THE DEVELOPMENT OF AN IRRIGATION GAUGE

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INTRODUCTION

Successful irrigation of an area on a long term basis requires a knowledge of when to apply irrigation water to the area and the quantity to apply. Without this information, land deterioration and water wastage can easily result. Careful scheduling of irrigation is one means of keeping a proper salt balance in the soil and at the same time using only the amount of water necessary to insure maximum production.

Actual soil moisture at any time can be either measured by various methods or estimated from evaporation devices or meteorological measurements combined with rainfall and irrigation water records.

Very few of the methods for measuring soil moisture content are suitable for use in irrigation practice. Tensiometers and electrical resistance blocks are not satisfactory because they do not operate over the complete water holding capacity range of soils. Gravimetric methods require considerable time and knowledge of the undisturbed density of the soil. The d/m gauge is an excellent method of determining soil moisture but is far too expensive for commercial use.

To estimate soil moisture from a knowledge of rainfall, irrigation and measured or calculated evaporation, it is necessary to measure the soil moisture initially using one of the methods mentioned above. Evaporation from open pans and other devices has been proposed as an index for estimating evapo-transpiration for many years. This is because evaporation has a higher correlation with evapo-transpiration than any other measurable weather characteristic. However, there are soil factors and crop factors which affect evapo-transpiration but do not affect evaporation from free water surfaces. For this reason, evaporation devices must be calibrated when used to estimate soil moisture changes for a particular soil and type of crop.

The disadvantages of calculating soil moisture changes from meteorological estimates of evapo-transpiration are that climatic conditions often vary considerably locally and that the methods are cumbersome. With evapo-transpiration rates as estimated from the above methods, rainfall and irrigation records must still be consulted before soil moisture changes may be computed.

It was suggested to the authors that they attempt to develop a gauge that would simulate evapo-transpiration, collect rainfall, and irrigation water and therefore indicate at any time the soil moisture in the root zone under a crop. The main value of such a gaugae is that it would eliminate the need to measure or compute soil moisture content periodically in order to schedule irrigation.

CONSTRUCTION & OPERATION

Irrigation gauges similar to those being used by Stanhill (1) were constructed and used during the 1959 and 1960 growing seasons using black Bellani plate atmometers to simulate evapo-transpiration instead of the white, porous ceramic discs used by Stanhill.

Each of the gauges consists of a water reservoir, a black Bellani plate, a funnel to intercept rain water, a saran tube connecting the glass tube projecting from the bottom of the Bellani plate to the water reservoir, a mercury valve, a scale on the side of the reservoir, an overflow spout and a support stand as shown in Fig. 1.

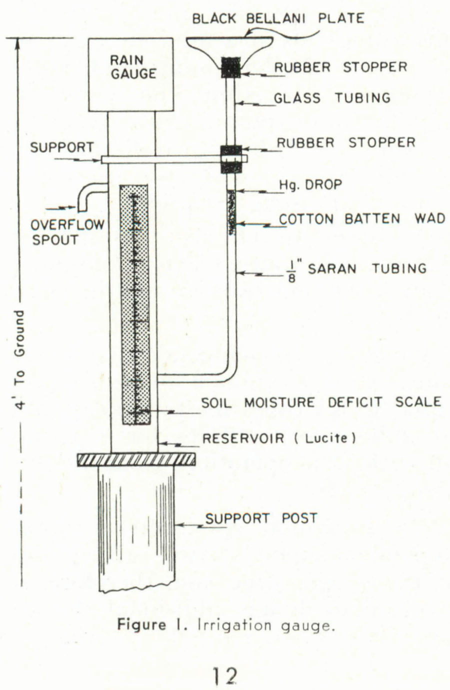

Figure 1. Irrigation gauge.

