Water Logging and Salinity as Factors Limiting Agricultural Production in West Pakistan

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There has been a constant decrease in yield of crops in West Pakistan although the area under crops registered an appreciable increase. The main cause of decrease in productivity is the accumulation of salts within the root zone of crops. The rise of sub soil water level to the root zone is another cause of decrease in productivity.

In general the effect of salinity and water logging on plant growth is similar. This results in the decrease of the physiological availability of water to the plants by way of either higher osmotic pressure or rendering the roots inactive on account of non-availability of oxygen or air. In this context the following aspects needs to be considered :

(*a*) Effect of increase of osmotic pressure of the soil solution during plant growth.

(*b*) Effect of the accumulated toxic quantity of various ions within the plants as a result of the increase of these ions in the more concentrated soil solution.

(*c*) Effect of waterlogging on plant growth due to the formation of anerobic conditions.

There is experimental data to show that plant growth is inhibited due to the accumulation of neutral salts in the substrata. The salts increase the osmotic pressure of soil solution with a consequent decrease in the water available.

In the presence of salines, the structure of soil tends to become unstable bringing about conditions of lower water permeability, poor aeration and unworkable tilth. Different ions have different effects of toxicity. Thus magnesium ions are more toxic than calcium. The general effect of a high salt content in the soil is to give a dwarfed, stunted plant and 20% or more decrease in yield of the crop can be due to salts without the salt damage being

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apparent. As the salts content goes higher the leaves of crop become dull coloured and often bluish green and they become coated with a waxi deposit.

Presence of high amounts of salts in the root zone of the plants greatly reduces their power of absorbing water. Hayward and Spurr have shown that maize roots absorb water at only one third the rate from a solution of osmotic pressure 4.8 atmospheres as from one at 0.8 atmosphere.

As a result of their work, Magistad and co-workers at the Regional salinity laboratory on the relation between the osmotic pressure of the soil solution around the plant roots and the growth of crop, have concluded that there is a linear relation between the reduction in yield and the osmotic pressure of the solution. Gauch and Wadleigh observed the same phenomenon in case of Beans.

Gauch and Magistad showed that the yield of the lucerne was reduced about 10% for each increase of one atmosphere in the osmotic pressure. Beans growing in a solution of osmotic pressure 4.4 atmosphere only give 20% while cotton and sugarcane give 70% of their yield when growing in 0.4 atmosphere solution.

Eaton observed the toxic effects of chloride and sulphate ions and inferred that the tolerance of different plants vary with the type of salts, their concentrations and the weather conditions.

Effect of increased salt concentration on the growth of alfalfa, oats and wheat grown in saline soils in Canada was observed by Doughty and Stalwick. A gradual decrease in crop yield with increase in salt concentration was recorded. As the salts increase from .4% to 1.09% the yield decreased from 77% to 33%. Alfalfa was found to be tolerant than oats and wheat.

As a result of their study Viehmenyer and Hendrickson consider the zone of available moisture to be bounded by field capacity and permanent wilting percentage. This moisture stress is, however, effected by salinity which in turn has a significant relation to growth and relative salt tolerance of plants. Wadleigh and Gauch observed that leaf alongation of cotton stopped when total soil moisture stress in a saline soil reached about 15 atmosphere.

It is thus clear that one of the main effects of moderate level of soil salinity is to limit water supply to the plant by increasing the osmotic pressure of the soil solution. This effect is intensified by an increase in soil moisture tension and the combined effect, total soil moisture stress conditions the growth of plants.

It is now believed that greater the salt content of the soil, the less water crop can remove from it before it begins to suffer from water shortage. Soils with a high salt content require, therefore, more frequent irrigation than similar soils of low salt content.

Tolerance of plants is usually low when they are young and high when established. The plants may be able to keep alive at high salt content but make very little growth under these conditions. Very recently in western states of America crops have been graded into 3 categories, tolerant, moderately tolerant and sensitive to plants as given in the following table :

Good tolerance	Moderate tolerance	Sensitive
Date	Pomegranate Fig and Olive Grape.	Grape fruit, Pear, Almond, Apricot and Peach Apple and Plum, Orange and Lemon.
Sugar and Fodderbeet, Milo, Rape and Kale Cotton.	Flax, Sorghum, Barley, Oats, Rye, Rice, Sunflower, Wheat.	Vetch, Pea, Potato, Bean.
Bermuda grass, Rhodes grass, Rye-grass, Western wheat grass.	Lucerne, Sweet clover, Strawberry clover, Sudan grass, Cereals for hay.	Red and white clover.

Dates, Sugarbeet, Milo, Cotton and some grasses are considered to be very tolerant to salts while peas, beans and most clovers are in the sensitive group. Similarly different varieties of a plant particularly cotton and strawberry clovers have different salt tolerance.

In Eastern countries potatoes, cowpeas and maize are considered salt sensitive and cucumbers, sunflowers and field peas are salt tolerant.

Stedman-Davies is of the opinion that adding Nitrogen and phosphate to a soil may increase the resistance of the crop to salts, but the tolerance will certainly be found to depend upon climate because the temperature effect soil conditions which in turn effect the development of the root system.

On their work on the amount of salt the soil can retain before the crops are affected, Magistad and Reitemeier showed that if the soil solution contains less than 0.4% dissolved salts, no crop suffer from salt trouble. The safe contents of salts in the soil solution may be taken up to 3000 ppm of the salts or less than 4 millimhos/cm. But if the salt content exceeds 5000 ppm or the conductivity 8 millimhos/cm. then only salt tolerant crops will grow and their yields are likely to be reduced and if the salt contents exceed 10,000 ppm or the conductivity exceeds 15 millimhos/cm. no crops are likely to give economic yields.

The average yield per acre of wheat which is the staple diet of the people of West Pakistan was 10.7 maunds in 1947-48 has gone down to 9.6 maunds in 1958-59. The position in respect of other crops is as under :

Crop	Yield (Mds./acre)	Yield (Mds./acre)
	1947-48	1958-59
Gram	6.8	5.8
Rice	10.5	9.2
Sugarcane (as gur)	35.2	30.0

The main cause of this decrease in yield is the accumulation of the salines in the root zone of the crops. There appears an appreciable effect of the increase in cropping intensity on the formation of salines. The observations of Punjab soil profile indicate that with a water table depth of 5′ the land develops salinity after 3 years under the prevalent high water duty in West Pakistan, land having 10′ and beyond 10′ water table may remain under production for 5 and 8 years respectively. The two problems of salinity—alkalinity and water logging under West Pakistan conditions are inseparable and it is thus essential that for better salinity control efficient drainage should simultaneously be adopted so as to keep the subsoil water level at a reasonable depth for the development of roots.

Laboratory and field scale experiments in the reclamation farms were carried out during the last two decades to see the effects of salinity and water-logging on agricultural production.

