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TILLAGE PRACTICES FOR IRRIGATED SOILS

Agricultural Experiment Station
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SUMMARY

Limited tillage practices not only give higher yields because of better soil aeration and moisture penetration, but can save the grower much in the cost of seedbed preparation.

In general, any practice which tends to keep the soil open, permitting the ready movement of air and water through it, is most desirable. On the other hand, any practice which inhibits the movement of either air or water through the soil is not good. Every tillage operation either helps or retards this movement of air and water.

In growing a crop, normal tillage and irrigation cause a certain amount of compaction of the surface soil. Even a limited amount of compaction will cause a decrease in the water intake rate and inhibit normal root growth.

Breaking up and aerating this compacted layer is the first essential in good seedbed preparation. To accomplish this the land should either be plowed, knifed or chiseled. Just disking under the plant residue and not plowing, generally results in poor moisture penetration with a resulting poor yield.

After properly breaking the soil the less work done on the land before the pre-planting irrigation, the better. If the land is disked and floated before irrigation, it is much more difficult to get a deep penetration than if the irrigation is given with the land in a rough state. When tillage is practiced to the extent of powdering the soil to a dusty texture, irrigation water will tend to puddle the soil, making it difficult to prepare a good seedbed or get good plant growth.

TILLAGE PRACTICES FOR IRRIGATED SOILS

By KARL HARRIS, D. C. AEPLI, AND W. D. PEW [1]

INTRODUCTION

The soil is a living and dynamic mass of material. It is as much alive as are the plants which it supports. In order to keep it alive, fertile, and productive it must be handled so that beneficial bacteria and fungi flourish and earth worms work freely through it. To bring about this condition good soil management practices must be followed. If these are properly followed air and water will move through the soil easily and will encourage proper plant growth.

In modern times many problems have been created by the inventive attitude of man. The use of heavy equipment such as rubber-tired tractors, land planes, discs, etc., have created many soil problems heretofore unknown. The problems created by the acceptance of this new equipment have come about so slowly that they have often gone unnoticed before they became serious. Generally the first noticeable sign of trouble is the breakdown of soil structure resulting in poor water penetration and excessive run-off when irrigation water is applied.

What should tillage accomplish? To consider realistically the values of tillage the following aims should be kept in mind and merit consideration.

(1) To obtain a more favorable water intake rate and obtain a uniform distribution of water throughout the soil.
(2) To facilitate air movement throughout the soil.
(3) To incorporate crop residues.
(4) To obtain a seedbed so ideal that the highest percentage of seed germination and seedling establishment is accomplished.
(5) To eliminate weeds which rob crop plants of vital water and plant nutrients.
(6) To control or minimize erosion.

If any tillage operation does not accomplish one or more of the above purposes it is wasted. Likewise any operation which inhibits or interferes with accomplishing any of these purposes is harmful.

Before the tractor came into general use tillage implements were light and each operation time-consuming. With the advent of the tractor came a host of tools to assist the farmer in his production operations. These tools have brought about a complete revolution in farming methods. They have made it possible to accomplish a great deal more work in much less time. Heretofore it has required several weeks for a man to plow or cultivate a field that may now be done in a single day. The ease and the rapidity with which work can be done with this heavy equipment often encourages the farmer to

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Plate I.—Land poorly leveled. Even distribution of water impossible.

work his land more frequently than is necessary. These repeated unnecessary operations with such equipment can result in only one thing —compacted soil with greatly decreased water intake capacity.

LAND LEVELING

The purpose of land leveling is to obtain an even distribution of water throughout the field and to assist the irrigator in applying it with a minimum of labor and waste. Because land will be irrigated for many years to come, there is probably nothing that will pay as big a dividend as proper leveling. Fields that have high or low spots or where the slope is too great are usually marked by unprofitable yields and poor plant growth. Where flood irrigation is used high spots in a field of only three-fourths of an inch or more than the adjacent area may often produce only one-half the plant growth as the remainder of the field. This is especially true in the case of alfalfa. Why should so slight an irregularity cause such a noticeable effect? Undoubtedly the major cause of such a condition is the result of getting reduced water penetration on such spots. Obviously the water used in irrigating must fill the lower areas before it can be forced over the higher spots. When the application is stopped the applied water moves away from the high spots most quickly. The net result is that the water remains on the high spots for a much shorter period of time. Associated with sharp increases in slope is a marked reduction in plant growth. As the slope increases, the velocity of the water increases, causing the rearranging of soil particles which will seriously reduce the rate of water intake into the soil.

Although there is usually better water penetration in the lower spots of a given field, there are certain definite disadvantages to this situation, namely, water waste and sparse plant growth due to water logging and effectual drowning of plants growing in these areas. Irregularity of contour is one of the most important causes of water waste and may be a major cause of yields being less than those which the soil, water and climate are capable of producing. It is not the purpose of this bulletin to go into all the facts of land leveling. It will suffice to point out that with modern equipment large quantities of soil can be moved with economical expenditures when considered in the light of improved plant growth and production which will result. The Soil Conservation Service is set up to give advice and assistance on leveling problems.

Leveling is land preparation. It should be considered as such but should remain independent of seedbed preparation. The use of implements such as land planes and specially designed drags can well be used in the leveling process. Their use every year has been found to do considerable damage by bringing about soil compaction and pulverization resulting in decreased rates of water intake.

BREAKING THE SOIL

A certain amount of soil compaction is a natural result of growing any crop regardless of soil type or texture. The simple matter of running irrigation water over the surface of bare soil may cause structure breakdown. Even growing alfalfa and grain, if pastured, may cause enough compaction to greatly interfere with the free movement of air and water throughout the soil.

