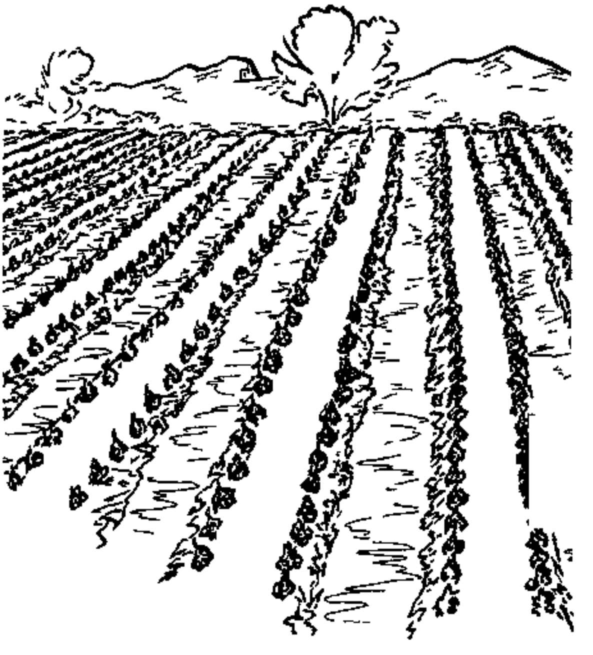
Irrigation

When?

How
Much?

How?



BULLETIN A-20

The University of Arizona

Cooperative Extension Service
And
Agricultural Experiment Station

Irrigation

WHEN?

HOW MUCH?

HOW?

Combine these guides and principles with your own judgment and experience. They will help you decide when to irrigate, how much to apply, and how to distribute the water evenly.

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College of Agriculture
Cooperative Extension Service
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Cooperative extension work in agriculture and home economics, The University of Arizona College of Agriculture and the United States Department of Agriculture cooperating. Distributed in furtherance of the Acts of Congress of May 8, and June 30, 1914.

10M—January 1962—Bulletin A-20

WHEN?

To decide when to irrigate, look at the plants and the soil. Both have signs which will help you. You must read the plant signs carefully because they will vary with the fertility and physical condition of the soil, the plant variety, and in some cases, disease infection.

Use all the plant and soil signs you can. Observe plants for wilting, color, growth rate, and stage of development. Check the soil for dryness or use a tensiometer as a guide.

Read the signs carefully and they will help answer your questions.

Read the Plant Signs!

Wilting

Wilting is a sign of the need for moisture. However, the yield potential of some plants has been reduced by the time wilting appears. Other plants often show wilt symptoms temporarily on hot afternoons even though they do not need an irrigation. Some diseases cause plants to wilt and appear as if they need water.

Color

Moisture stress is often reflected by the color of the leaves. With plenty of moisture, leaves have a light green color; when water is needed a darker, bluish-green appears. Color also is an indicator of plant variety and nitrogen supply, so take these into account.

Growth Rate

When plants need water, they grow slowly. You can see this easily in cotton. Lack of new leaves causes blossoms to be exposed and give a "flower-garden" appearance.

Another sign in cotton is the length of the green tip above the reddish color of the branch. Less than three or four inches indicates the plant is growing slowly. Lack of water may be the cause.

Stage of Development

Lack of moisture affects yields more at some stages than others. Moisture stress during germination or pollination is especially damaging.

Read the Soil Signs!

Available Moisture

Soil signs which indicate the amount of available moisture remaining depend on soil texture. With an auger or probe, take a soil

Table 1. Soil Moisture Description When Irrigation is Needed.

Soil Texture		
Coarse	**Medium**	**Fine**
Tends to stick together slightly but will not form a ball.*	Crumbly, but will form a ball.*	Pliable. Will form a ball.* Too dry to ribbon easily.**

* "Ball": formed by squeezing a handful of soil firmly.
** "Ribbon": formed between thumb and forefinger.

sample from a depth where most of the roots are located. Compare the samples with the descriptions given in Table 1. If they seem as dry, or dryer, it is time to irrigate.

Soil Moisture Tension

Plant roots must exert a suction force to remove moisture from soil particles. The amount of force can be measured with a tensiometer.

Install the tensiometer so the porous tip is in the active root zone. A second tensiometer, placed deeper at the same location, will tell you when irrigation water has penetrated to that depth.

Specific irrigation recommendations in terms of tensiometer readings and placement depths are available for some crops. Ask your County Agent for information about the crop you're growing.