The salt tolerance studies undertaken in the Laboratories showed that 0.2% total salt contents commonly taken as the critical value between good and deteriorated soil by no means holds true for all salts and all crops. For wheat variety C 591 the critical value of sodium chloride was 0.3% salt on dry soil basis and for sodium sulphate this value was 0.7 and 0.8%. With 1 : 1 mixture of sodium chloride and sodium sulphate the value was between 0.4 and 0.5%.

For the mineral contents of irrigation water applied on semi field conditions it was found that there was decrease in yield with the increase in the conductivity of irrigation water. At lower conductivities up to 1500 micromhos/cm. the yields were not affected to any great extent. At higher conductivities the relation was well established. In case of wheat water of 3000 to 3500 conductivity decreases the yield by about 10%. A decrease of 6% was noticed in case of cotton at a conductivity of 1500 and a decrease of 60% has been observed in case when water of 8000 conductivity was used. The yield of sugarcane was affected by 6% at a conductivity of 1500 and a 50% reduction was observed when saline water of 8000 conductivity was used. Berseem like sugarcane is a high delta crop. Decrease in this case was noticed at 4% at a conductivity of 1500, and at 52% at a conductivity of 8000. Gram and Barley behave almost similar so far as the decrease in their productivity is concerned. At 15000 conductivity a decrease of 5% has been observed and at the highest conductivity of 10,000 the yield is reduced by 55%. At the end of the growing season, accumulation of salts is maximum in case of Berseem and least in case of Gram and Barley under the conditions of the experiment. The other crops are intermediate. Detailed results are reproduced in Figs. 1 to 5 :

Effects of High Soil Moisture

Crops are greatly damaged by water-logged conditions and the productivity of the soil is sufficiently decreased. The main problems that need attention in the water-logged areas are :

1. Effect of soil processes on plant growth.
2. Plant responses to water-logged conditions and its relation to basic physiological process of the plants affected.
3. Determination of relationship between damage by excessive soil moisture, prevalent temperature and the stage of growth.

Physical and Chemical Progresses in the Water-logged soils

In the water-logged areas, plant growth is restricted because the high soil moisture level interferes with soil aeration. A lot of work on this aspect has been done by Kramer and Russell. Water filling the soil pores not only displaces air but also obstructs gases diffusion. Thus gaseous exchange takes place only in the top inches of the soil and below that free oxygen is practically absent. The rapid disappearance of oxygen from flooded soils is generally accompanied by increase of carbon dioxide concentration which may constitute more than 50% of all the dissolved gases. This has been ascribed to micro-biological activities.

In paddy soil in India, the principal gas produced after submersion was Methane with smaller quantities of carbon dioxide and hydrogen. Low levels of oxygen may also result in soils with slow drainage immediately after irrigation or rain.

In some cases, it has been possible to establish a relation between the Oxidation-Reduction potential of a water-logged soil and its productivity. Bradfield found an indication of the yield as a result of oxidation-reduction optential in a poorly drained orchard soil. Waild and Randll found a corelation between oxidation—Reduction potential, specific conductence of ground water and the rate of forest growth in Wisconsin.

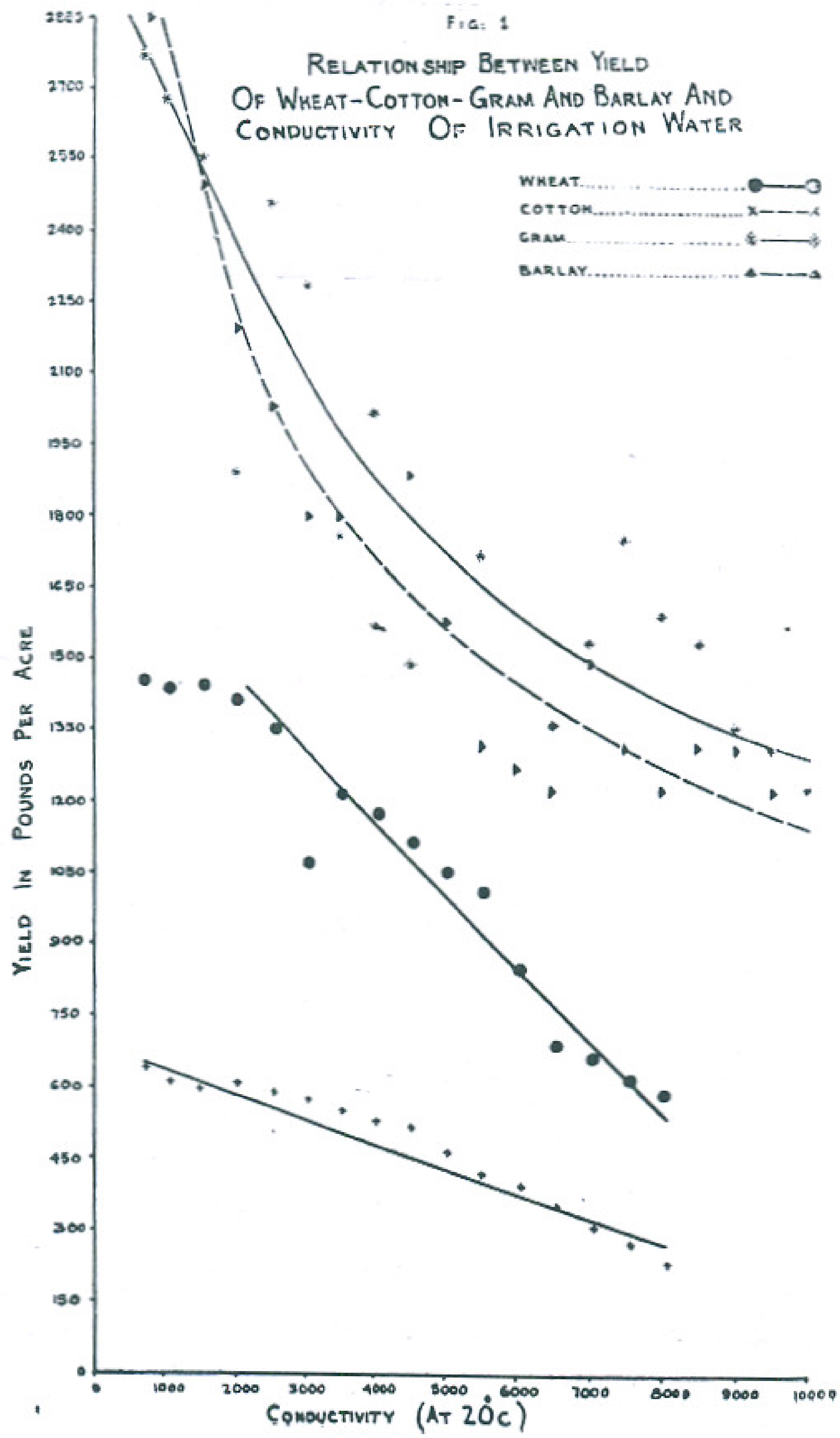
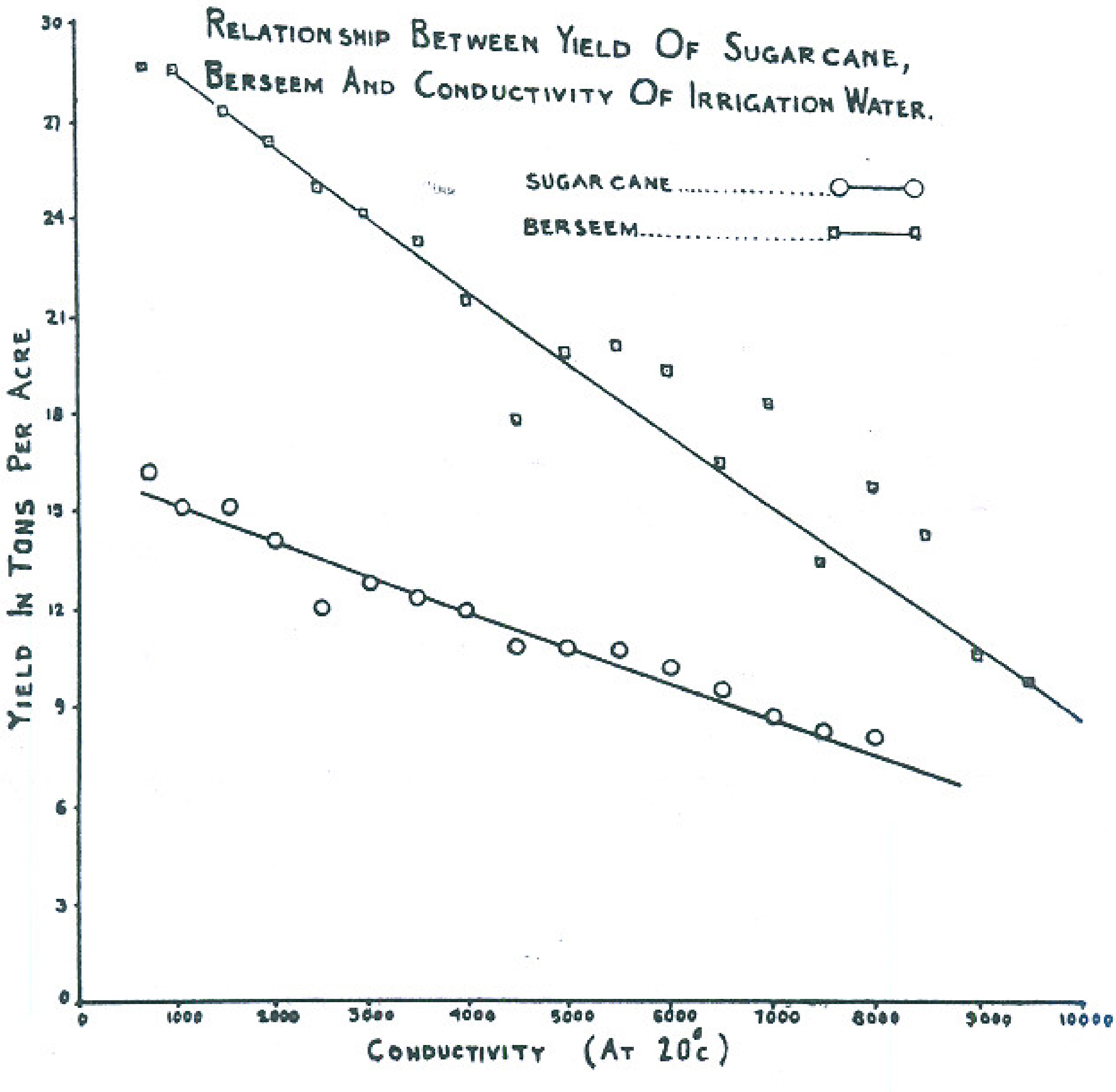


