been collected by cutting off a high place the blade is locked down and the machine driven to a depression where the soil is dumped in a heap or scattered in a thin layer at will.

MAKING DITCHES AND INSTALLING WEIRS

The main supply ditch enters the farm at its highest point and the distributing laterals were built to deliver the water from this place to the various plats. Waste ditches were built to collect the run off from each plat into a main waste ditch, which leaves the farm at its lowest corner.

In making these ditches two or three deep furrows were plowed side by side and the loose soil removed by means of a V shaped ditcher or crowder, such as is commonly used throughout the country.

All water used in the irrigation experiments was carefully measured over a 12 inch "Cippoletti" weir. Both the weir and the weir box were properly constructed and carefully placed at a point where the irrigation water enters the farm.

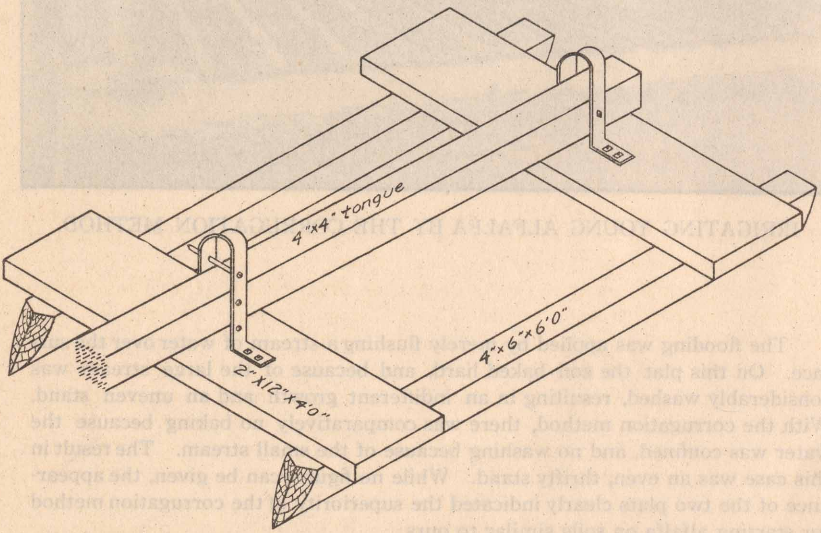
An automatic water register was used to secure a continuous and accurate record of the water flowing over the weir. This register consists of a metal cylinder which is revolved by means of a float and a counter weight as the water rises and falls. On the cylinder is a recording sheet over which a pencil is carried by clock work, the pencil tracing a continuous record of the water level. The recording sheets provide for an eight days record.

Four supplementary 12 inch Cippoletti weirs were placed in the distributing laterals. These allowed a measurement of the water closer to the point of application and also provided for a measurement in case the stream was divided below the head weir. A 12 inch Cippoletti weir, constructed and placed like the head weir, was located at the lowest corner of the farm. This weir was also provided with an automatic water register, which kept a continuous and accurate record of the amount of waste water leaving the farm. A portable Cippoletti weir, made by cutting the weir notch in a piece of galvanized iron wide enough to extend acrcss the ditch and into the bank on each side, and of sufficient height to still the water was properly placed wherever needed to measure waste water from plats which were a considerable distance frcm the main waste weir.

ALFALFA

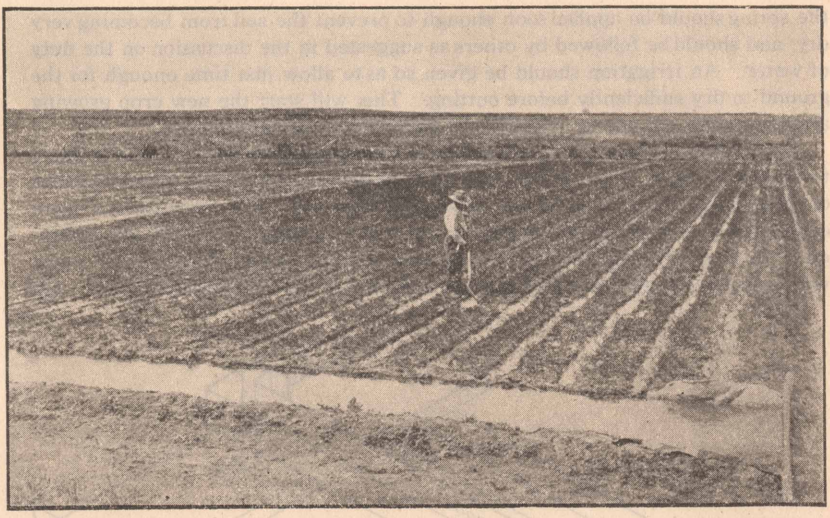
The time at which irrigation water should be applied to alfalfa is governed by soil and weather conditions and the time of cutting. The first irrgation in the spring should be applied soon enough to prevent the soil from becoming very dry, and should be followed by others as suggested in the discussion on the duty of water. An irrigation should be given so as to allow just time enough for the ground to dry sufficiently before cutting. This will start the new crop growing as soon as the old one is cut, thereby gaining several days growth.

