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9. ABSTRACT

A three year program involving research and demonstration on modern concepts of irrigation management for corn was conducted in the Aconcagua Province. Irrigation, land management, fertility, corn variety and plant population were emphasized. Results proved that yield potential of corn is well above the current level of production. By adopting the practices in this bulletin, corn producers can increase yields at least 50% with the resources they currently have available. While all of the research was conducted in the Aconcagua Province, the technology can be transferred to other provinces in the corn producing area with slight modification or adaptation. Based on the results of the project, the following recommendations are made for increased corn production in Chile. Proper timing and amount of irrigation is essential for increased production, since corn is very susceptible to moisture stresses. Even short periods of moisture stress, particularly during the critical stages of tasseling and silking, will sharply reduce yields. Plowing should be done prior to irrigation at a 25-30 cm. depth to adequately incorporate residue from previous crops. A preplant irrigation should then be applied. Seed-bed preparation can be done after soil is dry enough to prevent undue compaction by equipment. The tandem disc should be followed by a spike-tooth harrow to break up clods and leave a fine surface mulch. A recommendation of 200 kg. of N per hectare would be adequate for most soils in Aconcagua. In the event that the field has a history of heavy use of nitrogen fertilizer, smaller applications may be sufficient. Several good varieties of corn are available in Chile, including short and full season hybrids. If water is limited, a short season hybrid may be used with greater assurance that enough water will be available to bring the crop to maturity. If irrigation water is not limited then the long season hybrid will produce higher yields.

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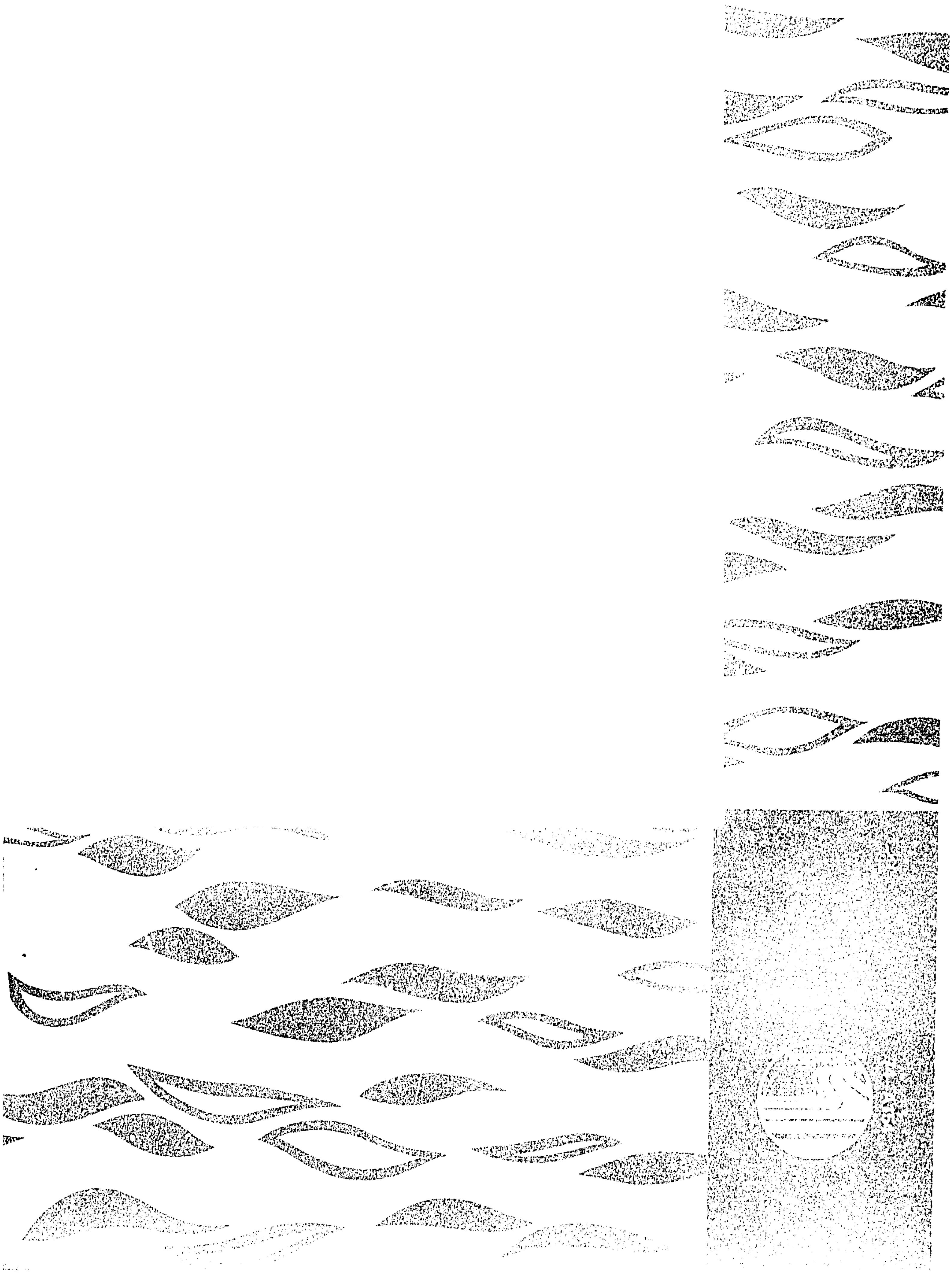