In General

Weather, plant, and soil characteristics influence irrigation frequency as shown in Figure 1.

Figure 1. Influence of Weather, Plant, and Soil Characteristics on Irrigation Frequency

	←	→	
Irrigate Less Often	**Weather**		Irrigate More Often
	Cool Damp Still Air	Hot Dry Windy	
	Plants		
	Deep Rooted Healthy Roots Incomplete ground cover	Shallow Rooted Damaged or Diseased Roots Complete ground cover	
	Soil		
	Deep Fine-textured	Shallow Coarse-textured	

HOW MUCH?

This depends on your reason for irrigating. If you want to germinate seed, soften a crust, cool the soil, or prevent frost damage, a very light irrigation is enough.

If you want to leach salts out of the soil or provide moisture for plant growth, a heavier irrigation is needed.

To Leach Salts

Leach salts out of your soil with a heavy irrigation. The extra water carries salts downward out of the root zone as shown in Figure 2. The amount of water needed depends on the amount of salt, soil porosity, and the crop to be grown.

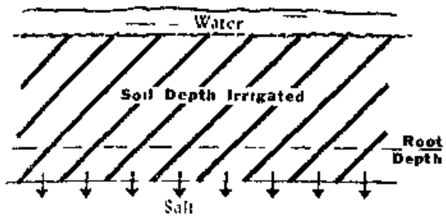

Figure 2. Leaching Salts out of Root Zone

To Provide Moisture For Plants

If you irrigate a growing crop **at the time it needs water,** use Table 2 to estimate the acre-inches per acre you must deliver to the field. Use more water if the plant and soil signs indicate irrigation is over-due.

For greater accuracy, use an auger to take samples of soil from each foot of the root zone. Look in Figure 3 for the description that fits each sample. Find the corresponding moisture deficiency on either side. (See pages 8 and 9).

Tabulate the results. Add together the inches needed for each foot of soil in the rooting zone of the crop to estimate the inches of water needed.

Increase the total about one-third to allow for losses.

EXAMPLE:

DEPTH (IN FEET)	TEXTURE	DESCRIPTION	INCHES OF WATER NEEDED
0-1	Loam	Small clods Crumble easily	1 5
1-2	Loam	Forms a weak ball	1 2
2-3	Loam	Forms a weak ball	1 2
3-4	Sandy Loam	Forms a weak ball	0 8
4-5	Sandy Loam	Makes a good ball	0.6
5-6	Sandy Loam	Makes a good ball	0 6
		Inches Needed in the Soil	5 9

Add 2 1 inches to allow for losses.
Total water needed 8 0 acre-inches per acre.

To find the total acre-inches needed for various lengths of run and border widths, use Table 3. For furrow irrigation, use Table 4.

Table 2. Delivery Requirements in Acre-Inches per Acre for Various Soil Textures and Plant Root Depths*.

Root Depth of Plants**	Soil Texture		
	Sandy	Medium	Fine
2 feet	2-3	3-4	4-5
4 feet	4-6	6-8	7-9
6 feet	6-9	9-12	10-13

* Based on 50% to 65% depletion of available moisture from the root zone and 60% application efficiency. For higher application efficiencies, decrease the delivery requirement accordingly.

** To wet the soil to half the depth of the root zone, apply about ¾ of the amount shown.

Table 3. Total Acre-Inches Needed per Border for Various Border Lengths and Widths With Different Delivery Requirements. (To the nearest one-half acre-inch)

Length (feet)	Width (feet)	Delivery Requirement (Acre-inches per acre from Table 2)					
		2	4	6	8	10	12
660	30	1.0	2.0	2.5	3.5	4.5	5.5
	40	1.0	2.5	3.5	5.0	6.0	7.5
	50	1.5	3.0	4.5	6.0	7.5	9.0
	75	2.5	4.5	7.0	9.0	11.5	13.5
	100	3.0	6.0	9.0	12.0	15.0	18.0
880	30	1.0	2.5	3.5	5.0	6.0	7.5
	40	1.5	3.0	5.0	6.5	8.0	9.5
	50	2.0	4.0	6.0	8.0	10.0	12.0
	75	3.0	6.0	9.0	12.0	15.0	18.0
	100	4.0	8.0	12.0	16.0	20.0	24.0
1320	30	2.0	3.5	5.5	7.5	9.0	11.0
	40	2.5	5.0	7.5	9.5	12.0	14.5
	50	3.0	6.0	9.0	12.0	15.0	18.0
	75	4.5	9.0	13.5	18.0	22.5	27.5
	100	6.0	12.0	18.0	24.0	30.5	36.5
2640	30	3.5	7.5	11.0	14.5	18.0	22.0
	40	5.0	9.5	14.5	19.5	24.0	29.0
	50	6.0	12.0	18.0	24.0	30.5	36.5
	75	9.0	18.0	27.5	36.5	45.5	54.5
	100	12.0	24.0	36.5	48.5	60.5	72.5