It is often necessary to plant alfalfa in a comparatively dry soil, and irrigate to sprout the seed. When this is done, the method of applying the water becomes of great importance. During the seasons of 1910 and 1912, experiments were conducted to determine the relative value of the corrugation and flooding methods. In preparing land for the corrugation method, small furrows are made with a simple home made tool such as is shown in the accompanying cut. On



HOME MADE CORRUGATOR

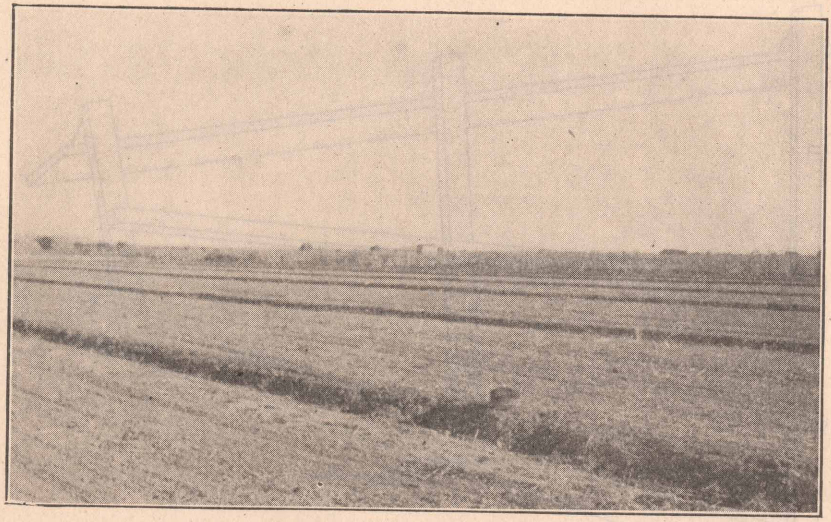
or inary soils they should be twenty-four to thirty inches apart, four or five hundred feet long, and should run with the slope of the land unless the slope is too great, when they should be run across the slope on such an angle as will give the proper grade. It is necessary to make these corrugations immediately after seeding. A feed ditch is built along the upper end of the field and the water backed up in this ditch by means of a canvas dam. Tubes are used to convey a small stream through the ditch bank to each corrugation. The tubes are often made by nailing four laths together; cement tubes are being used to some extent and some are made of tin. In any case, they are embedded firmly into the bank and carry the water through without any danger of washing the bank away. In some cases the water from one tube is divided between two or even three corrugations. The small stream is allowed to run until it has soaked across from one furrow to the other. See accompanying illustration of this method.



IRRIGATING YOUNG ALFALFA BY THE CORRUGATION METHOD.

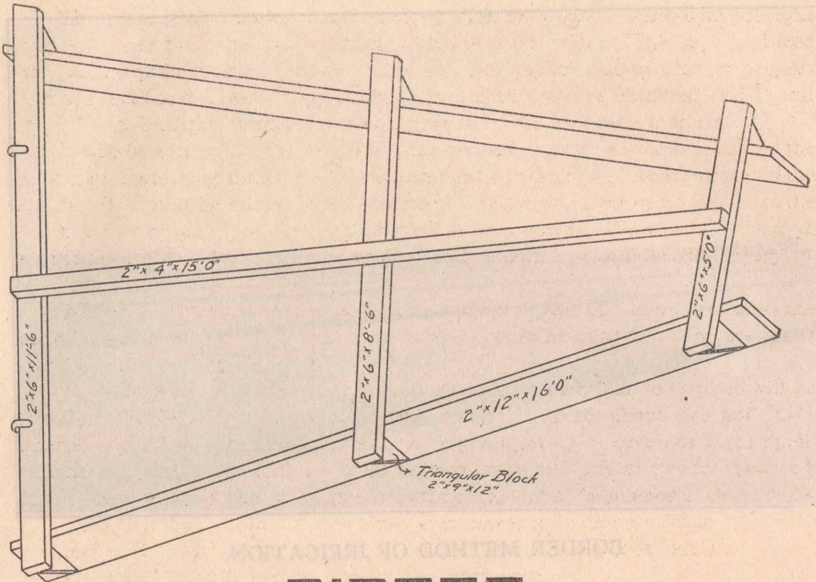
The flooding was applied by merely flushing a stream of water over the surface. On this plat the soil baked hard, and because of the large stream was considerably washed, resulting in an indifferent growth and an uneven stand. With the corrugation method, there was comparatively no baking because the water was confined, and no washing because of the small stream. The result in this case was an even, thrifty stand. While no figures can be given, the appearance of the two plats clearly indicated the superiority of the corrugation method for starting alfalfa on soils similar to ours.

The continuation of these tests has failed to show any advantage of corrugations after the first season. This is due to the fact that the undesirable features of the flooding system have been eliminated. The shade afforded by the crop prevents baking, and the roots tend to hold the soil from washing. It is safe to say that on medium or heavy soils with a good slope, the corrugations will have no value after the alfalfa is well started. On sandy soils or steeper land, however, they may still be valuable to prevent washing and to aid in an even distribution of the water.



BORDER METHOD OF IRRIGATION.

On fields of uniform slope, flooding between borders or dikes is to be preferred to ordinary free flooding. The preparation of land for this system is well shown in the above illustration. The dikes are made by throwing up a plow furrow and following with the "Ridger" shown in the accompanying cut.



RIDGER

A.V.T.

The dikes are usually made from thirty-five to fifty feet apart and should be parallel with the greatest slope, unless the slope is too excessive. The land between should be carefully leveled, taking out the side fall. While the side fall between the dikes should be taken out, the slope parallel to them need not be made absolutely uniform. The dikes can be seeded over and need offer no obstruction to ordinary field operations. A medium sized head of water is allowed to spread between the dikes. The length of run is usually five to six hundred feet, although shorter runs should be used with the more porous soils With this system properly installed, the thorough irrigation of a field becomes an easy matter.