FIG: 1
RELATIONSHIP BETWEEN YIELD OF WHEAT-COTTON-GRAM AND BARLAY AND CONDUCTIVITY OF IRRIGATION WATER
WHEAT
COTTON
GRAM
BARLAY
YIELD IN POUNDS PER ACRE
2700
2550
2400
2250
2100
1950
1800
1650
1500
1350
1200
1050
900
750
600
450
300
150
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
CONDUCTIVITY (AT 20°C)

FIG: 2


RELATIONSHIP BETWEEN YIELD OF SUGARCANE, BERSEEM AND CONDUCTIVITY OF IRRIGATION WATER.
SUGAR CANE
BERSEEM
YIELD IN TONS PER ACRE
CONDUCTIVITY (AT 20°C)
0
3
6
9
12
15
18
21
24
27
30
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

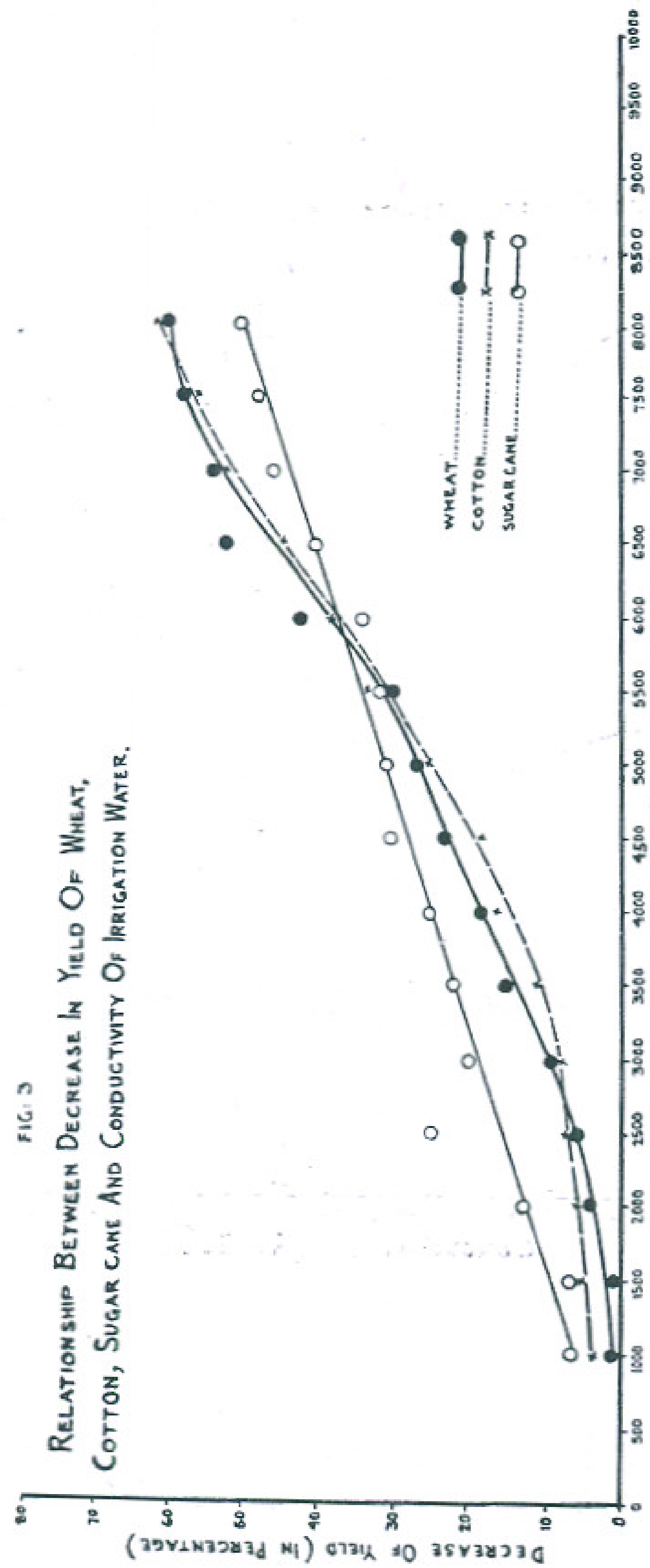


FIG. 3

Relationship Between Decrease In Yield Of Wheat, Cotton, Sugar cane And Conductivity Of Irrigation Water.