Table 4. Total Acre-Inches Needed per Set for Various Furrow Lengths, Numbers of Furrows, and Delivery Requirements (To the nearest one acre-inch).

Length (feet)	Number of 40-inch furrows	Delivery Requirement (Acre-inches per acre from Table 2)					
		2	4	6	8	10	12
660	50	5	10	15	20	25	30
	100	10	20	30	40	50	61
	150	15	30	45	61	76	91
	200	20	40	61	81	101	121
880	50	7	13	20	27	34	40
	100	13	27	40	54	67	81
	150	20	40	61	81	101	121
	200	27	54	81	108	135	162
1320	50	10	20	30	40	50	61
	100	20	40	61	81	101	121
	150	30	61	91	121	151	182
	200	40	81	121	162	202	242
2640	50	20	40	61	81	101	121
	100	40	81	121	162	202	242
	150	61	121	182	242	303	364
	200	81	162	242	323	404	485

You can find the acre-inches delivered by different stream size and time of set combinations in Table 5.

Table 5. Acre-Inches Delivered by Streams of Various Sizes in Different Time Periods

Stream Size			Time (hours)								
CFS[1]	GPM[2]	MI[3]	2	4	6	8	12	16	20	24	36
1.0	450	40	2	4	6	8	12	16	20	24	36
1.5	675	60	3	6	9	12	18	24	30	36	54
2.0	900	80	4	8	12	16	24	32	40	48	72
2.5	1125	100	5	10	15	20	30	40	50	60	90
3.0	1350	120	6	12	18	24	36	48	60	72	108
3.5	1575	140	7	14	21	28	42	56	70	84	126
4.0	1800	160	8	16	24	32	48	64	80	96	144
4.5	2025	180	9	18	27	36	54	72	90	108	162
5.0	2250	200	10	20	30	40	60	80	100	120	180
6.0	2700	240	12	24	36	48	72	96	120	144	216
7.0	3150	280	14	28	42	56	84	112	140	168	252
8.0	3600	320	16	32	48	64	96	128	160	192	288
9.0	4050	360	18	36	54	72	108	144	180	216	324
10.0	4500	400	20	40	60	80	120	160	200	240	360
12.0	5400	480	24	48	72	96	144	192	240	288	432
14.0	6300	560	28	56	84	112	168	224	280	336	504
16.0	7200	640	32	64	96	128	192	256	320	384	576

[1] Cubic feet per second.
[2] Gallons per minute.
[3] Arizona Miner's Inches

Many soils take water more slowly as the season progresses. During late June, July, and August, you may find it impractical to completely refill the soil to the depth of the roots. Store deep moisture with a pre-planting irrigation during the time the soil takes water more rapidly.

Young plants grown on beds must be irrigated until moisture has moved into the bed even though this often results in losses by deep seepage.

For sprinkler irrigation, estimate

(Continued on page 10)

Figure 3. Soil Moist

SOIL TEXTU

Moisture deficiency in./ft.	Coarse (loamy sand)	Light (sandy loam)
0.0	(field capacity) Leaves wet outline on hand when squeezed.	(field capacity) Leaves wet outline on hand; makes a short ribbon.
0.2		
	Appears moist; makes a weak ball.	Makes a hard ball.
0.4		
	Appears slightly moist. Sticks together slightly.	
0.6		Makes a good ball.
	Very dry, loose; flows through fingers. (Wilting point)	
0.8		Makes a weak ball.
1.0		Will not ball.
1.2		
		Wilting point.
1.4		
1.6		
1.8		
2.0		