During the season of 1911 the experiment on the duty of water for alfalfa consisted of three plats. With this number, the difference between the amounts of water applied to the various plats was small. In order to make possible a wider variation between the plat receiving maximum and the one receiving minimum irrigation, six plats were used during 1912-1913. In these seasons the variation ran from one irrigation per cutting to all that could be applied. The following table gives the average results from the fifteen plats used in the three years work.

DUTY OF WATER FOR ALFALFA

Plat No.	Soil moisture at beginning of irrigation season Per cent	Precipitation during season in feet	Number of irrigations	Length of irrigation season in days	Total water applied in acre feet	Soil moisture at close of season per cent	Yield of cured hay in tons per acre	Tons of hay per acre foot of water
1	13.91	.299	3	78	1.1887	10.08	3.782	3.18
2	14.36	.299	4	76	1.5637	10.93	4.421	2.83
3	17.00	.299	6	87	1.9529	15.00	5.309	2.72
4	13.74	.299	7	103	2.6143	17.12	5.603	2.14
5	13.39	.299	10	99	2.9929	16.92	6.597	2.20
6	12.64	.299	11	110	3.7806	19.44	6.805	1.80

NOTE: In all of the tables in this bulletin the amounts given in the column "Total Water Applied" do not include precipitation.

These plats were given their first irrigations about the middle of May, and all water was applied by the border method. The difference in amount of water applied caused a slight variation in time of blooming, the dryest plats having shown their first bloom six days earlier than the ones receiving the most water.

The crops grown under maximum irrigation showed an average height eight inches greater than the ones grown with the least water. The hay produced with an adequate moisture supply was of superior quality, due to a larger proportion of leaves and a less woody stalk. Three cuttings were obtained in 1911 and in 1913. In 1912 the third growth was plowed under for green manure.

It will be noted that plats receiving the greatest amount of water returned the most hay, indicating that the excessive amount of water was not injurious to the alfalfa. It should be stated in this connection, however, that in no case was the water forced to pond up, but was allowed to run off and the waste measured. Had it been allowed to cover the ground and remain so, considerable injury to the crop would have resulted.

While it is true that three and three quarters feet of water produced the most hay, it does not follow that that is the proper amount from the economic standpoint.

The above results indicate that under conditions similiar to ours, it will be found profitable to apply irrigation water to alfalfa up to about two and three quarters acre feet per season. This can be given nicely in seven or eight applications, allowing three each for the first two crops and one or two for the third. It has been noted in the experimental work that this frequency is more desirable than the application of same amount in fewer irrigations. While a slightly greater yield may be obtained by the use of more water, it is doubtful if the extra hay will be sufficient to justify the extra expense.

WINTER WHEAT

Since winter wheat is started in the fall, its development in the spring is much faster and earlier than the spring sown varieties. On this account, the spring moisture is usually sufficient to bring it to the booting stage, without any need of irrigation. In the duty of water experiments reported below, the first irrigations were given the last week in May with the grain in the booting stage, and subsequent irrigations were applied as often as was necessary to put a sufficiently great amount of water on the maximum plats.

All water was applied by flooding between borders.

DUTY OF WATER FOR WINTER WHEAT

Plat No.	Soil moisture at first irrigation per cent	Ppt. during season in feet	No. of irrigations	Length of irrigation season in days	Total water applied in acre feet	Soil moisture at harvest per cent	Yield of grain in bu. per acre	Yield of straw in tons per acre	Wt. of grain per bu.	Bu. of wheat per acre foot water
1	14.98	.240	1		.635	12.75	30.36	1.081	62	47.81
2	15.66	.240	2	27	1.066	14.59	27.76	.963	62	25.04
3	15.94	.240	4	38	1.464	16.02	30.63	1.043	63	20.92

The above table gives the average results of the work during 1910--11 and 1912. In all of these years Turkey Red was the variety used and the experiments consisted of three plats.

In each season the plats were given their first irrigation at the same time to eliminate any variation that might be caused by early or late irrigation. The date of heading was not effected in any way by the difference in moisture supply, but the excessive amounts of water delayed the time of ripening three days. The crops grown under maximum irrigation showed an average height three inches greater than the ones receiving the least water. Samples of grain from each of the plats were sent to the Department ot Chemistry, University of Idaho, for milling and bread making. The results of these tests will be reported by the Station chemist.

We are not able to understand why the medium plats produced a smaller yield than either the maximum or minimum. At any rate, it seems to be a safe conclusion that less than one acre foot of water applied in one or two irrigations will produce the most economic results in the irrigation of winter wheat on soils such as ours.

SPRING WHEAT.

The development of the wheat plant is marked by several rather distinct steps or stages. They are first jointing, booting, heading, flowering, soft dough, hard dough and maturity. A close observance of the production of cereals under irrigation has led to the belief that the time, with reference to these stages, at which irrigation water was applied is just as important as the amount of water given. The following experiment has been conducted during the seasons of 1911--12--13 and, while its results might be more conclusive, we believe that they throw considerable light on the subject.

TABLE I --- TIME OF IRRIGATING SPRING WHEAT

Number	Plan of Irrigation	Number of irrigations	Length of season in days	Total depth of water in feet	Yield of grain in bu. per acre	Yield straw in tons per acre	Weight of grain per bu.
1	No irrigation	0		.00	29.22	.966	56
2	One at heading	1		.426	35.55	1.072	59
3	One at booting and one at flowering	2	22	.848	45.00	1.298	59
4	One at booting and one at soft dough	2	26	.854	46.53	1.200	59
5	One at jointing, one at booting and one at soft dough	3	42	1.007	50.12	1.645	60
6	One at jointing	1		.542	39.63	1.399	56
7	One at jointing and one at flowering	2	31	.902	46.90	1.520	58
8	One at jointing, one at booting and one at flowering	3	38	.963	45.88	1.618	58
9	One at jointing, one at booting, one at flowering and one at hard dough	4	57	1.235	43.39	1.536	59

The average precipitation during the growing periods of these seasons was .299 feet, about seventy-five per cent of which fell before the booting stage.