To eliminate this compacted layer, breaking the soil is the most effective and efficient method. Such a procedure includes any tillage which shatters the soil below the compacted zone providing free passage of water and allowing the air to circulate freely through it. The implements commonly used for this purpose are: plow, knife, chisel, subsoiler, and rotary tiller.

Breaking the soil is the most important of all tillage operations; but its beneficial effects can be easily nullified by improper handling of the soil afterwards. To be effective and serve its major purpose the soil must be broken below any compacted layer within the normal root zone. For the average farm operations this depth need not be over twelve inches. In certain instances, however, particularly where vegetables have been harvested under muddy conditions, the soil may be compacted to a depth of 18 to 20 inches. Where such practices have been followed the soil must be broken to a point below these depths. If this compacted layer is not broken it will be difficult, if not impossible, to get a proper deep moisture penetration in many soils. The effect of compaction on water intake is quite clearly shown in the figures and charts in the appendix. (Table I, Plates V, VI, VII, Figures 1, 2, and 3.)

Another important reason for the elimination of any compacted layers is that these layers contain less air than do normal soils. An abundance and free exchange of air within the soil is very important for root development. Further, by providing these more ideal soil conditions, plant nutrients in the soil may become more readily available for use by the growing crops, hence there could be a saving in fertilizer. Figures 1, 2, and 3 in the appendix show the relationship between compaction and the reduction of soil air.

Plate II.—Two-way moldboard plow.

PLOWING

There has been much discussion during recent years about the desirability of plowing. It is thought by a great number of people that many soils have been plowed that should never have been so treated. This reasoning may have stemmed from the fact that successful crop production can be carried out without plowing the soil where the water requirements are provided by rainfall. However, from the standpoint of irrigated agriculture none of the arguments raised thus far against plowing seem valid.

Two distinct types of plows are currently used. One of these, the disc plow, is most commonly used in the large scale farming operations in the state of Arizona. Perhaps the chief reason is the difficulty in obtaining heavy-duty moldboard type plows capable of doing the job in hard, dry soils. With the manufacture of heavier moldboard plows and the use of hydraulic lifts, this type is coming more and more into general use.

From the standpoint of keeping a field level the use of disc-type plows has not been satisfactory. After the use of this type of plow it becomes necessary to disc, drag, and land-plane these fields to re-establish the original level of the field. The costs arising therefrom are excessive and the amount of work done on the soil leaves it in such a powdered condition that irrigation water does not penetrate to the desirable depth. Once the land has been properly leveled a

Plate III.—Plowing 24 inches deep. Plowing to such depth is not often necessary.

much more satisfactory method of tilling the soil for the succeeding crop is to plow with a one-way moldboard-type plow. The number of bottoms mounted on such plows will be determined by the power available to pull them through the field at the desired depth. Simply plowing crosswise of the land, turning the soil in one direction, leaves the land in proper level and no further soil preparation is normally needed before irrigation except to replace the borders in the same location. Obviously such a minimum number of operations will cost much less than the conventional method and will leave the soil open to allow for free movement of essential air and water through the soil.

DEEP PLOWING

Deep plowing is that type which extends just below that normally affected by ordinary tillage operations. The principal purpose of deep plowing is to break up and aerate compacted layers or zones below the surface soil. The effects of this method of tillage are aimed toward improving the soil structure which has been broken down by tillage, irrigation, or harvesting operations. Deep plowing has no general limitations in respect to kinds or types of soil. It must be remembered, however, that such plowing should not be required or practiced any oftener than necessary to maintain a satisfactory permeability rate. Deep plowing is seldom required at greater depths than fourteen inches.

SUBSOIL PLOWING

Subsoil plowing is plowing below that depth which the soil is modified by any normal tillage operation. Its purpose is to break up deeply located cemented or compacted layers or deep layers of low water permeability. This practice has severe limitations in its practical use and application. Subsoil plowing should be used only under very special conditions and seldom where the soil profile is uniform. It may sometimes be used to advantage where clay pans or detrimental inhibiting layers exist below the zone of normal tillage or deep plowing but within depths that can be reached with specially constructed plows. It is normally considered a reclamation or land conditioning practice and should not be repeated often. Further, areas to be exposed to such treatment should be carefully investigated before its use is recommended or applied.

KNIFING

Of increasing importance is a practice called knifing. This operation is accomplished by means of a knife-like blade mounted horizontally and attached to the bottom of two vertical, long, very heavy-duty shanks. It is used to improve aeration and water intake by breaking, heaving, or lifting the soil. It is also used to advantage in cutting off roots of brush, in clearing new land, or in killing or crowning alfalfa stands in preparation for another crop. In its action the soil is loosened by fracturing or heaving but without turning or displacing it.

Knifing is often recommended instead of plowing because it has many advantages, a few of which are: (1) It does not adversely affect the level of a field; (2) It may be done while the soil is dry without danger of damaging soil structure; (3) For a given depth knifing takes less power than does plowing; and (4) It is much more effective in killing old alfalfa stands or brush. In knifing, one precaution should be pointed out, namely, that of breaking the soil into pieces which are too large to accomplish the desired results. If a narrow blade passes under the soil in a horizontal position it may pass under the compacted layer and not make a crack in pieces of soil as large as 3 feet square. Unbroken pieces of this size may accomplish the job of letting the water into the soil but leaves the surface soil in poor physical condition which will interfere with proper seedling growth.

CHISELING

The operation of soil chiseling is normally used for the purpose of breaking up hard or compacted layers in the zone modified by cultivation. It is performed by various types of implements having one or more narrow pointed teeth capable of being extended into the soil at varying depths. These teeth may or may not be equipped with sweeps but should be distinguished from a knifing implement in that the shanks of the latter are connected by a knife-like blade. Where sweeps are used instead of the connecting knife the sweeps are very wide and the whole soil area is cut.