[1] Adapted from "Field Method of Approximating Soil Moisture for Irrigation," by J

d Appearance Chart*
ASSIFICATION

Medium (loam)	Fine (clay loam)	Moisture deficiency in./ft.
(field capacity) Leaves a wet outline on hand; will ribbon out about one inch.	(field capacity) Leaves slight moisture on hand when squeezed; will ribbon out about two inches.	0.0
		0.2
Forms a plastic ball; slicks when rubbed.	Will slick and ribbon easily.	0.4
Forms a hard ball.	Will make a thick ribbon; may slick when rubbed.	0.6
Forms a good ball.	Makes a good ball.	0.8
		1.0
Forms a weak ball.	Will ball, small clods will flatten out rather than crumble	1.2
Small clods crumble fairly easily.	Clods crumble.	1.4
		1.6
Small clods are hard (wilting point)		1.8
	Clods are hard, cracked (wilting point)	2.0

L. Merriam, Transactions of the A.S.A.E., Vol. 3, No. 1, 1960.

the acre-inches needed per acre from Table 2 or Figure 3. Divide by the application rate in inches per hour to find the time of set.

Use a soil tube or probe a few days after an irrigation to see if moisture penetrated to the desired depth.

HOW?

Distribute Evenly

Delivering the correct amount of water is not enough; you must distribute it evenly.

System design is important for either sprinkler or surface irrigation. A well-designed sprinkler system assures relatively even distribution without an experienced irrigator. For surface irrigation, even distribution depends on system design and the skill of the irrigator.

To evaluate your surface irrigation, compare the total time water is on the soil at several different places down the border or furrow. You can do this by observing the time when water reaches each place and when it has all seeped into the soil.

For distribution to be even, the elapsed times must be approximately equal. This assumes all the field takes water at the same rate. If your soil is not uniform, try to keep hard spots under water longer than sandy streaks.

You may be able to get even distribution by adjusting the stream size and width of border or number of furrows. If not, consider a change in the length of run or slope, or both.

Use large streams for flat slopes, long runs, light irrigations and soils which take water rapidly.

Use small streams for steep slopes, short runs, heavy irrigations, and soils which take water slowly.

To Border Irrigate

Choose a combination of stream size and border width so the upper end is irrigated by the time the advancing stream approaches the lower end. At that time, move the water to the next border. The water in the first border will continue to move down the slope and complete the irrigation as shown in Figure 4.

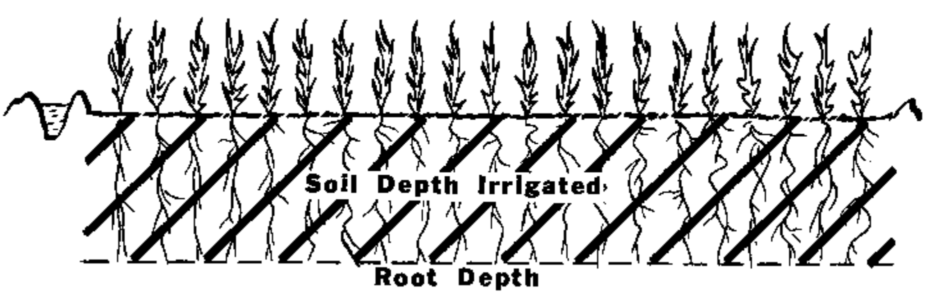

Figure 4. Correct Amount of Water, Evenly Distributed

On soils which take water slowly, moisture may not have penetrated very deeply at the upper end when the stream reaches the lower end. If you shut the water off at that time, none of the field will be irrigated adequately. As shown in **Figure 5,** plant growth will be limited.

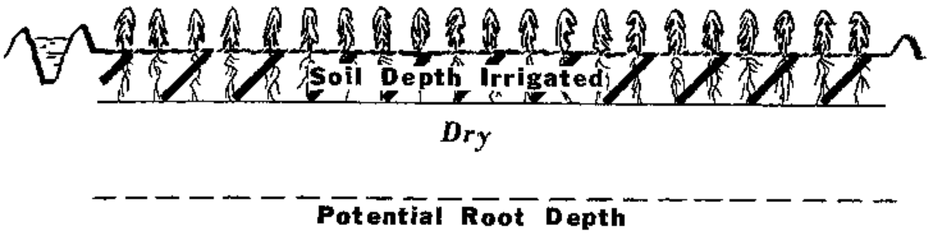

Figure 5. Water Evenly Distributed, But Not Enough

In an effort to obtain penetration, you may let the stream continue. This will cause greater penetration at the lower end. Excessive ponding or run-off may occur. (See Fig. 6.)