In each season Dicklow has been the variety of spring wheat used in this work. The plats were one--tenth of an acre in size.

The difference in time of irrigation caused no variation in the dates of heading. The grain which received no water ripened five days earlier than that receiving the most. Plats 5--10 inclusive which were irrigated first at the jointing stage, produced the greatest height of plant. Although an unavoidable dissimilarity in soil conditions may be partly responsible for some of the variation in yield, we believe, after having watched this experiment carefully for three years, tnat the results given in the above table are fairly accurate and reliable.

The grain from Plat 1 which received no water, and from Plat 6 irrigated only at the jointing stage, was so badly shrivelled that it was unfit for milling purposes.

It is interesting to note that while one irrigation at the jointing stage (Plat 6) produced a slightly greater yield than one at the heading stage (Plat 2), the grain from the latter was far superior in quality, indicating that if only one irrigation can be applied it had better be withheld until the crop is in head.

The water given to Plat 9 at the hard dough stage seems to have been of no value. Plat 5 irrigated at the jointing, at the booting and at the soft dough periods produced the best results both in quantity and quality of crop and this seems altogether reasonable. At the jointing the embryo head is forming, at the booting it is about to emerge and at the soft dough the kernel is filling, at which time adequate moisture will insure plumpness. Furthermore, the time between these periods agrees very well with the time that our soil and normal climatic conditions require between irrigations. Of course, if in any season the climatic conditions are abnormal this plan will have to be modified to suit them.

ILLUSTRATING DIFFERENCE IN TIME OF IRRIGATION.

Wheat on the left irrigated first at booting, that on the right irrigated first at jointing stage.

TABLE II --- TIME OF IRRIGATING SPRING WHEAT

Soil Moisture and Percentages

No.	Plan of irrigation	Soil moisture at planting	At jointing.	At booting	At heading	At flowering	At soft dough	At hard dough	At harvest	Yield grain bu per acre	Yield straw t. per acre	Wt. grain per bu.
1	No irrigation	18.18	14.99	13.17	13.48	12.33	9.15	10.31	10.52	29.22	.966	56
2	One at heading	19.03	16.69	16.05	14.59	14.30	11.37	10.52	11.29	35.56	1.072	59
3	One at booting and one at flowering	17.71	17.13	13.84	17.09	13.56	14.11	11.68	11.70	45.00	1.298	59
4	One at booting and one at soft dough	17.81	16.62	14.47	17.47	14.26	13.88	13.58	13.76	46.53	1.200	59
5	One at jointing, one at booting and one at soft dough	18.15	17.70	16.24	17.25	13.28	13.13	10.78	11.96	50.12	1.645	60
6	One at jointing	18.40	18.92	17.79	15.08	12.41	10.14	10.31	10.79	39.63	1.399	56
7	One at jointing and one at flowering	18.16	17.75	16.56	16.55	11.92	10.86	9.95	11.43	46.90	1.520	58
8	One at jointing, one at booting and one at flowering	18.40	17.72	16.19	14.93	13.49	12.47	12.12	11.40	45.88	1.618	58
9	One at jointing one at booting one at flowering and one at hard dough	18.36	17.58	15.21	15.50	11.88	14.02	11.95	12.32	43.39	1.536	59

While the data given in the soil moisture table are not very conclusive, they agree fairly well with the facts brought out in the other table. In general the plats showing a relatively high moisture content at the jointing and booting stages, produced the largest yields, and the ones which were low at the soft dough period produced grain of the lightest weight.

In all of the work, irrigation water was applied by flooding between borders, which seems to be the most satisfactory method for irrigating wheat.

In the work on the duty of water for spring wheat the Station has co-operated with the Department of Chemistry, Idaho Experiment Station. In addition to the duty of water the experiments have included a study of the effect of irrigation upon the protein content of the wheat, and upon the movement and production of nitric nitrogen in the soil.

These latter phases will be reported by the Station Chemist.

During the seasons of 1910-11 twenty-four plats were used and in 1912-13 twenty-one each. In all, four varieties of spring wheat have been grown. They are Bluestem, Sonora, Little Club, and Dicklow. The following table gives the average results of the ninety plats and four varieties extending over the four years work. When such a great amount of carefully compiled data has been reduced to one small table, the results obtained can be considered accurate and reliable.