A thorough job of soil chiseling should help to obtain a better moisture penetration in pastures or old alfalfa fields. In general it has limited application in breaking the soil as a step in seed bed preparation.

SUBSOILING

Subsoiling is tillage below the zone modified by ordinary tillage operations. Subsoiling is an ambiguous term as it is generally used and includes many types of tillage operations. As defined here it includes all tillage operations which go below the normal tillage zone regardless of the type of implement used. Subsoiling has serious limitations from an economy standpoint and should be recommended only in those cases where reclamation or special land conditioning practices are required.

ROTARY TILLER

Rotary tillers are tillage implements designed to utilize the rotary action of tough steel tines for soil breaking action. The tines revolve in unison and are rotated at varying speeds depending on the setting used. Power for the revolving motion may be from one or two sources, depending on the make and size of the tiller. Certain tillers are powered by a separate engine mounted directly on the implement. In this case the engine powers only the tines and is not used to move the implement through the field. Power to move such equipment through the field is derived from a separate wheel or track laying tractor. Other types are moved through the field by the same engine which powers the tine action.

The underlying principle of the rotary tiller is to chop, beat, and mix the soil through the action of the tines as the machine moves through the field. Such action results in a thorough mixing of the soil to the tilled depth. Obviously there are advantages and certain definite disadvantages in its use. The mechanical principle involved can best be utilized where large quantities of crop residue remain after a crop is harvested which should be incorporated into the soil. In this respect rotary tillers do an excellent job. In such an operation the surface soil is left in such a fine dusty condition that water penetration is seriously retarded. Therefore, it is recommended that this type of tiller be used only in the job for which it is best adapted, namely, in the incorporation of crop residue into the surface few inches of soil. Further, when using it for this purpose the depth of tillage should be as shallow as possible. After the use of the implement the soil should be plowed to a depth well below that which is affected by the rotary tiller to enhance better water penetration.

TILLAGE AFTER PLOWING AND BEFORE PRE-PLANTING IRRIGATION

Tillage after plowing and before pre-planting irrigation includes going over the land one or more times with implements to pulverize the clods. This having been completed, a float or harrow is used to smooth the soil still more. To eliminate the small irregularities a land plane is often applied to the field parallel or at right angles to the direction of water flow. After all this work, the field is either furrowed out or borders made, depending on the crop to be planted. Following such treatment the water should spread evenly across the field. At this point the obvious question one should ask is: Are all

Plate IV.—After an irrigation is given to a field in this rough condition, all the work needed to prepare a good seedbed is to apply a light drag or harrow.

of these operations necessary and do they aid the irrigation water in the purpose for which it is applied? With the purpose of an irrigation being to get water into the soil the answer is NO. Merely encouraging an even and rapid flow of water over the field without getting the water into the soil is certainly overlooking the real value of irrigation.

The widespread belief that working the soil while dry will do no harm is far from the truth. Tests made on the University Farms and elsewhere have shown that tillage on the dry side generally tends to destroy structure. Tillage done while the soil is dry breaks the soil into small particles or aggregates. When irrigation water is applied fine particles of soil are carried into the openings among the larger particles causing a closure or cementing of the soil surface. Such a closure reduces the water intake and reduces the air movement into the soil. Therefore, after the initial tillage operation is accomplished the least amount of work done on the land before the pre-planting irrigation the better will be the resulting soil structure and crop responses.

SEEDBED PREPARATION

Dating back to the days when the authors of this publication were just old enough to observe farming operations, the only farm power available was horses. In those days little consideration was given to land preparation prior to the planting of crops. This lack of emphasis on land preparation stems from the fact that adequate power and time were not available to accomplish the necessary operation in a thorough and timely fashion.

As time advanced and with the purchase of tractors and tractor-drawn machinery, more attention was given to what was then considered adequate soil tillage and seedbed preparation. This period was marked by the belief that the farmer who worked his soil to a fine dusty mulch through the excessive use of the newly developed implements was considered the best operator. Of course it must be remembered that prior to this era the soil was in a more or less virgin state and had not been compacted through machine operations in preparing for crop production. From time to time more modern machinery continued to be developed and used by the farmers. It was during this period that rubber-tired tractors came into prominence. These tractors so equipped, created undue compaction, especially where repeated trips were made in seedbed preparation. After many years of using these tillage methods with this modern machinery, the land was so affected that it absorbed water only very slowly or not at all.

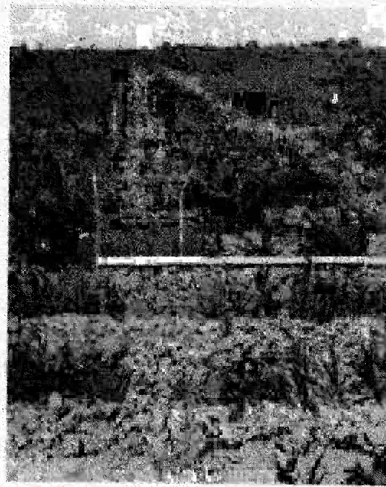

Plate V.—Sorghum field west of Glendale, Arizona. Pick-up driven over field three years before picture. Soil powder dry at time truck was driven across field.

ROUGH TILLAGE

With the creation of these conditions it became obvious that improved soil tillage and seedbed preparation methods would be neces-

Plate VI.—Cotton field south of Mesa, Arizona. Note no cotton growing where tractor wheels have run.

sary if the soil was to be returned to its original productive state. Through research, a simple but effective soil preparation program for general field crop production has been developed. This consists of plowing and irrigating the soil in the rough [2] without further preparation. As soon as the soil is sufficiently dry on the surface a light drag is used to break up the remaining rough lumps or clods of soil, thus leaving the planting surface smooth. This means that only one operation rather than several after the irrigation leaves the soil in ideal condition for drilling alfalfa and small grains. For row crops such as cotton, corn, and sorghums, a light harrowing after dragging is needed to allow for ease in placing the planter shoes at the proper depth for seed placement. The cost of seedbed preparation is far less than that incurred in the usual previously accepted practice and leaves the soil in much better tilth.