The Bellani plate, reservoir, and rain gauge were combined in such a way that the inches of water in the reservoir at any time corresponded to the inches of water held in the top four feet of soil. The initial water level was determined by measuring the soil moisture by gravimetric means or with a d/m neutron gauge. Rain water was collected in the rain gauge and irrigation water was manually placed in the rain gauge and both were stored in the reservoir. Evapo-transpiration was simulated by the black Bellani plate which was supplied with water from the reservoir. A scale on the side of the reservoir, which was calibrated for stage of growth for the crop being scheduled, also showed the soil moisture at field capacity and permanent wilting point and made possible the determination of the soil moisture deficit at any time. This scale was calibrated for stage and type of growth during the 1959 growing season and checked during the 1960 season. It was placed on the side of the reservoir with the overflow spout at the field capacity level so that water that was wasted from the reservoir simulated the irrigation water that moved through the root zone to deep percolation.

1959 CALIBRATION

On June 24, 1959 an eighty-acre plot was planted in the Univrsity sprinkler irrigation field. The authors selected seven random sites in the plot and obtained the daily soil moisture in inches of water in the top four feet of the soil at each site during the growing period.

The irrigation gauges were placed at these random sites and the water depths in the gauges were adjusted to correspond to the inches of water in the soil at each site. The sprinkler irrigation water was measured with rain gauges at ground level for all seven sites. This depth of water was added manually to the irrigation gauges.

Soil moisture retention curves for each of the four depths at the seven sites mentioned were obtained using a pressure membrane apparatus. The soil moisture content for each site at field capacity and permanent wilting was determined using these curves, and from these values the true readily available moistures of the soils were computed. Knowing the field capacity at each site enabled the authors to place the scales on the reservoirs with the overflow spouts at these points.

The measured soil moisture in the top four feet of each of the seven sites was compared to the soil moisture as indicated daily by the readings of the irrigation gauges. This comparison during the 1959 growing season showed that the ratio of the measured evapo-transpiration from oats, as compared with that indicated by the irrigation gauges, was approximately one-half for the first ten inches of growth, three-quarters for the next fifteen inches of growth and one for the remainder of the crop growth. The irrigation gauge readings from all seven random sites were adjusted using these ratios. A typical comparison of the actual soil moisture content vs. that indicated by the irrigation gauge is shown in Fig. 2. A study of the results showed that the soil moisture as measured was always within one and one-half inches of water of the soil moisture as indicated by the irrigation gauges.

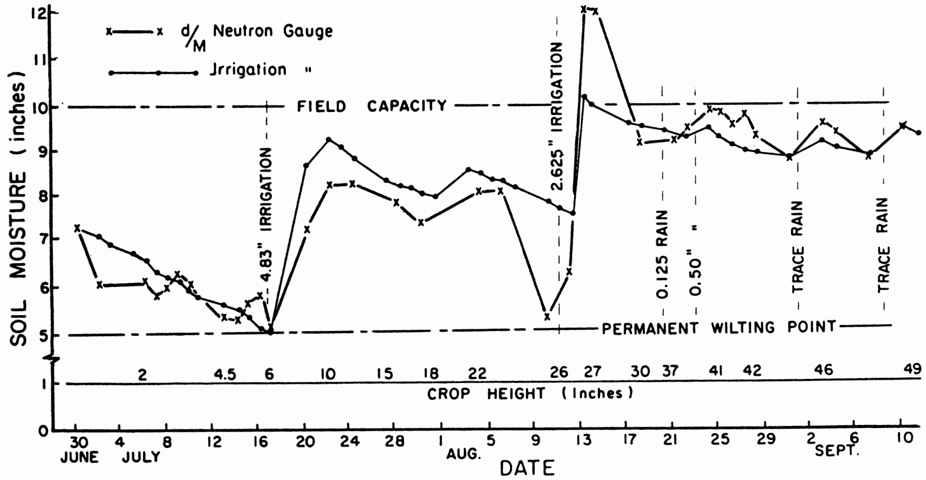

Figure 2. Root-zone soil moisture as indicated by an irrigation gauge versus actual soil moisture as measured by a d/m neutron gauge. (1959).