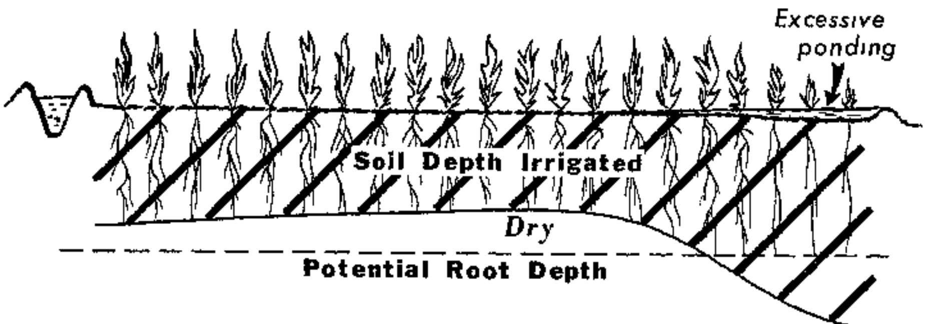

Figure 6. Excessive Ponding

Another way is to reduce the stream size when it approaches the end of the run and let it continue as long as necessary. In this way, you can reduce the amount of ponding or run-off.

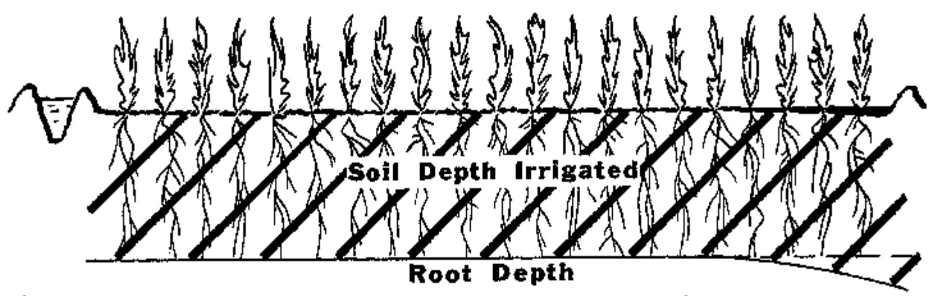

Figure 7. Correct Amount of Water, Nearly Uniform Distribution (Reduced Stream)

A smaller stream or wider border will tend to help.

If you still have trouble getting adequate penetration at the upper end without excessive ponding or run-off at the lower end, consider grading to a flatter slope.

On soils which take water rapidly, you are likely to have deep seepage losses at the upper end or too shallow an irrigation at the lower end. Figure 8 illustrates this condition.

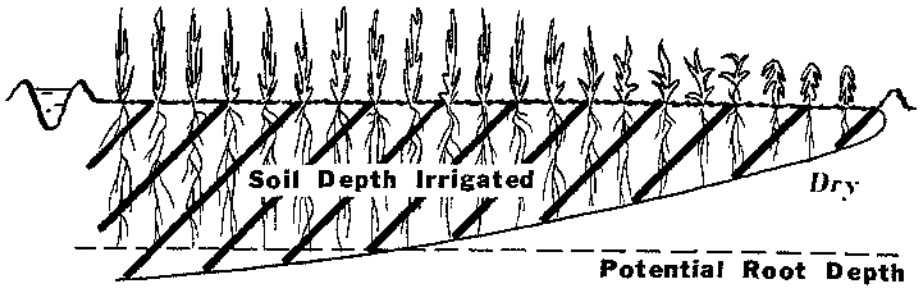

Figure 8. Too Deep at Upper End or Too Shallow at Lower End

You can partly correct this by letting the stream continue after it has reached the end of the border. Water ponds and moves downward into the root zone at the lower end. Notice from Figure 9 (Below) that a "Four-Fifths Zone" is likely to persist.

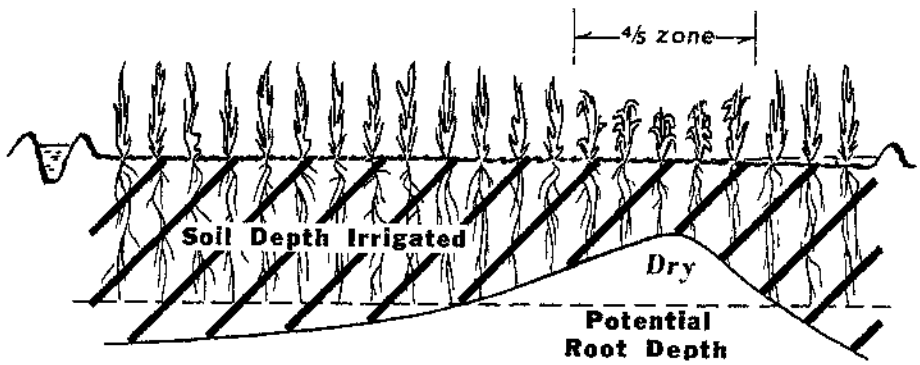

Figure 9. "Four-Fifths Zone"

In this case, try a larger stream or a narrower border. If that doesn't help, consider shortening the length of run.