In the case of vegetables, other variations of the first discussed plan are necessary. These changes become necessary in view of the methods used in planting and irrigating and the small size of most vegetable seeds. It is of utmost importance in such crop production that the elevated seedbeds used in planting be as free from irregularities and level as can be obtained without undue working of the soil. This prevents the water used in irrigating from covering the bed surface where the seeds are planted. To accomplish this it is suggested that after the pre-planting irrigation the land be given a single deep disking. This will facilitate drying of the soil in preparing for furrowing or listing, destroy germinating weed seeds, and allow for removal of the border used in the pre-planting flooding irrigation. When the soil has had a chance to air-out and become sufficiently dry in the upper 6 inches or so, a light float or drag is applied, being drawn at an angle different from that to be used in planting, prior to listing. This having been accomplished, the field is ready for furrowing, seeding, and irrigating for seed germination. In spite of the precision necessary in preparing soil for vegetable production, under no circumstances should more tillage operations be made than are absolutely necessary.

CULTIVATION

Too frequent cultivation is an expensive mistake. Today cultivation is considered essential only for the control of weeds which compete with the crops for moisture and plant nutrients. The beneficial effects of cultivation merely to establish a mulch is of doubtful value since mulching more often than not interferes with and usually reduces water penetration of subsequent irrigations. Where row crops are planted and the soil has become seriously infested with weed seeds, it is essential that proper cultivation be practiced. It is deemed advisable to make each cultivation as effective as possible in order that the number of cultivations necessary be kept at a minimum. This will facilitate remaining off the soil as much as possible with heavy equipment which is the principal cause of soil compaction.

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[2] Rough tillage is tillage where no smoothing or pulverizing operations are performed after regular or deep plowing, or knifing, etc., prior to irrigation.

Irrigated with River Water

A—Plowed, disked, harrowed, irrigated, disked, harrowed and planted.
Yield: 3,900 lb. barley per acre.

Seed broadcast on plowed land and irrigated.
Yield: 4,350 lb. barley per acre.

Irrigated with Well Water — 4,017 PPM Salt

B—Plowed, disked, harrowed, irrigated, disked, harrowed and planted.
Yield: 1,400 lb. barley per acre.

Seed broadcast on plowed land and irrigated.
Yield: 3,550 bl. barley per acre.

Plate VII.—Effect of tillage on yield of barley on a silty clay soil irrigated with two classes of water.—Safford, Arizona.

DO

Practices which tend to keep the soil open allowing ready movement of air and water through it.

1. Plow below compacted layer.
2. Air out after plowing as long as possible before giving pre-planting irrigation.
3. Return all possible organic matter to soil.
   a. Plant residue
   b. Animal manure
   c. Green manure
4. Crop rotation.
   a. Legumes
   b. Cash crop
   c. Fiber-root crops
5. Give only one heavy pre-planting irrigation instead of two or more light ones.
6. Do minimum amount of preparation on land between plowing and pre-planting irrigation.
7. After irrigation, reduce work on seedbed preparation to absolute minimum. Leave cloddy.
8. After crop is planted give minimum cultivation. Cultivate only for weed control.

DON'T

Practices which tend to retard movement of air and water through the soil.

1. Plow the same depth year after year.
2. Apply the pre-planting irrigation soon after plowing.
3. Burn off all stubble and other plant residue.
4. Use a one crop system, especially row crops.
5. Give several light pre-planting irrigations.
6. Work surface soil up into dusty mulch by excessive working with disk, float or land plane.
7. Make a powdered seedbed by use of disk and float or land plane after irrigating.
8. Cultivate to maintain dust mulch which may require two cultivations between each irrigation.

APPENDIX

TABLE 1.—EFFECT OF VARIOUS CULTURAL AND TILLAGE PRACTICES ON COMPACTION AND INTAKE RATES AT VARIOUS LOCATIONS IN ARIZONA.

Location	Soil Type	Treatment	Ring Setting	Intake Rate Range	Intake Rate Av. of 10 Samples
				In/Hr	In/Hr
Safford	Silty Clay Loam	Rough tillage[1]	Surface[3]	0.90-1.00	0.92
		Smooth tillage[2]	Surface[3]	0.06-0.10	0.09
Mesa	Clay Loam	Rough tillage[1]	Surface[3]	0.70-1.40	1.07
		Smooth tillage[2]	Surface[3]	0.20-0.50	0.28
Yuma Valley	Silty Clay Loam	Rough tillage[1]	Surface[3]	0.35-0.60	0.46
		Smooth tillage[2]	Surface[3]	0.08-1.00	0.09
Mesa	Clay Loam	Plowed (only)	Surface[3]	1.30-1.90	1.56
		Plow, disk, irrigate	Surface[3]	0.65-0.90	0.80
		Plow, disk, irrigate, drag, plant and irrigate twice	Surface[3]	0.40-0.50	0.43
Stanfield	Clay Loam	Plowed (only)	Surface[3]	3.00-4.70	3.80
		Plowed, planed, disced	Surface[3]	0.20-0.30	0.25
		Above plots furrowed and preplanting irrigation	Surface[3]	0.06-0.10	0.08
			1 foot[4]	0.40-0.80	0.53
		Above plots after cotton irrigated and cultivated twice	Surface[3]	0.03-0.06	0.04
			1 foot[4]	0.40-0.50	0.45
Phoenix (Adjacent fields)	Clay Loam	Vacant field puddled by rains	Surface[3]	0.40-0.60	0.44
			1 foot[4]	2.50-2.90	2.66
		Com. vegetable field	Surface[3]	0.03-0.08	0.04
			1 foot[4]	2.20-2.90	2.68
		Sorghum field	Surface[3]	0.80-1.90	1.08
			1 foot[4]	2.30-3.00	2.62
Tempe	Clay Loam	Between tractor wheels	Surface[3]	0.17-0.35	0.24
		In tractor tracks	Surface[3]	0.08-0.14	0.11
		Cattle puddled soil	Surface[3]	0.01-0.09	0.05
		Less puddled	Surface[3]	0.16-0.25	0.21

[1] Rough Tillage—Land plowed, irrigated and planted without additional work.
[2] Smooth Tillage—Land plowed, disced, floated, irrigated, disced and then planted.
[3] Single infiltration rings driven into soil 6 inches.
[4] Top foot of soil removed and rings driven into soil an additional 6 inches.