1960 CALIBRATION

On June 5, 1960, an eighty-acre oat plot was planted in the University sprinkler irrigation field. The authors selected six random sites and repeated the procedure of 1959.

The results from the 1960 growing season showed that the 1959 calibration should be changed slightly. In 1960, the ratio of the measured evapo-transpiration from oats, as compared with that indicated by the irrigation gauges, was approximately one-half for the first ten inches of growth, three-quarters for the next six inches of growth, and one for the remainder of the crop growth. It was felt that the reason for the change in the calibration was due to the late seeding in 1959.

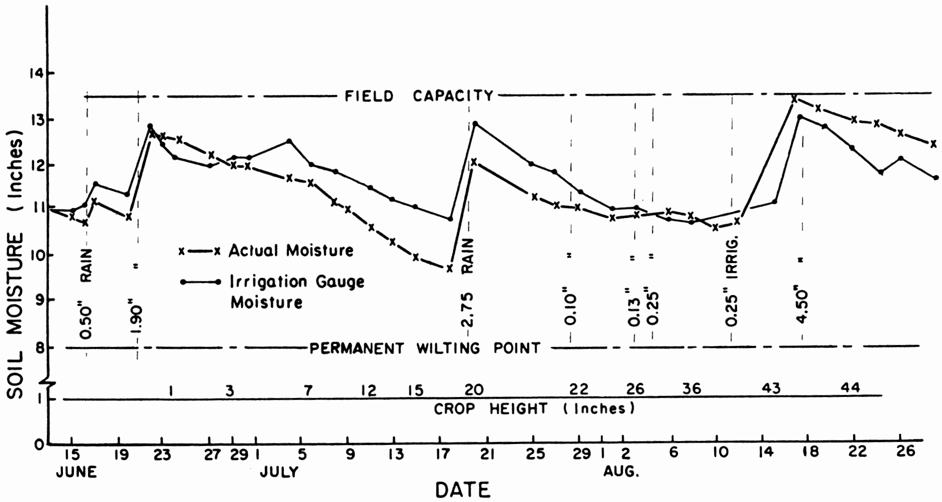

Figure 3. Root-zone soil moisture as indicated by an irrigation gauge versus actual soil moisture as measured by a d/m neutron gauge. (1960)

The 1960 results were all adjusted using the ratios obtained in 1960. A typical comparison of the actual soil moisture content vs. that indicated by the irrigation gauge is shown in Fig. 3. A study of the results show that the soil moisture as measured was always within one inch of water of the soil moisture as indicated by the irrigation gauges.

THEORETICAL CONSIDERATIONS

Because it was obviously impractical to consider calibrating a gauge for every root zone soil type that may have been encountered, it was necessary to assume that the differences in the rate of soil evaporation for different soil types was negligible when considered with transpiration. The work done by J. W. Wolfe (2) indicated that different soil types under grass had little effect on consumptive use.

Although the irrigation gauge in this study only indicated soil moisture within one inch of the measured moisture during 1960, this was considered to be sufficiently accurate for field use. Modern irrigation practice, because of uneven water distribution, makes it impractical to schedule irrigation with an accuracy of less than one inch of water.

The three different 1960 ratios of measured evapo-transpiration to that indicated by the irrigation gauges require that each gauge used for scheduling irrigation of oats in the future be equipped with three calibrated scales and three sizes of rain gauge funnels. All three scales could be fastened to the reservoir, but the funnels would have to be changd for each stage of growth. Also, the water level in the reservoir would have to be adjusted to accommodate the different scales when the crop height reached ten inches and sixteen inches.