DUTY OF WATER FOR SPRING WHEAT

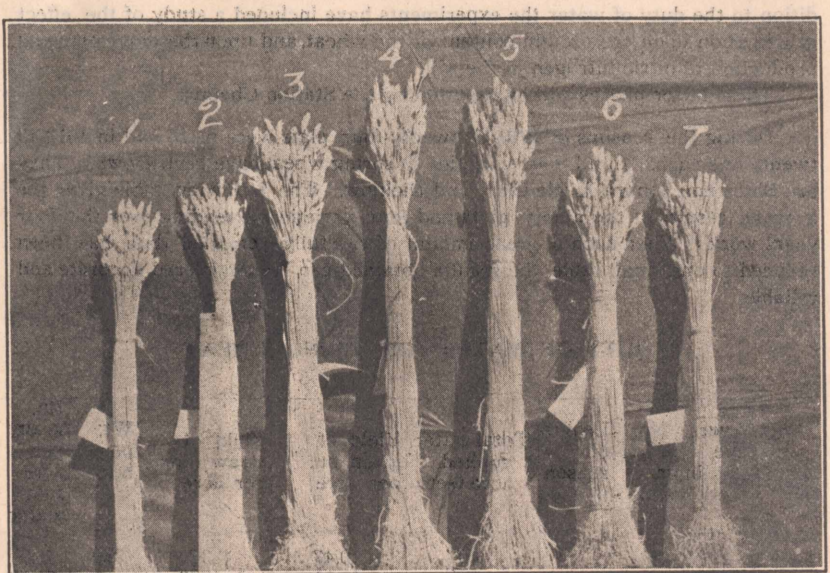
No.	Average ppt. in feet	No. of irrigations	Length of season in days	Total water applied, acre feet	Yield of grain bu. per acre	Yield of straw tons per acre	Wt. per bu.	Bu. grain per acre foot water
1	.299	0		.00	10.47	.370	59	
2	.299	1		.392	21.11	.706	59	51.53
3	.299	3	36	.727	25.23	1.020	58	34.70
4	.299	4	42	1.235	28.16	1.069	61	22.80
5	.299	5	49	1.775	31.21	1.221	60	17.59
6	.299	8	52	2.276	31.74	1.093	62	13.94
7	.299	9	54	2.833	25.10	.924	61	8.86

In all cases the plats in each set were given their first irrigations at the same time, in order to come as near as possible to making the amount of water applied the only variable factor in the experiment. All first irrigations were given during the first week in June.

No variation was noted in the dates of heading although the most water delayed the time of ripening five days. Very little difference was shown in the height of plant due to the fact that the first irrigations were applied at the same time.

The above table clearly brings out the fact that while there was an increase in yield up to about two and one-half feet of water, that which was applied beyond this amount was not only unnecessary, but positively harmful. As was mentioned in the case of alfalfa, because of the economic law of diminishing returns, the amount of water produceing the largest yield is not necessarily the amount that produces the best result.

A careful study of the above table will lead one to the conclusion that about one and one-half to one and three quarters acre feet of water, given in four or five applications, is the proper irrigation for spring wheat on new sage brush land.



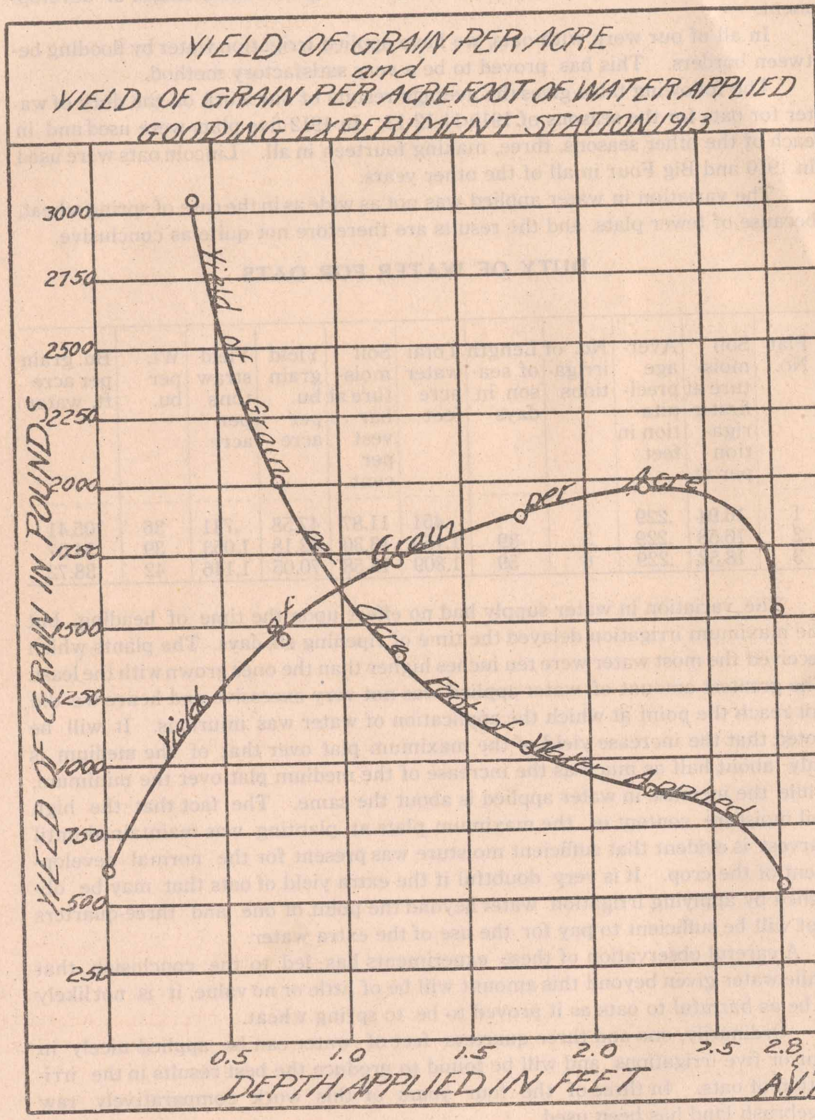
Results with Different Water Applications. Left to Right.

	Acre feet water	Yield grain in bu. per acre
1 st bundle	2.820	17.03
2 nd "	2.558	24.54
3 rd "	1.737	26.08
4 th "	1.516	22.85
5 th "	1.285	22.05
6 th "	.479	18.47
7 th "	.00	15.87

The accompanying picture shows a bundle of wheat taken from each of the Bluestem plats in 1911.