To Furrow Irrigate

Slope has an important influence on selection of the procedure used to achieve even distribution. The best way is the one which keeps water on all parts of your field for equal periods of time.

Very Flat Slopes

On very flat slopes, water in furrows responds very much as it does in borders. You may be able to use a constant stream size and get even distribution. Follow the guides outlined for border irrigation.

Steep Slopes

Estimate the time water must be on the soil to provide the desired penetration. Try several non-erosive furrow stream sizes. Choose one which reaches the end of the furrow in one-fourth the estimated time or less. Change the set when water has been on the lower end for the required time.

For example, if water must be on the soil for 20 hours to provide penetration to the bottom of the root zone, the stream should reach the end of the furrow in 5 hours or less. The total set would be 25 hours.

To avoid excessive ponding or run-off, reduce the stream size when the water reaches the end of the furrow. If you don't want to do this, you may prefer to use a tail-water or pump-back system.

The purpose of the "one-fourth" rule is to get even distribution down the entire furrow. There is a tendency for water to be on the upper end longer than on the lower. By using a large stream at first, you can make the times more nearly equal. By reducing the stream size when it reaches the end, you can avoid excessive ponding or run-off. Figure 10 shows the result.

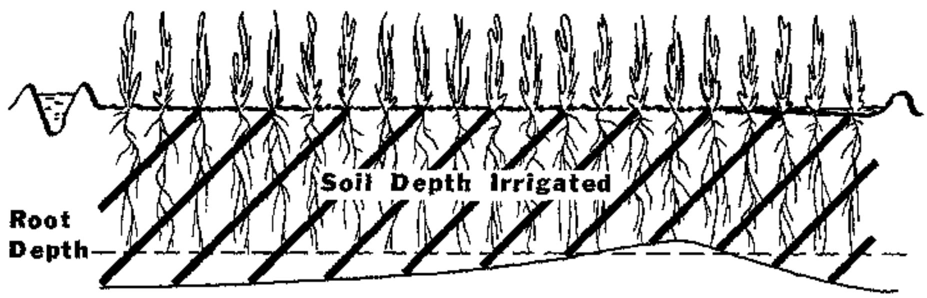

Figure 10. Correct Amount Nearly Evenly Distributed (Reduced Furrow Stream)

Moderate Slopes

Follow a procedure between the extremes used for very flat slopes and for steep slopes. Choose an initial stream which advances to the end of the furrow in less than the irrigating time required. For example, distribution may be acceptable if the initial stream advances to the end of the furrow in one-half the time required for the desired penetration.

Reduce the stream size when it reaches the end of the furrow to avoid excessive ponding or run-off. If you prefer, use a tail-water or pump-back system.

On soils which take water slowly, you'll need a small stream for a long time. Figure 11 shows what can happen if the time is too short and the stream too large. The only adequate penetration may be where water was ponded. Too much water will cause excessive ponding or run-off.

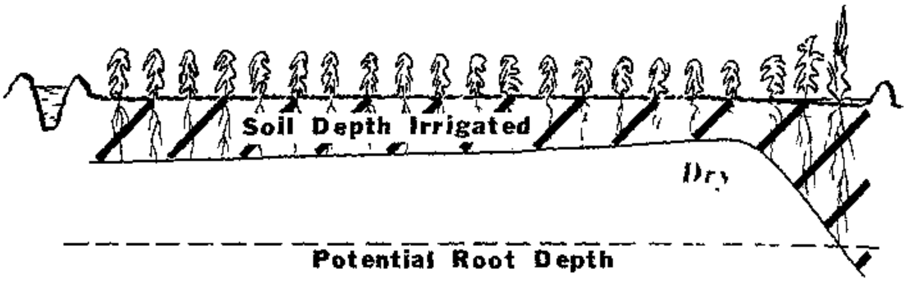

Figure 11. Poor Penetration Except in Ponded Area

Where tractor wheels have compacted the bottom of the furrow, a small stream will seep into the soil very slowly as indicated in Figure 12.