A single scale on the reservoir and only one rain gauge funnel could be used if Bellani plate covers were used. For instance, when the ratio of measured evapo-transpiration to that as indicated by the irrigation gauge is one-half, approximately one-half of the Bellani plate evaporation area could be covered. Calibration would be necessary to determine what area of the Bellani plate to leave uncovered, so that the covered plate would evaporate one-half the amount of water that the uncovered plate would evaporate for the same climatic conditions. Capillary action of the water

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DISCUSSION

From model tests baffle No. 16 was found to be the most effective in protecting the grain surface. When this baffle was prototype tested the limiting speed was found to be higher than the speed calculated with the prediction equation by approximately 20 *percent*. Modelling was considered satisfactory, for the model result was conservative and 20 percent was not considered excessive since there are a number of variables which could not be completely controlled.

Side baffles did not greatly improve the performance of baffle No. 10 or No. 16. For the other baffles the use of side baffles increased the limiting velocity as much as 17 mph.

Type 4 baffles were the most effective. Any slotted baffle approximately 30 percent porous and solid for the first 6 inches above the box will protect the grain surface against fairly high headwinds. Protection from cross winds is not easily obtained. Side baffles are not completely satisfactory although their use is almost the same as leaving the box unfilled.

These results cannot be extrapolated to include grains other than wheat unless further testing is carried out. Baffles which are effective for wheat will undoubtedly be effective for other grains also, but the limiting velocities have not been determined.

CONCLUSIONS

1. A wind tunnel can be used to test the effectiveness of wind baffles for trucks. Model theory and fluid flow theory must be carefully followed for satisfactory results.
2. A simple baffle, constructed from $5.00 worth of material, will permit air velocities of at least 60 mph without loss of wheat. The identical truck without baffle lost wheat when air velocities exceeded 35 mph. This baffle was also satisfactory for a forward velocity of 40 mph and a cross wind of 25 mph.
3. Considerably more elaborate baffles are necessary to protect against cross winds in excess of 25 mph.

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from under the cover and air turbulance effects over the uncovered portion of the plate due to the thickness of the cover would affect the calibration.

USE OF THE GAUGE

Assuming that a gauge, with three calibrated scales mounted on the reservoir and three calibrated rain gauge funnels supplied, is to be used to schedule irrigation for a crop of oats during the growing season, the following procedure should be followed.

1. The field capacity and permanent wilting point of several soil samples should be determined or estimated. Because the soil with the greatest sand content will have the lowest water-holding capacity, this soil should be used as a basis for computing the end points on the three calibrated scales. The scales should have a permanent wilting point mark put on each of them at a distance below the spout, which is at the field capacity point, equal to the water-holding capacity of the soil with the most sand.

2. The day the crop emerges, the actual moisture in the soil with the most sand should be determined and the corresponding water level placed in the irrigation gauge according to the scale to be used for the first ten inches of crop growth. The largest rain gauge funnel should then be placed on the gauge. The gauge is then ready to indicate soil moisture deficit during the first ten inches of crop growth.

3. Whenever the gauge indicates that approximately two-thirds of the effective water-holding capacity of the soil has been depleted, the moisture deficit as shown on the gauge should be replaced in the soil with irrigation water and in the gauge with distilled water.

4. When the crop reaches ten inches in height, the water level in the reservoir must be changed so that it indicates the same soil moisture deficit on the scale to be used during the ten to sixteen inch period of crop growth as it did in the first scale. The rain gauge funnel for this stage of crop growth should then replace the first one. The gauge is then ready to function for this growth stage.

5. Similarly, when the crop reaches sixteen inches in height, the water level must again be adjusted to suit the third scale and the smallest rain gauge funnel must be placed on the reservoir.

The gauge, if used as described above, should indicate soil moisture deficit for a crop of oats within an inch of the actual soil moisture deficit on the basis of the tests conducted in 1960.

CONCLUSIONS

It has been shown that a calibrated irrigation gauge used to schedule irrigation will indicate soil moisture deficit within one inch of water of the actual. The gauge has several advantages over existing methods used to schedule irrigation. One advantage is that it is relatively cheap. The gauge could be produced commercially for approximately thirty dollars. This means that in an irrigated area many gauges could be used and local differences in climatic conditions would be taken into account by the gauges, thus reducing land damage and increasing production.