It might appear at first sight that there is considerable discrepancy between these results and the ones given in the time of irrigation table, because of the fact that the latter shows a much greater yield with less water.

The duty of the water experiments were conducted on raw sagebrush soil, while the time of irrigation tests were made on old alfalfa soil. This only goes to emphasize further the point that will be brought out later in this bulletin concerning the great value of soil improvement in increasing the duty of water. We consider the above results accurate and reliable for new lands, but we believe that the next four years work of the Station along this line, will show a higher duty because of a better soil.



GRAPHIC REPRESENTATION OF DUTY OF WATER FOR SPRING WHEAT

OATS

No tests have been made in the irrigation of oats at different stages, but we believe that what has been said of the time of irrigating wheat will apply with a good deal of force to oats, since the two go through the same stages of development.

In all of our work with oats, we have applied irrigation water by flooding between borders. This has proved to be a very satisfactory method.

The following table gives the average results of our work on the duty of water for oats for the seasons of 1910-11-12-13. In 1912 five plats were used and in each of the other seasons, three, making fourteen in all. Lincoln oats were used in 1910 and Big Four in all of the other years.

The variation in water applied was not as wide as in the case of spring wheat, because of fewer plats, and the results are therefore not quite as conclusive.

DUTY OF WATER FOR OATS

Plat No.	Soil moisture at first irrigation per ct.	Average precipitation in feet	No. of irrigations	Length of season in days	Total water acre feet	Soil moisture at harvest per cent	Yield grain bu. per acre	Yield straw tons per acre	Wt. per bu.	Bu. grain per acre ft. water
1	16.94	.229	1		.451	11.87	47.58	.741	36	105.41
2	16.58	.229	3	39	1.150	13.30	62.18	1.053	39	54.07
3	18.52	.229	6	59	1.809	18.58	70.05	1.146	42	38.72

The variation in water supply had no effect upon the time of heading, but the maximum irrigation delayed the time of ripening six days. The plants which received the most water were ten inches higher than the ones grown with the least. The greatest amount of water applied was not very excessive and hence we did not reach the point at which the application of water was injurious. It will be noted that the increase yield of the maximum plat over that of the medium is only about half as much as the increase of the medium plat over the minimum, while the increase in water applied is about the same. The fact that the high soil moisture content of the maximum plats at planting was maintained until harvest is evident that sufficient moisture was present for the normal development of the crop. It is very doubtful if the extra yield of oats that may be obtained by applying irrigation water beyond the point of one and three-quarters feet will be sufficient to pay for the use of the extra water.

A careful observation of these experiments has led to the conclusion that while water given beyond this amount will be of little or no value, it is not likely to be as harmful to oats as it proved to be to spring wheat.

Ordinarily, one and three quarters feet of water can be applied nicely in four or five irrigations and will be found to produce the best results in the irrigation of oats. In three of the four years of this work comparatively raw sagebrush land has been used.

SPRING BARLEY.

While wheat and barley go through the same stages of development, the intervals between the stages in the growth of the barley are usually shorter. It is believed, however, that this difference is not great enough to hinder the general application of the conclusion reached in the case of time of irrigating spring wheat.

As with oats and wheat, we have found the method of flooding between borders to be well adapted to the irrigation of barley.

The experiments on the duty of water for Spring barley have extended over the four years of the Station work. In each season three plats have been used, one receiving minimum, one medium and one maximum irrigation.

In the season of 1910 White Moravian barley was grown, and in all of the other years California Feed has been used. The following table shows the average result obtained from the twelve plats and two varieties.

DUTY OF WATER FOR SPRING BARLEY

Plat No.	Soil moisture at 1st. irrigation per ct.	Average precipitation ft.	No. of irrigations	Length of irr. season days	Total water acre feet	Soil moisture at harvest per ct.	Yield grain bu. per acre	Yield straw tons per acre	Wt. per bu.	Bu. grain per acre ft. water
1	15.04	.229	2	20	.848	12.15	34.95	.754	46	41.21
2	16.10	.229	3	42	1.499	13.18	46.54	.891	48	31.05
3	14.99	.229	5	49	1.957	16.71	49.50	1.009	49	25.29

As with other cereals, no variation was caused in the date of heading. The date of maturity was delayed three days by the maximum irrigation. The plants which received the most water were three inches higher than those grown with the least. Irrigation began during the first week in June, and all plats in each season were given their first applications at the same time.

It is unfortunate that we were unable to use more plats in this work. Because of having only three plats each year, the variation in water applied was not wide and the maximum amount was not enough to be injurious to the crop. It will be noted that the difference in yield of grain between the maximum and medium plats is only one-fourth as great as the difference between the medium and minimum plats. This shows that irrigation applied up to one and one-half feet produced far greater returns per unit of water than that applied beyond this amount. The fact that the maximum plat showed a higher moisture content at harvest than at planting is evidence that more moisture was applied than the crop could make use of. One and three-quarters feet can be applied in four good irrigations and it is a safe conclusion that this will be a satisfactory plan for the irrigation of spring barley, under conditions like ours.

POTATOES

There is considerable difference of opinion among the farmers of the state concerning the stage of plant growth at which the first irrigation should be applied to potatoes. In order to furnish accurate information along this line the following experiment was planned and has been conducted for two years. We do not wish to be too positive in our conclusions until the work has been carried over a longer period, but we believe that the results so far obtained are interesting and valuable:

PLAN OF TIME OF IRRIGATION EXPERIMENTS.