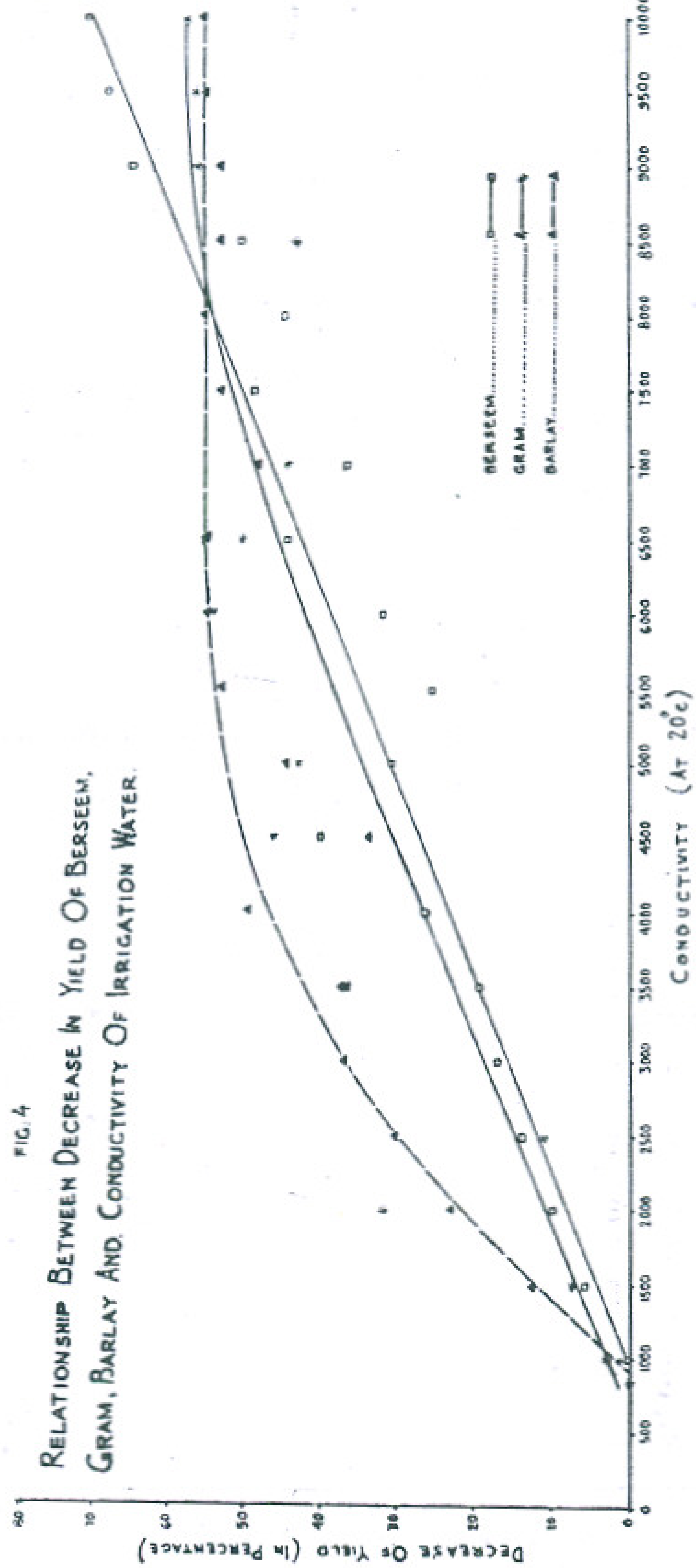


FIG. 4

RELATIONSHIP BETWEEN DECREASE IN YIELD OF BERSEEM, GRAM, BARLAY AND CONDUCTIVITY OF IRRIGATION WATER.