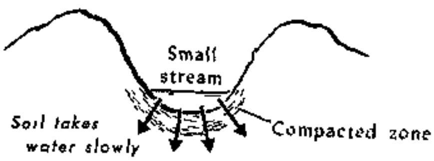

Figure 12. Small Stream, Compacted Furrow, Steep Slope

Consider grading the field to a flatter slope. This will cause the water to rise higher in the furrow and seep into the soil faster as shown in Figure 13.

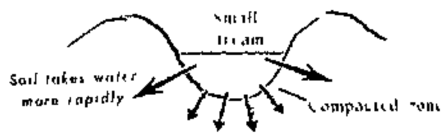

Figure 13. Small Stream, Compacted Furrow, Flat Slope

If your soil takes water rapidly, you'll need as large a stream as possible at first. Size of the maximum stream will be limited by erosion on steep slopes. On flat slopes, it will be limited by furrow capacity.

If the run is too long, you will tend to over-irrigate at the upper end and under-irrigate at the lower end. If you pond water at the lower end, you are still likely to have a

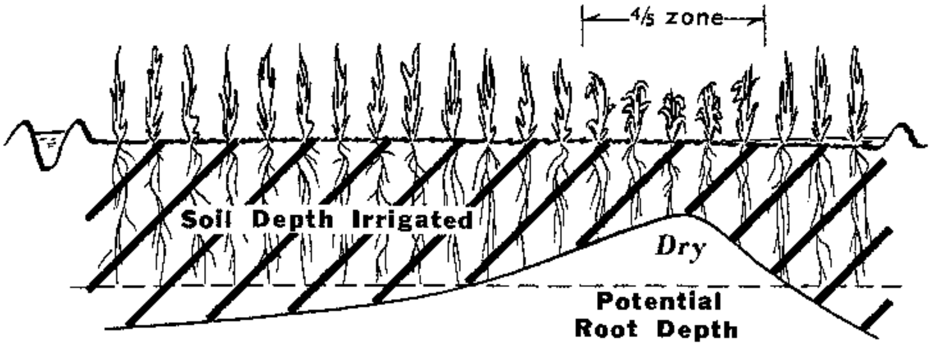

Figure 14. Too Long a Run

"four-fifths zone" develop where there isn't enough soil moisture.

To Basin Irrigate

To irrigate a basin with no fall in any direction, use as large a stream as possible without causing erosion. Water should cover the entire area in no longer than one-fourth the time it stands on the field. If it doesn't, consider making the basin smaller.

To Irrigate With Corrugations

Use the same guides for corrugation irrigation as for furrows.

Space corrugations so water will move into the areas between corrugations in about the time it penetrates to the desired depth. Usually you will need a wide spacing for fine-textured soils and a close spacing for sandy soils (see Figure 15).

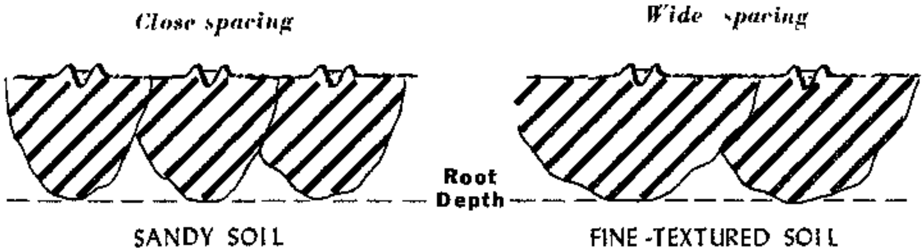

Figure 15. Corrugation Spacing

A few days after irrigation, use a soil probe or auger to determine how evenly water has penetrated in different parts of the field.

You may be limited in **WHEN, HOW MUCH,** and **HOW** you irrigate. Even so, the first step is to know what is best and come as close to this as possible.

Use these principles and guides as the basis for your decisions:

WHEN? Read the Plant and Soil Signs.

HOW MUCH? Apply according to the soil moisture deficiency in the root zone.

HOW? Use any procedure which permits even distribution of water. You can check this by comparing the time water is on the soil at different places in the border or furrow.

THE LAND-GRANT SYSTEM CENTENNIAL 1862-1962 THE UNIVERSITY OF ARIZONA

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