Plat 1. First irrigation when plants are four or five inches high. From then as often as is necessary to keep sufficient soil moisture to furnish good growing condition until the tubers are the size of an egg. Then no more irrigation.

Plat 2. First irrigation when plants are four or five inches high and as often as is necessary during the remainder of the season.

Plat 3. First irrigation when the tubers begin to form and as often as is necessary during the remainder of the season.

Plat 4. First irrigation when the tubers are the size of an egg and as often as is necessary during the remainder of the season.

Plat 5. No irrigation.

This plan has been carefully followed during 1912-13. Idaho Rurals have been used in both seasons.

TABLE TIME OF IRRIGATING POTATOES

Plat No.	Average ppt. in feet	No. of irrigations	Length of irrig. season days	Total water acre feet	Yield marketable potatoes lbs.	Yields culls lbs.	Percentage of total yield marketable	Lbs. marketable potatoes per acre foot water
1	.234	2	23	1.387	9281	3838	70.54	6691.42
2	.234	4	48	2.449	14454	3618	76.65	5902.00
3	.234	4	32	1.759	14847	3482	80.70	8440.51
4	.234	2	17	1.897	12912	4165	75.60	6806.54
5	.234			.00	5649	3465	61.21	

In all cases the last irrigations were applied about the middle of August. This is the usual time of ceasing irrigation in all of our work with potatoes. By this time the tubers have attained their growth and the soil should be dried to allow them to ripen.

These plats were cultivated after irrigation from the beginning of the season until further cultivation was made impracticable because of large vines and extensive root systems. In all cases the plats were given the same cultivation.

One of the first things that will be noted in a study of the above table is that when the irrigation of a crop of potatoes has been started, it should be continued throughout the rest of the season. Plat 3, which received its first irrigation at the formation of the tubers, produced a greater yield and a higher percentage of marketable potatoes with less water than did either plats 2 or 4. It is believed that the difference in yield and uniformity between plats 1 and 4 is due far more to the time of application than to the amount applied. This work so far indicates that potatoes should be irrigated first when the tubers begin to form and from then should be given frequent light applications until time to allow them to dry and ripen. If the work of the next two or three years substantiates these results we shall be able to outline a plan for time of irrigating potatoes that will increase the duty of water, and the quantity and quality of the crop.

It must be remembered that this work is based upon climatic and soil conditions that are normal, or nearly so, for Southern Idaho. It is possible under extreme drouth that irrigation may be required as soon as the plants are up, or even before that.

FURROW IRRIGATION OF POTATOES

Potatoes should never be flooded. Neither should they be irrigated with furrows that are so shallow that the water is allowed to come in direct contact with the tubers. An examination of the potato plant will show that the roots which supply the plants with moisture and food are below the potatoes. These feeder roots are the only parts of the plant that need to reach the moisture supply. If the soil around the tubers is once saturated with water it will become hard and more compact, the uniform growth of the potato will be checked and as a result it will be irregular and ill shaped. A wet tuber bed will allow such diseases as scab and rhizoctonia to have a much greater effect. While if the top soil is only moist due to the water that has risen from below by capillary attraction, it will remain loose and easily displaced and the tuber will make a uniform healthy growth.

In order to produce this desirable condition, potato rows should be well hilled up and the furrows between them comparatively deep. A small stream should be allowed to run in these furrows until the lower soil is well soaked although it need not run until the top of the row is wet. In some cases the first irrigations are applied in every other row. This practice may be satisfactory in the lighter soils, but the medium or heavy soils should have water in every row The early irrigation should be followed by cultivation. This breaks the crust preventing the escape of moisture and keeps the furrows deep. It is not advisable, however, to cultivate after the vines have become large enough to interfere.

While the station has conducted no direct experiments on the method of irrigating potatoes, we have made some conclusive observations on irrigated farms in various parts of the country that go to substantiate these statements.

The experiments on the duty of water for potatoes have extended over the four years of Station work. In 1910-11 Red Peachblows were grown and in 1912 and 1913 Idaho Rurals. In 1910-11 this work was conducted on new sagebrush soil, in 1912 on land that had been heavily manured and in 1913 on alfalfa land, so that the results represent average conditions.

The potatoes were planted about sixteen inches apart in the row and the distance between the rows was forty-two inches. In 1910 the potatoes were irrigated at planting time, but in all other cases the first irrigations were given when the tubers began to form, to avoid any variation that would be caused by a difference in time of application. The water was applied in deep furrows and the plats were cultivated as suggested above. In harvesting, the potatoes which passed through a two inch screen and those which were knotty and ill shaped were classed as culls.

The following table gives the average results of four years and two varieties.

DUTY OF WATER FOR POTATOES

Plat No.	Ppt. in feet	No. of irrigations	Length of irri. season days	Total water acre feet	Yield marketable potatoes lbs. per acre	Yield culls lbs. per acre	Percentage of total yield marketable	Lbs. marketable potatoes per acre foot water.
1	.229	2	20	.687	6310	2772	65.25	9184.86
2	.229	4	51	1.724	13499	2925	81.61	7830.04
3	.229	6	60	2.831	13385	4078	76.98	4728.01

NOTE: The average length of irrigation season is increased because of the fact that in 1910 the first irrigation was given at the time of planting.

It will be noted that one and three-quarters feet of water produced the greatest yield and the highest percentage of marketable potatoes. The maximum plat with about two and three-quarters feet produced much the same yield, but a considerably smaller percentage of marketable potatoes. Since culls are almost valueless, we are safe in saying that the time and expense of applying the last foot of water to the maximum plat was practically a dead loss.