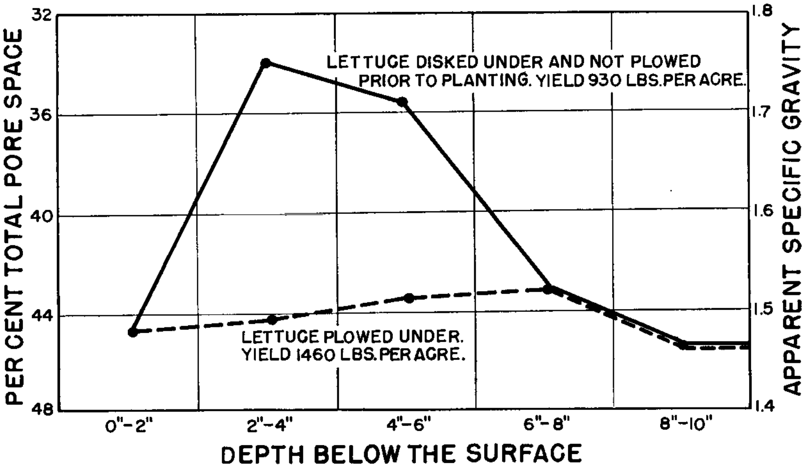

Figure 1 — Effect of different methods of seedbed preparation on apparent specific gravity and total pore space. Planted to soybeans on a clay loam soil following a lettuce crop. Mesa — 1944.

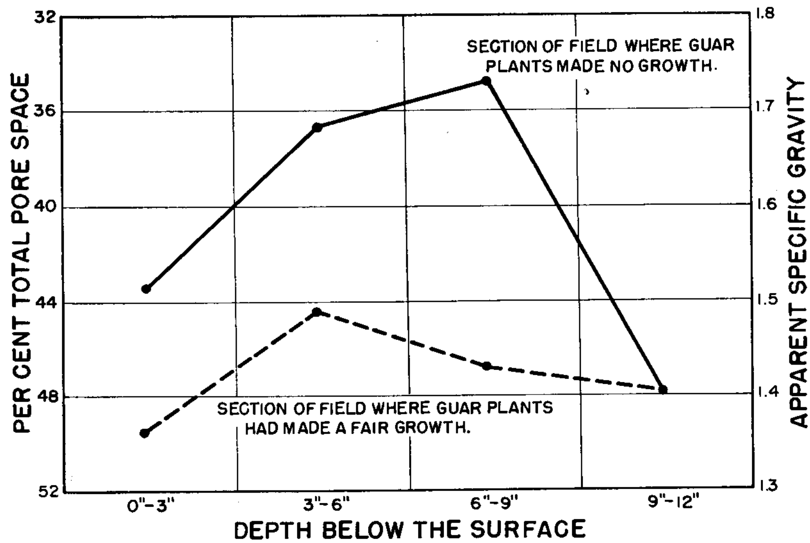

Figure 2 — Effect of soil compaction with its decrease in per cent total pore space in the soil on the growth of Guar. Silty clay soil — Yuma Valley.

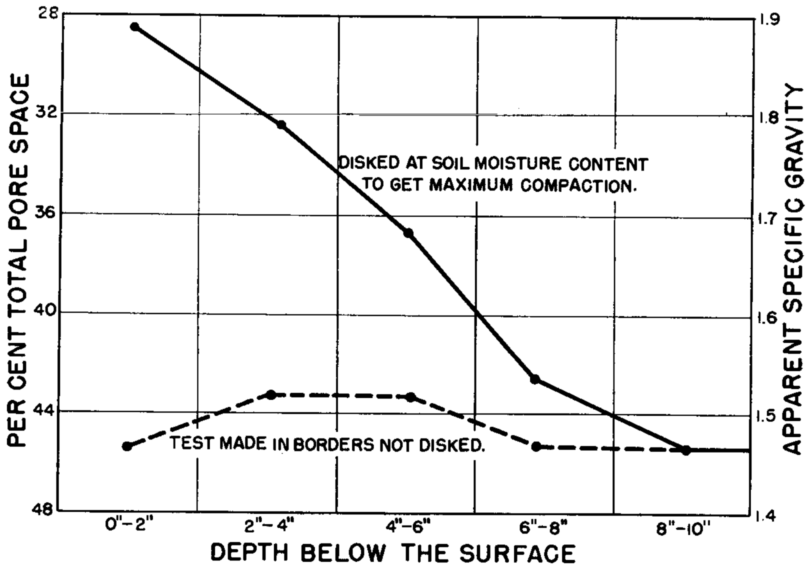

Figure 3 — Effect of disking a clay loam soil low in organic matter at a moisture content to get maximum compaction.