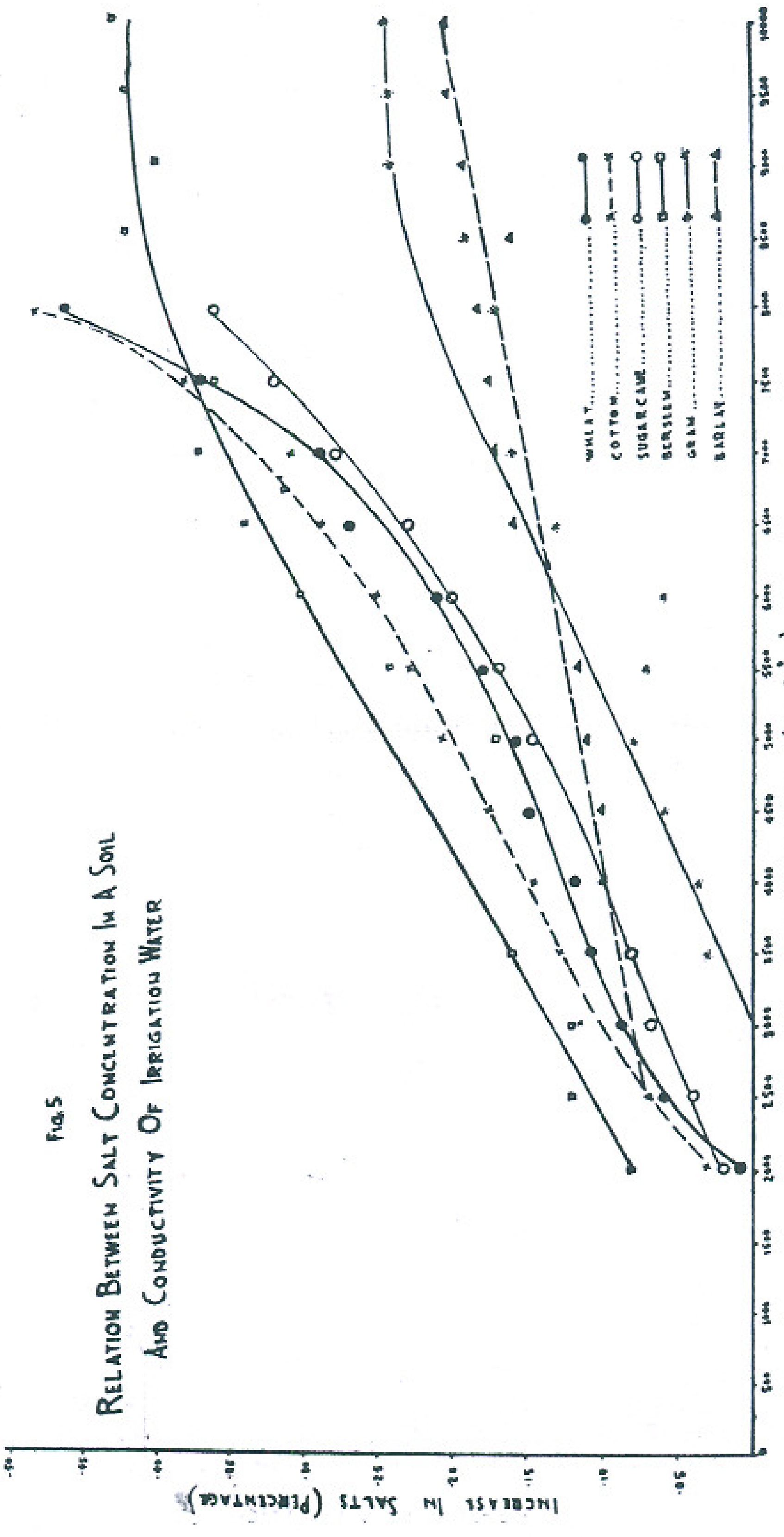


Fig. 5
Relation Between Salt Concentration In A Soil And Conductivity Of Irrigation Water
Wheat
Cotton
Sugarcane
Berseem
Gram
Barley
Conductivity (At 20°C)
Increase in Salts (Percentage)

In the submerged soil the minerals are changed from an oxidised to a reduced state as under :

Oxidised State	*Reduced State*
Nitrate ions.	Ammonia, Nitrite, Nitrous oxide, and Nitrogen gas.
Sulphate ions.	Sulphide ions or Hydrogen sulphide.
Ferric ions.	Ferrous ions.
Manganic ions.	Manganous ions.
Phosphate ions.	Phosphene.

Because of the very slow rate of decomposition of organic matter, the Nitrogen remains locked up in the organic residue. Lack of Nitrogen Fixation under such conditions, may accentuate the deficiency. On the other hand, in a drained soil the release of nitrogen upon the decomposition of organic matter proceeds at a steady rate.

In paddy soils this decomposition process differs from other water-logged soils because the root zone of rice is kept in an oxidising condition as a result of the excretion of oxygen by the roots. The increase in pH which occurs when well drained soils are submerged and the decrease in pH which takes place when these soils are drained has been related to the presence of sulphate ions in a well drained soil and of sulphide ions in a water logged soil.

In case of phosphorus, the evidence now available shows that under reducing conditions, this is converted into a soluble form which is leached out. Robinson pointed out that soils which have been submerged for a long period, become so profoundly leached that they support little plant growth upon drainage. The degradation of rice soils is an example.

Physiological Behaviour of Plants Grown on Water-logged soils

Plants growing naturally on water-logged soils adapt themselves by a superficial rooting system. Of all important crop plants, only rice is considered to thrive while its roots are submerged as rice roots are able to maintain oxidising condition in their immediate environments. The capacity of the plant to survive the flooding seemed to depend upon whether or not adequate adventitious root formation took place. Several varieties develop white and turgid roots from nodes of the stem particularly at the water level. Penetration of roots below the watertable has been reported by the various workers. The tolerance to submersion during the growing season exhibited by pear trees, certain forest trees and grasses may be related to the capacity of these plants to develop intercellular spaces in their roots after submersion. This tolerance is further related to inherent characteristic of the plant.

Low Oxygen concentration in poorly drained soils have an inhibiting effect on root formation. Under such conditions roots tend to concentrate in spots which are best aerated *i.e.,* near cavaties and channels.

Bognton and Reuther established that aerated conditions in New York Orchards are often ideal in the spring, which is a time for trees to form new roots which died during the preceding winter. Plants show different response to Waterlogging, Transpiration, Photosynthesis, nutrient uptake and respiration are greatly reduced when the roots are submerged. In some cases either moisture deficiency is created in some tissues or an abnormal growth occurs owing to oxygen deficiency. From India it has been reported that the juice of sugarcane plants which had been flooded from July to September have 90% of their Nitrogen present as non-protein Nitrogen, which accumulated for poor quality of the juice and for losses in sugar recovery. Invert sugar and gums were found most affected.

Artificial aeration was tried by Kramer and Jackson as a measure to prevent damage caused by flooding the soil. It was noticed that though aeration reduced injury but the damage was not eliminated. Kramer pointed out that lack of aeration and consequent interference with water and nutrient uptake does not provide a complete and satisfactory explanation for the injury to plants. Toxic concentration of ferrous and sulphide ions which are built up soon after waterlogging and organic compounds which are produced by an anerobic decomposition are also harmful to plant growth. According to Woodford and Gregory injury due to lack of aeration is more marked at low than at high levels of nutrient. Barley could be grown for 12 days in Nitrogen atmosphere and in the absence of oxygen without being much affected as long as the nutrient concentration was 4 times that of aerated solution.

Damage to Crops by flooding

Damage caused by flooding to the standing crops depends upon (*a*) plants species (*b*) the duration of flooding (*c*) the prevalent temperature at the time of flooding (*d*) Organs which are in the process of being formed. There are also instances where flooding is used to advantage, the production of rice being the example. In principal there is only a gradual difference between damage caused by flooding and that caused by high water table and by waterlogged soils. The prevalent temperature at the time of flooding markedly affect the degree of injury, and the severe damage which occurs on the hot days is referred to as " Scalding."

Sweet clover, strawberry, clover and Red clover showed negligible germination at the end of 3 weeks of flooding, but Alsike clover and Alfalfa emerged fairly well at that time. The seeds of various grasses withstood submersion well and after the longest period of 12 weeks only the seeds of intermediate wheat grass germinate poorly after submersion.

From Finland, Kaitera,[25] reported that during late April clover withstand inundation for 2 weeks, while Timothy could tolerate even longer period of flooding. Later in the growing season the crop was killed by a water-table kept at 2 cm. for 5 days and by a watertable kept as 5 or 6 cm. below the surface lasting for one month. Towards the end of September the susceptibility of clover to flooding tended to be even greater. Timothy was killed by a flood in August lasting for about 3 weeks. In California, narrowleaf trefoil is considered most tolerant legume to flooding.

Cereals are severely damaged when flooded at the time of flowering and initial ear-formation, but are quite tolerant when the grain mature. During hot days, however, injury to crops by flooding is very severe. Spring Wheat was reported to exhibit about the same tolerance as Oats to waterlogged soils, but under California conditions wheat is considered to be more tolerant than either Barley or Oats. Rice is severely damaged by accidental flooding during the flowering stage and also 15-20 days after transplantation, but is relatively resistant to flooding a few days after transplantation or during grain maturation.