In the fall of 1911 six average-sized potatoes from each plat were baked to determine the effect of varying amounts of water on the quality of the tuber.

The potatoes from the minimum plat were more mealy and whiter than any others. The ones grown with medium irrigation were nearly as good as the ones receiving the least water. The tubers from the maximum plat were soggy and inferior in quality to either of the others.

These results indicate conclusively that about one and three-quarters feet of water given in four applications, is the proper and economic amount to be used in the irrigation of potatoes on soils like ours.

EFFECT OF SOIL IMPROVEMENT UPON THE DUTY OF WATER.

The improvement of our sagebrush lands by the addition of barnyard manures, by the growing of leguminous crops and by using a proper system of crop rotation is one of the most potent means by which we shall be able to increase the duty of water.

The reason for this is two fold. In the first place fertile soils will produce far greater yields per unit of water than poorer soils. Secondly, the water holding capacity of raw sagebrush soils is greatly increased by the addition of humus. The Station has conducted no direct experiments along this line but we have noticed in the compilation of the above data a number of cases where an improvement in soil conditions has indicated a great difference in water requirement. The results in these cases are shown in the following tables.

Treatment of soil	Number of irrigations	Length of irrigation season in days	Total water acre ft.	Yield oats bu. per acre	Yield straw tons per acre	Wt. per bu.	Bushels grain per acre foot water
Unmanured	4	31	1.015	49.38	.655	39.5	48.65
Manured	3	36	.857	83.11	1.181	39.5	96.98

Both of these plats were cleared of sage in 1909. During the seasons of 1910-11 both were cropped to cereals. In the winter of 1911-12 the manured plat was given a heavy dressing (thirty loads per acre) of fresh barnyard manure. Both were plowed in the spring of 1912 and seeded to Big Four Oats at the same time and at the same rate per acre. The above table gives the irrigation data and the yields of oats from both plats. The difference in yield per unit of water is certainly remarkable.

Treatment of soil	No. of irrigations	Length of irr. season days	Total water acre feet	Yield wheat bu. per acre	Yield straw tons per acre	Wt. per bu.	Bushels grain per acre foot water
Unmanured	2	16	1.009	24.17	.840	63	23.95
Manured	2	23	1.087	38.93	1.012	62	35.81

The results shown in this table are from the same piece of land. The plat was seeded to Turkey Red Winter Wheat in the fall of 1910. The upper line of the table gives the amount of irrigation given to this crop and its yield of grain and straw. As soon as the grain was removed (fall of 1911) a very light dressing (six loads per acre) of barn yard manure was applied. The land was plowed, disced, harrowed and seeded again to Turkey Winter Wheat. The lower line of the table shows the irrigation this crop received in the summer of 1912 and its resulting yield. While the application of manure was very light its results are by no means insignificant.

Kind of land	No. of irrigations	Length of irr. season days	Total water acre ft.	Yield barley bu. per acre	Yield straw to per acre	Wt. per. bu.	Bushels grain per acre foot water
New sagebrush soil	3	31	1.678	33.02	.790	49	19.68
Alfalfa sod	3	29	1.061	84.87	1.159	48	79.99

This table represents two seasons work with California Feed Barley on two different plats. The data given in the upper line were secured in 1911 on new sagebrush soil. In 1912 the barley was grown on land which had been in alfalfa two years.

As was stated above these results have been gathered from various parts of the Station record because of the interesting comparison they afforded. For the purpose of each comparison plats have been selected which had received, as nearly as possible, the same irrigation.

From a consideration of such striking results as the above, we are justified in the belief expressed in another part of this bulletin that our investigations for the next four years would show a higher duty of water for all of the ordinary crops, than that given in the foregoing pages.

SUMMARY.

1. In the preparation of new lands for irrigation farming careful attention should be paid to proper leveling. Time and money spent in this way will yield good returns.

2. Alfalfa should be irrigated by the corrugation method during its first season, after which flooding between borders is more satisfactory in most cases In the production of alfalfa hay seven or eight irrigations should be given in a three crop season, totaling about two and three-quarters acre feet per acre.

3. The moisture supplied by winter and spring precipitation is usually sufficient to carry winter wheat to the booting stage, after which one or two irrigations totaling less than one acre foot per acre should be given. Flooding between borders is a desirable method of application.

4. In the irrigation of spring wheat, oats and barley, care should be taken to have a comparatively high soil moisture content at the jointing, booting and soft dough stages. The water can be applied to advantage by flooding between borders. For all of these cereals one and one-half to one and three-quarters acre feet per acre is the proper amount. This can be given in about four good applications.

5. The irrigation of potatoes should commence about the time the tubers begin to form. During the next five or six weeks about four irrigations should be given, applying in all about one and three quarters acre feet per acre. The water should be applied in deep furrows and the early irrigations should be followed by cultivation.

6. The improvement of sagebrush lands by the addition of barnyard manures and by the growing of leguminous crops will result in a saving of water.

In addition to the foregoing it should be mentioned that the growing of diversified crops is one of the most efficient means by which the duty of water can be increased. The results given above for winter wheat for instance, indicate its value in securing the desired diversification. Its comparativly low water requirement can be made to offset the great amount used by alfalfa, thus reducing the average requirement of the entire farm.

In our State the amount of irrigable land is proportionately far greater than the amount of water available for irrigation purposes. So that if, by a careful study of the various phases of irrigation practice, we can increase the duty of water and thereby make our available supply do service for more land, we shall have made possible the ultimate establishment of more homes and a greater commonwealth.