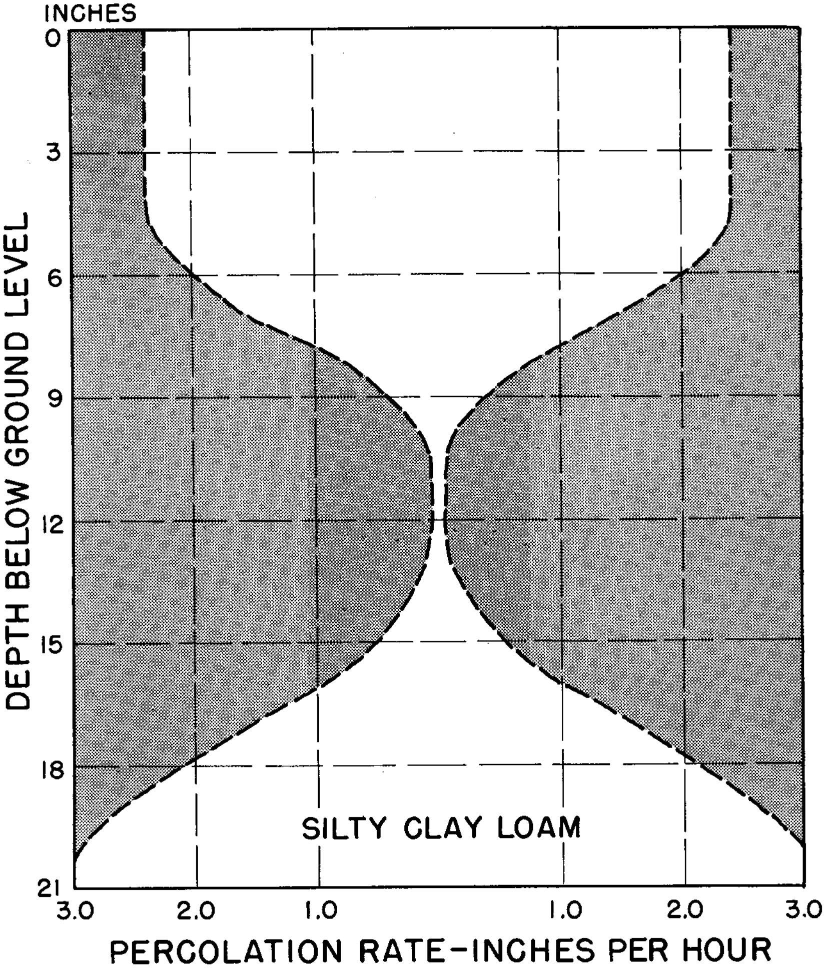

Figure 4 — Percolation rates in field of yellow lettuce. North of Phoenix.

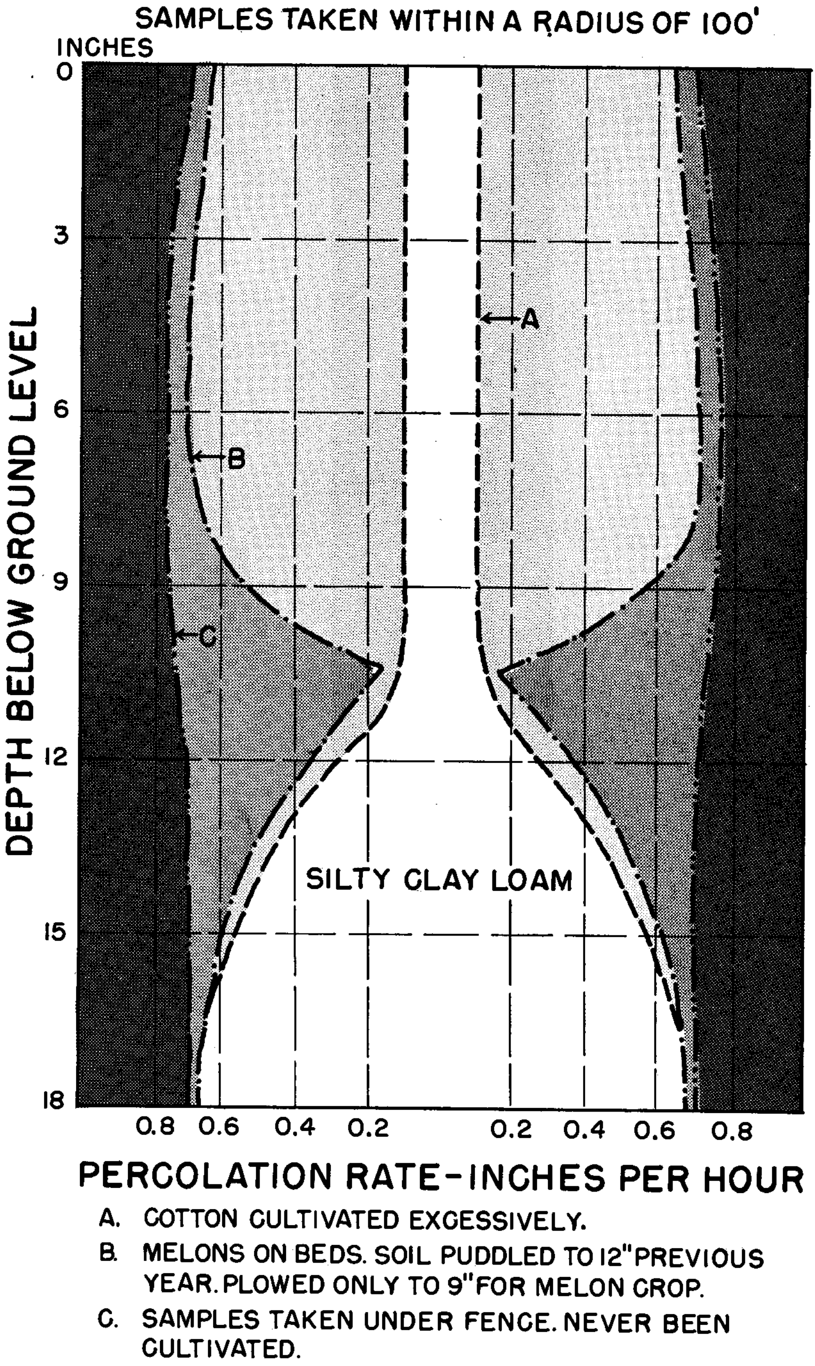

Figure 5 — Water percolation rates under three types of management.