Fruit-trees are considered more susceptible to injury to water logging than any other crops. Pear-trees are particularly resistant to flooding. Angou-pears were less affected than Bartlett-pears. Besides the yield losses, the quality of fruit from the flooded trees tended to be inferior. Apricot, plum and peach trees died a few days after a 12 days flood of Nile river even when the soil was covered by only 6-18 cm. of water.

Irrigated cotton and grain sorghum grown on fine textured alluvial soils in California can be flooded for several days during the hot summer months, without suffering damage, but under the same circumstances alfalfa, beans, tomatoes and clovers would suffer severe injury.

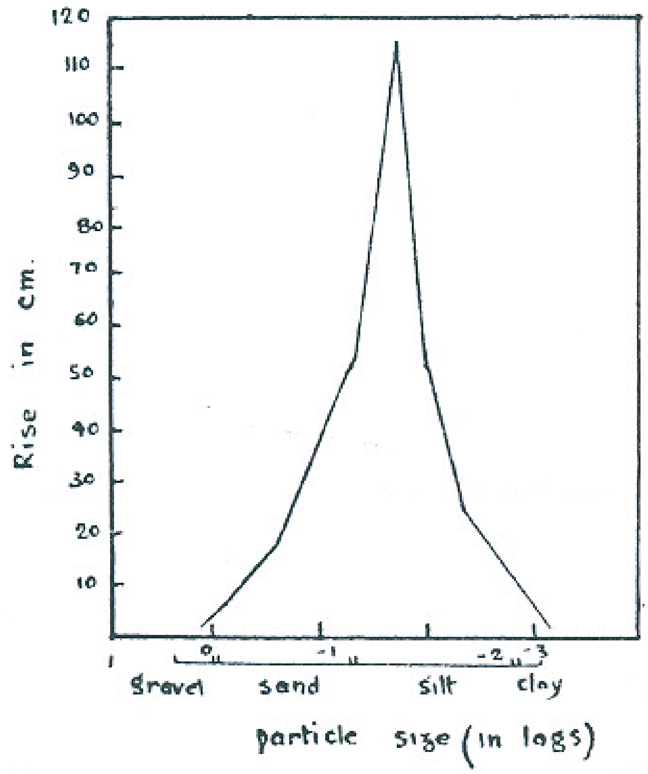
Crop response at High Water Table

Considerable amount of work has been done on the effect of water table on crops production. In order to evaluate the optimum level of water-table, Keen stated that in an ideal soil, moisture can theoretically be moved by capillarity to the following heights above a water table :

Fine gravel	15 Cms.
Coarse sand	46 ,,
Fine sand	229 ,,
Silt	31.5 Ft.
Fine silt (.01-.002 mm)	150 ,,
Clay	150 ,,

It is obvious that with increasing fineness of the particle the height of rise of water table increases.

From a stand point of field conditions the rise of water table is not as important as the rate at which this takes place. Since the rate determines whether moisture in the root zone can be replenished at a rate fast enough to match the rate of removal of moisture by roots. Atvereg's work shows that the maximum rate of rise occurs in the range of coarse silt as indicated below :



In coarser and finer soils the rate falls sharply and this observation explains in principle why systematic sub-irrigation in the field has been found practicable, in relatively coarse soils only, mainly in fine sandy soils.

Rate of capillary rise is affected as much by particle size as by the structural arrangement of the particles. Viscar expressed the effect of fluctuations in water table on crop yields. His conclusions are :

1. The thicker the layer of humus containing top soil the lower the optimum level of water table.
2. Where the water table is below 80 cms. the depression in yields is greater, the thinner the layer of peat underlying the surface soil.
3. The higher the water table the more is the yield depressed by fluctuations and the depression is greater with greater fluctuations.
4. The poorer the soil structure the more is yield depressed by a water table.

The permeability in clays falls off less sharply than in other soils. Thus in clay soils there is not the same requirement for keeping soil moisture in root zone at such a high level as in sandy soils. Yet practical experience has shown that in clay soils the rate of extraction by roots tends to get ahead of moisture replenishment by capillary rise, apparently because of low rate of capillary rise under any condition in this soil.

The prevalent temperature during the year fluctuates the water table. West was able to show the increasing temperatures during the spring lead to an appreciable rise in water table and the reverse happened when the temperature dropped during the autumn.

Variable rate of moisture withdrawal by plants and moisture addition by rainfall have a much greater effect on water-table fluctuations. These fluctuations are considered to have an appreciable effect on yield. Deep rooting alfalfa does poorly where a high water-table is present although it has been reported that under certain California conditions, alfalfa does well where a water table is as high as 20″ from the surface.

Kaliesvaart suggested that the following important crops require increasing depth of water table as they show increasing natural rooting depths in the order given :

Permanent grass-land, longly grass-land, shortly grass-land, Cereals, winter cereals, Flax, Potatoes, fodder beets, sugar beets and alfalfa.

Soil aeration, soil structure and the Nitrogen economy tend to be impared more rapidly at high water table in a heavy soil than at high water table in a lighter soil. Several additional harmful effects may result from a high water table, such as wood infestation, disease and difficulty in operating the land. A disease which is particularly active during wet season may cause the initially beneficial effect of high water table to be turned into harmful ones.

Eden etal, reported on the effects of sub-irrigation of newly sown Italian Rye grass without a clover component and without nitrogen top dressing on calcarious Finland peat in Eastern England. The yield with a water table kept at 14″-16″ was almost half that obtained at a water table kept below 20″, while the crude protein yield increased from 497 lbs/acre at the high water table to 1318 lbs at the medium (22″-26½″) and to 1513 lbs. at the low water table (30″-41″) level. The uptake of Potassium, Magnesium and Chlorine had been depressed at the high water table, but the uptakes of Calcium and Phosphorus were not affected.

In contrast with the moderate negative results from sub-irrigation from England, significant benefit of sub-irrigation have been claimed in the Netherlands. The data given by Kalisvaart for grass-land serves as an example. The results were :

Depth of water table, cm.	40	55	70	110
Average annual yield Kg/Hectare	19780	16150	15450	11840

The work of Hoog-houdt showed that on a heavy clay soil in the Netherlands the yield of cereals tended to be depressed at water table above 90 cm. In sandy soils somewhat higher water table may give better results.

In experimental work by Ware in Finland, it was found that a depth of water table of 60 cm. in peat soils gave optimum results. At water table above 60 cm. the yield was depressed and there was a considerable infestation of weeds.

In another Peat soil, a gradually rising water table did not cause any damage to spring wheat and oats where the watertable did not rise above 32-36 cm. from the surface. In Barley, however, a depth of 57 cm. was required to prevent damages.

It is generally recognised that fruit trees require well-drained soils but there are certain indications that under certain conditions, they can benefit from the presence of water table of convenient depth.

Lewis and Work considered that orchards in Oregon require ideally a depth of water table at 6′-8′ but a higher water table persisting for 3 or 4 days following rain or irrigation during the growing season, generally does not harm. The actual height of watertable which trees can tolerate often depends upon the species and the root stock used.