Also, the gauge will indicate soil moisture deficit from the field capacity level to the permanent wilting point level. Another advantage is the fact that once the gauge is placed in operation in the spring of the year, it requires very little maintenance and indicates directly the soil moisture deficit at any time.

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4. Table IV shows the percentage aphid population on the sprayed and unsprayed plots before and after each spraying.
   The figures indicate that good aphid control was maintained on the sprayed plots.

5. As seen in tables III and IV spray coverage and aphid control was as good or better when the same active chemical ingredient was spread in 55 gallons of water as when spread in 100 gallons. This is an encouraging result and indicates that through the use of properly designed equipment it is possible to reduce the amounts of water used as a carrying agent. This, in turn, makes for a much more efficient operation.

6. Yield data in Table V shows an increased yield on plots that were properly sprayed. Data was collected from one row of each replicates for the three treatments used. Higher yield is attributed mainly to the effective control of leafroll and late blight diseases.

TABLE IV

RELATIVE APHID POPULATION

Date	55 pga plot	100 gpa plot	Check Plot
June 30, 1961	17.5%	12.5%	27.5%
July 3, 1961	2.5%	5.0%	17.5%
July 10, 1961	12.5%	5.0%	12.5%
July 11, 1961	0.0%	0.0%	22.5%
July 20, 1961	22.5%	15.0%	40.0%
July 21, 1961	2.5%	2.5%	32.5%
Aug. 1, 1961	2.5%	2.5%	7.5%
Aug. 2, 1961	0.0%	0.0%	12.5%
Aug. 14, 1961	17.5%	20.0%	40.0%
Aug. 15, 1961	0.0%	2.5%	32.5%

TABLE V

POTATO YIELD

	Plots Sprayed at 55 gpa	Plots Sprayed at 100 gpa	Check Plots
Saleable	644 lbs.	743 lbs.	559 lb.s
Culls	202 lbs.	131 lbs.	125 lbs.

Note: Sample weights equivalent to yield from 450 ft. of plot row.

7. Fabricated wheel guards were effective in reducing foliage damage until the end of July. The plants at this stage were about 75 percent fallen over. By the first week in August the plants had completely fallen over and become a tangled lattice work. In this stage of growth the wheel guards were unable to separate the vines effectively. Further work in this regard will be required.

SUMMARY

To obtain full benefits from the use of chemical insecticides and fungicides for controlling insects and diseases in potato crops, proper application with good spray equipment is essential.

Through several years of testing it has been found that tractor-mounted spray rigs, equipped with booms specifically designed for the job, are the most effective. The spray boom that appears most suitable consists of a horizontal cross boom with attached pendants that drop between each row. Two double swivel-type fan nozzles are fitted onto the pendant, one at a point 8 inches below the cross boom, and the other at the bottom. These nozzles force spray to the sides and bottom of the plant and a fifth nozzle clamped to the cross boom between each pendant forces spray onto the top of the plant. To maintain uniform spray pattern throughout the plant canopy, fan nozzle tips should be graduated so that the largest tips are used on the bottom of the pendants, medium size on the sides and the smallest on the overhead nozzle.

Tests to date indicate that by using well designed spray equipment much less water per acre is required to spread chemical insecticides and fungicides.

Further work is required to find ways of reducing variables encountered, so that one year's data can be compared directly to another. Further work is also required to improve the effectiveness of tractor wheel guards in reducing foliage damage.

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It should be noted that the gauge does not allow for surface runoff due to periods of heavy precipitation. Whenever the precipitation rate is greater than the infiltration rate of water into the soil, the runoff would have to be estimated and a correction applied to the water level in the reservoir of the gauge.

Also, the gauge will not indicate the correct soil moisture deficit if the soil moisture is allowed to remain at the permanent wilting level for any appreciable length of time.

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Complete details of the work described in this paper can be found in the Master's Thesis, "Development of an Irrigation Gauge", E. E. Brooks, 1961, available at the University of Saskatchewan.