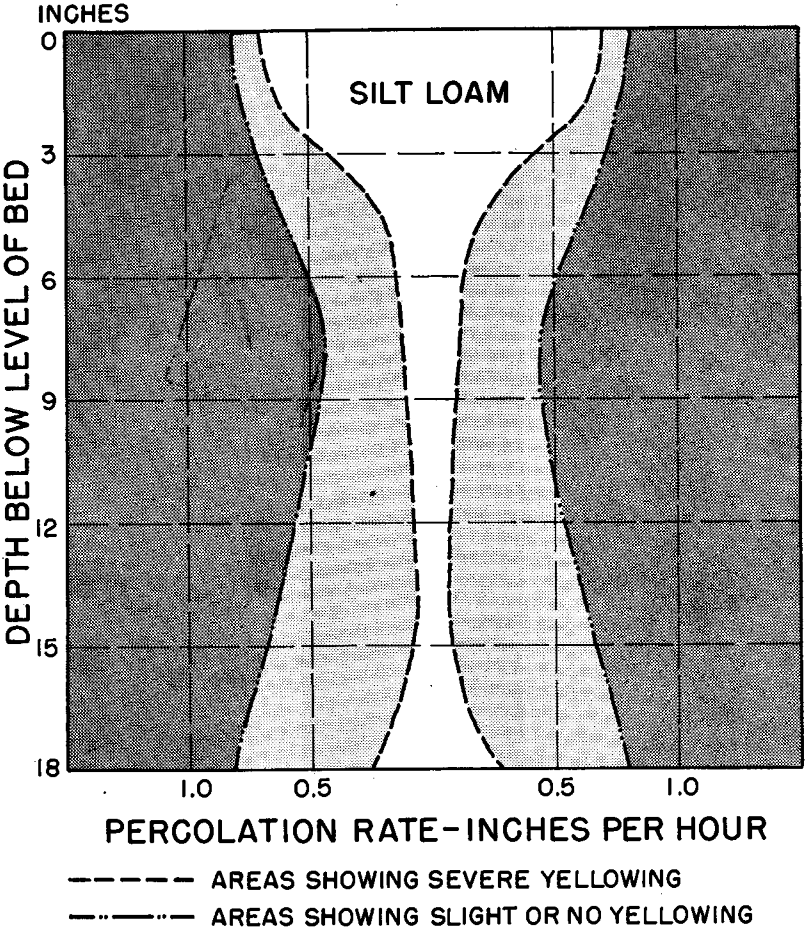

Figure 6 — Water percolation rates in areas of field with yellow and normal appearing lettuce. Northwest of Phoenix.

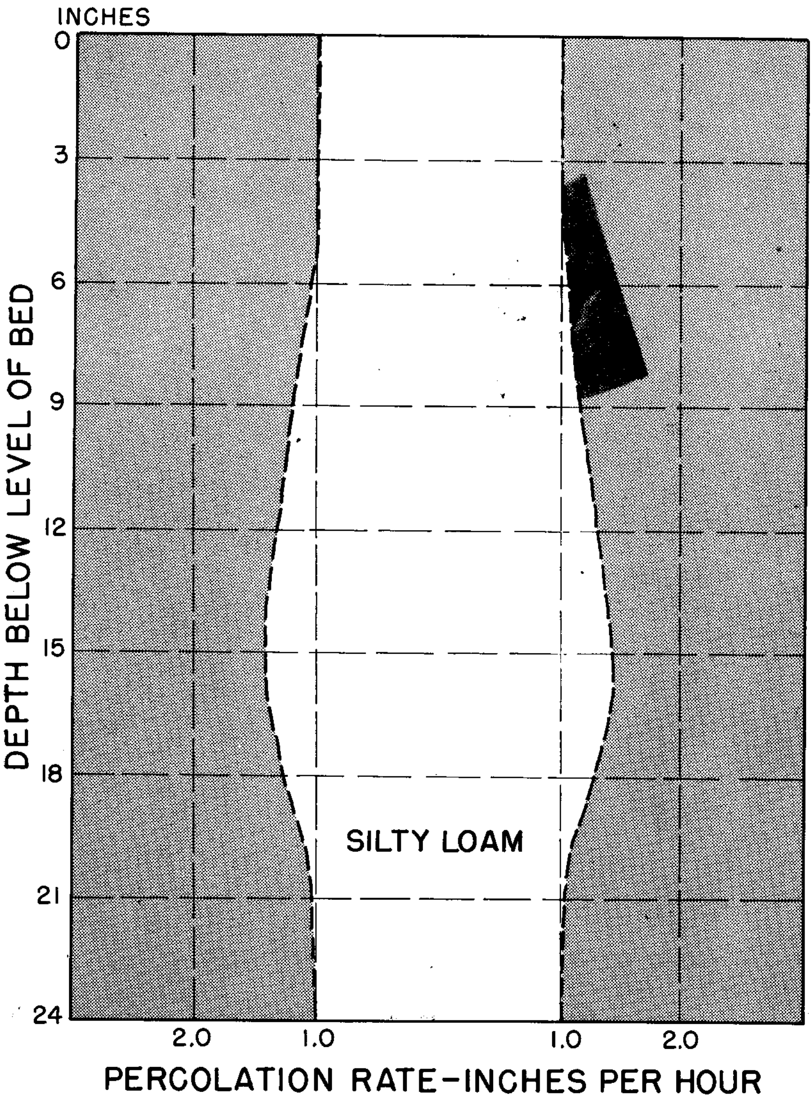

Figure 7 — Water percolation rates in field with normal lettuce. West of Phoenix.