Schuster and Stephenson stated that walnut trees require a water-table preferably as deep as 8′-10′.

Oskamp and Batjer classified the orchard soils and found a clear relationship between orchard condition, size and quality of yiled and drainage behaviour, the orchard being poorest where shallow rooting is induced by a high water table.

Penmen observed in Australia that citrus trees remained in a healthy condition for their first 8-10 years of life where a water table was within 4 ft. of the surface. In the Netherlands, it was observed that young plum trees are less adversely affected by high water table than are older ones.

Work on vegetable crops show that variable responses can be obtained according to the crop species and weather conditions. The quality of crop is often adversely affected by conditions of excessive moisture. The general findings are that a water table between 12″ to 24″ from the surface is required for most vegetable crops, a level higher than 12″ generally depresses yield.

The consideration of the reports on crop yield from drained and undrained land shows that it is hard to generalize on the possible benefits which can be obtained from drainage, because of the over ruling effects of local conditions. Effects of drainage are often felt in an indirect manner and the benefits are sometimes delayed.

The small amount of information available on the optimum depth of water table during the off growing season indicates that a high water-table during that period may lower crop production in the subsequent season, perhaps, related to a deterioration of soils structure under waterlogged conditions.

Konekemp studied effect of ground water on growth of reed and canery grass. It grew well even with the water table 1.3 feet from the surface. However the protein in the plants increased with the lowered water table. Stephens stated that most vegetables preferred water table of about 2.5 feet, but barley, oats, mangels, rye and wheat grew best when the water table was deeper than 3 feet. The yield and quality was not considered to decrease, until the watertable was less than 3 feet. Corn did best with a depth of 4 feet. High water level apparently interfered with Nitrogen metabolism in the soil and considerably lower percentage of crude protein were found in the grass, growing in high water level plots than at the other level. High water level has also a depressing effect on the percentage of Potassium, Magnesium and Chlorine in grass. It has no obvious effect on Calcium and Phosphorus level in plants. The silica content of grass rose steadily as the season advanced, this being most marked on the high water table plots.

The yield of barley were influenced by different water table as under :

Period of time in which watertable rose and duration		Watertable 30″ at all times	Watertable 30″ but rose once to		
		Yield %	4″	10″	20″
			Yield %	Yield %	Yield %
June 10—25 ..	Grain	100	21	30	57
	Straw	100	23	38	57
June 20—July 5 ..	Grain	100	26	46	76
	Straw	100	26	47	70
July 1—15 ..	Grain	100	20	29	39
	Straw	100	33	50	51
July 10—25 ..	Grain	100	33	36	45
	Straw	100	37	45	41

Both the quality and quantity of milk were affected when the animals were fed from fodder grown at different watertables as under :

	Milk	Butter fat	Loss or gain in weight
40 Cm.	1600 Kg.	44.8 Kg.	—20 Kg.
120 Cm.	3300 ,,	105.6 ,,	+50 ,,

It is clear that the plants grown on poorly drained area were of relatively low feeding value and vigour.

In West Pakistan large scale experiments were conducted at Chakanwali Reclamation Farm on the dewatering of the soils and to bring them into original productivity level. To start with, when Chakanwali was taken up for reclamation the soil could be classified as below :

Marshy water logged land	..	700 acres
Water logged and saline alkaline land	..	2,260 ,,
Culturable, mostly fit for rice only	..	685 ,,
Total	..	3,645 ,,

Several methods of providing drainage and lowering of watertable were tried, and as a result of these investigations the open drainage system was finally adopted as practicable. The method of reclamation of water-logged area is essentially the same as for saline lands with the difference which helps to check any rise of subsoil water level. The watertable is kept away from the root zone of the crops and is not allowed to interfere adversely the crop growth. The distance between the two lines of field drains depend upon the nature and quality of the soil. For a typical Punjab soil containing 15% clay, field drains at regular distance of 220′ with a water course passing through the middle is essential. It may be mentioned that with a system of field drains, discharging themselves into collector drains even if the watertable is not depressed to any appreciable depth from the natural surface, all crops can be grown successfully as long as the drainage system is maintained properly. The success of this method depends upon the continuous removal of water from the natural surface of the soil through soil profile and finally to the drainage system.

As a result of these measures adopted in the Chakanwali Reclamation Farm, the present condition of the area can be gauged from the classification given below :

Area under cultivation		2,688 acres
Area occupied by road and drains	..	511 ,,
Area under canal and villages	..	103 ,,
Area still require levelling	..	100 ,,
Uncommandable area	..	243 ,,
Total	..	3,645 acres

A vegetable-*cum*-fruit garden was established in the year 1944 in 10 acres, but has now been extended to 36 acres. Trials with oranges (Citrus dinensis) and sangtras (Citrus reticulata) have proved a failure. Plants of guavas (Psidium guayava), falsa (Grewia asiatica), pomegranates (Punica granatum), pears (Pyrus communis) and peaches (Prunus persica) have established well and are bearing fruit. Plants of Kikar (Acacia fistula), Shisham (Dilbergia sisso), Willow and Poplar have been established with the aim to produce wood at the farm for fuel and implements. The willow wood finds many uses. It can be used for agricultural implements and in the manufacture of sports goods.

It would thus be seen that although the problem of water-logging is a serious one and as a result some very important changes are brought about in the soil profile, attempts to reduce water logging as well as reclaiming the areas affected by this menace have been appreciably successful.

Lysimeter experiments were conducted at the Directorate of Land Reclamation and from the results of these trials it is observed that in high water table areas it is necessary to ensure 10%-20% drainage while in case of area with low water table drainage provided may be 5% to 10%. Washing down salts after their appearance on the soil surface is more difficult, involves greater cost, labour and larger quantities of water. If suitable drainage is provided when salts are in lower soil layers these can be carried away more efficiently and crop rotations recommended for adoption in areas with low water-table to keep a downward trend of soil moisture are :

1. Chari Guara - Wheat - Maize - Wheat.
2. Maize - Wheat - Bajra - Turnips.
3. Maize - Wheat - Chari - Berseem.
4. Chari Guara - Wheat - Cotton - Berseem.
5. Guara (Green manured) Wheat - Maize - Senji - Sugarcane
6. Sugarcane - Sugarcane.
7. Chari Guara - Gram - Cotton - Sugarcane.
8. Maize - Wheat - Chari Guara - Gram - Cotton - Berseem.
9. Sugarcane - Cotton - Maize / Senji.

The first 2 rotations have 200% cropping intensity and by keeping the soil covered throughout the year are expected to keep the surface evaporation low. Those are, however, suitable for areas where salts exist at a great depth. There is data to show that sugarcane is cultivated with advantage, when salts are 2′ beyond the soil surface. Rotation No. 6, is, therefore, adopted to the soils where salts reside near the surface.