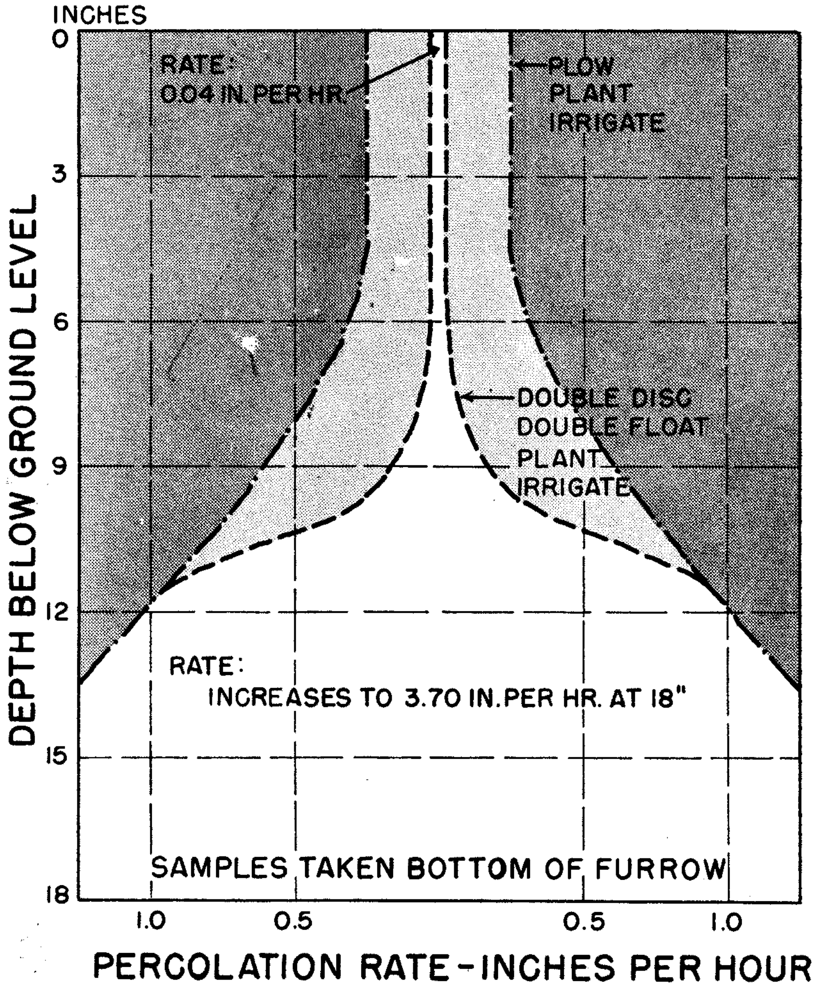

Figure 8 — Water percolation rates in lettuce field under two types of seedbed preparation. Mesa Farm, Field A — 1952.

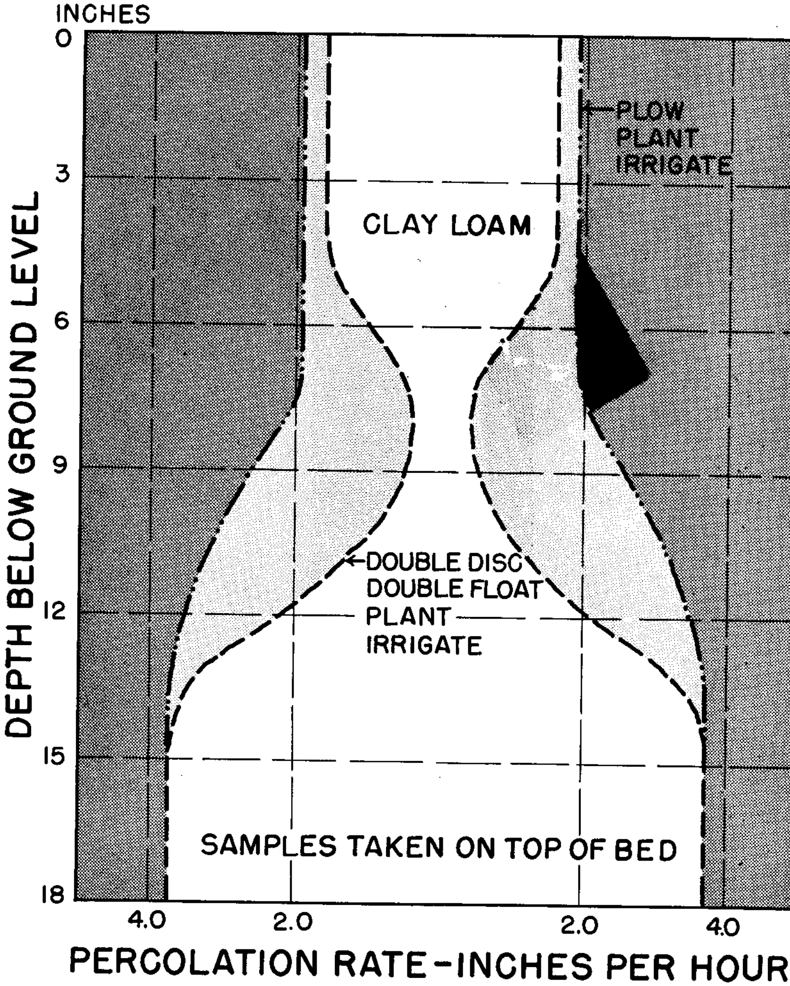

Figure 9 — Water percolation rates in lettuce field under two types of seedbed preparation. Mesa Farm, Field A — 1952.

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