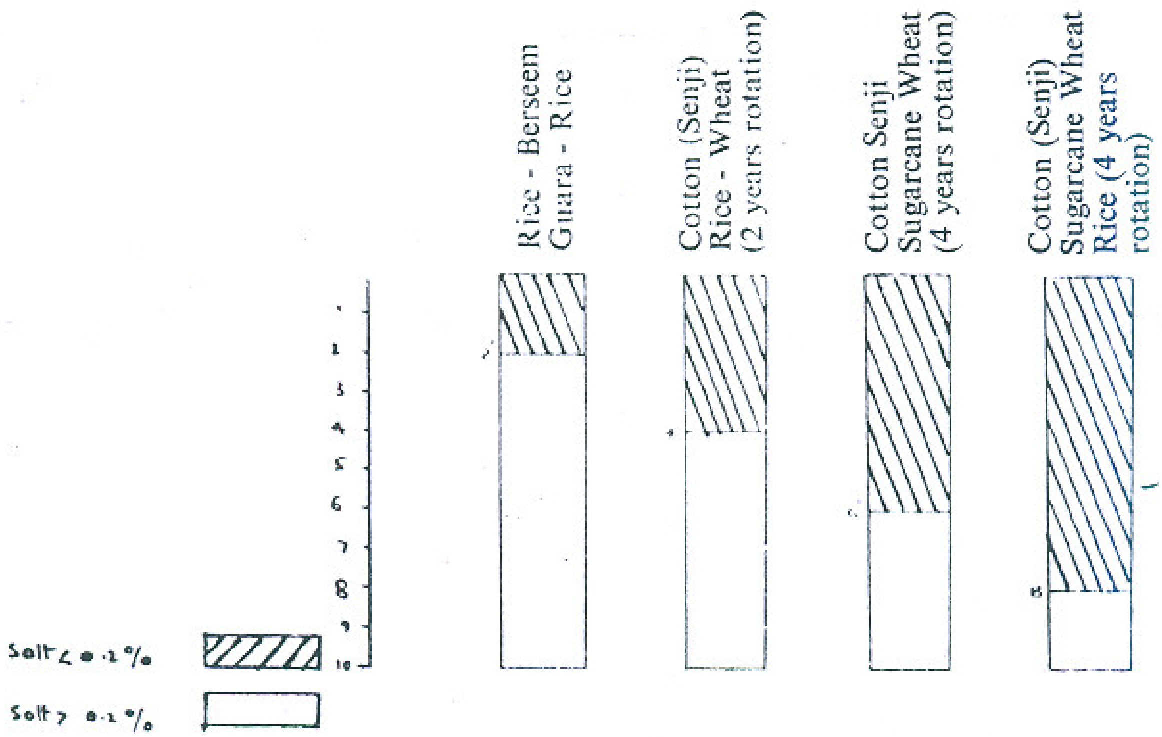
Cotton in rotations 4, 8, 7 and 9 is to receive higher delta than normally applied. Experiments in the field and laboratory trials indicate that this crop is capable of withstanding fairly heavy delta of water without substantial decrease in yield. Growing of rice on 8% area is also recommended. It should be rotated in such a manner as to ensure that every field carries this crop within a suitable period.

In high water-table areas rice growing has to be a regular feature. Due to the nearness of sub-soil, water, which is usually highly impregnated with salts, rice, should occupy 25%-33% area every year. The rotations suggested for such areas are :

1. Rice - Berseem - Chari Guara - Wheat - Maize - Senji.
2. Rice - Lentil - Chari Guara - Wheat - Bajra - Senji - Sugarcane.
3. Rice - Shaftal - Chari - Moong - Oats - Guara - Wheat.
4. Rice - Berseem - Sugarcane - Sugarcane.
5. Rice - Gram - Chari Guara - Toria - Sugarcane - Chari - Senji.

Cropping patterns have been worked out on these considerations and it is expected that these can be adopted with a water allowance of 150 acres per Cs.

Crop rotations for prevention of salinization of soils and to have satisfactory growth of crops would be as under depending upon the amount of salts present in the soil profile.



Experiments were also undertaken in the Directorate to select amongst the existing varieties, the best variety of wheat which may stand high soil moisture conditions, and still yield maximum.

Three improved varieties of wheat *viz.* C-271, C-273, C-591 were tried, Barley, which cannot replace wheat as a food crop, but can still at least to some extent, improve the food situation, was also included in the study. Three varieties of Barley included in the study were T-4, T 6-5 and C-141.

All the six varieties were sown under identical favourable conditions and showed uniform germination and growth. After the plants got a foot hold, 15 types of special irrigation treatments were done to create artificial high soil moisture conditions, for various periods in order to find out the relative sturdity of the 6 varieties under these 15 types of conditions.

Various varieties were then allowed to mature without any further irrigation.

The results have shown that the yields are reciprocal to the period of high soil moisture conditions, *viz.* each variety has yielded highest with one day treatment and lowest with 7 days treatment. It has further been observed that yields have been less under stagnant water treatments in comparison to flow water treatments.

Various varieties have also behaved differently under identical conditions.

C-273 variety of wheat has out-yielded all wheat varieties under all the treatments, while C-141 Barley has out-yielded all Barley varieties under 9 of the 15 treatments.

Experiments are also in progress in the Directorate where different crops are being grown under artificial waterlogged conditions in specially designed lysimeters to observe the influence of excessive moisture on the yield of crops and other physiological changes in plants. Concrete Lysimeters of dimensions $2' \times 3' \times 1\text{-}1/2'$ and Iron Lysimeters of dimensions $4' \times 4' \times 4'$ were constructed and filled with sandy loam type of the soil and allowed to settle under excessive moisture. The watertable in the Concrete and Iron Lysimeters was kept at 8″ and 30″ respectively.

During Rabi 1962-63, Wheat and Berseem (Egyptian Clover) were tried and the results are given below :

S. No.	Lysiemeters/Field plot	Crop	Water-table	Yield in lbs/acre
1.	Concrete Lysimeter ..	Wheat	8″	365.0
2.	Iron Lysimeter	,,	30″	886.0
3.	Field Plot under natural conditions.	,,	20′	1628.0
4.	Concrete Lysimeter ..	Berseem (Egyptian Clover)	8″	7767.0 (Green matter)
5.	Iron Lysimeter ..	,,	30″	9084.0 (Green matter)
6.	Field Plot under natural conditions.	,,	20′	26814.0 (Green matter)

There is a marked decrease in the yields when the watertable is at 8″. Poor stunted growth accompanied by yellow coloration of the plants was observed during the growth period of the crops. In case of Wheat in concrete tank with water-table at 8″ withering of the leaves was noticed and 20% of the leaves were affected. With water-table at 30″ the withering effect started in the middle of January and 8% of the leaves were affected. In case of water-tables at 8″ and 30″ the yield of wheat obtained was 22.5% and 54.8% respectively of the normal yield of the crop under natural conditions.

Similar stunted growth and consequent fall in yield was noticed in case of Berseem (Egyptian Clover). The yield of green matter was 28.5% and 33.5% in case of watertable at 8″ and 30″ respectively of the normal yield of the crop under natural conditions.