IRRIGATED CORN PRODUCTION IN CHILE:

INCREASING YIELDS THROUGH INTENSIVE IRRIGATION MANAGEMENT

by

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INTRODUCTION

Agricultural production in Chile depends almost exclusively on irrigation, with the exception of the southern part of the country where precipitation provides sufficient moisture for plant growth during the growing season.

There are approximately 1,171,000 hectares of irrigated land in Chile (6)[1]

As in most of the Western Hemisphere, corn has been one of the basic food crops in Chile and of course has been closely related to irrigation. For the 15 year period from 1954 to 1969 an average of 80,431 hectares of corn have been planted with an average yield of 24.9 qq. per hectare for an average annual production of 2,002,730 qq. of 100 kilos each or 200,273 metric tons (1).

Yield estimates for the 1970-71 crop year are 33.1 qq. per hectare with 86,370 hectares planted. An estimated 90,000 hectares of corn were planted for the crop year 1972-73. The present total consumption of corn in Chile is 600,000 tons. An approximate breakdown of the consumption is as follows: 16%-17% for industrial uses which include starches, glues and dextrines; 16% for human consumption including corn starch, oil, glucose, coloring and fresh corn; and 67% for livestock feed.

To meet its internal consumption of corn, Chile must import some 320,000 tons annually. By increasing the area planted to corn and/or increasing the yield per unit area this deficit can be reduced.

To assist in this problem, Utah State University, under contract with the United States Agency for International Development, began a research program in cooperation with La Platina Experimental Station of the Chilean Agricultural Research Institute (INIA) in 1969. During three crop years, research was conducted on irrigated corn in the Aconcagua Valley. Among the factors studied were irrigation, nitrogen fertilization, corn varieties and plant population. Improved cultural practices were also incorporated into the experiments. The research results were extended to Chilean farmers throughout a series of demonstration experiments in cooperation with the Chilean Extension Service (SAG).

The results of the research and extension program have been presented in a series of annual reports and summarized in a technical publication (3, 4, 5, 7). The purpose of this extension bulletin is to present recommendations that came out of the research. It is intended primarily for extension specialists and corn producers in Chile; and secondarily for farmers and extensionists outside of Chile who will find some of the recommendations applicable to their conditions.

LAND AND WATER RESOURCES

Land Area

Total irrigated land is estimated to be 1,171,000 hectares or about 31% of the agricultural land (excluding pasture) of the country. An additional 80,000 hectares is under canal and has been irrigated some time in

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[1]Numbers in parentheses refer to references.

the past, but presently the dependable water supply is not great enough to irrigate these areas (7).

It has been estimated that an additional half million hectares can be economically irrigated using surface methods. This additional area would be even larger if sprinkler irrigation were adopted for some of the soils and slopes not considered as potentially irrigable using present irrigation methods (see Figure 1).

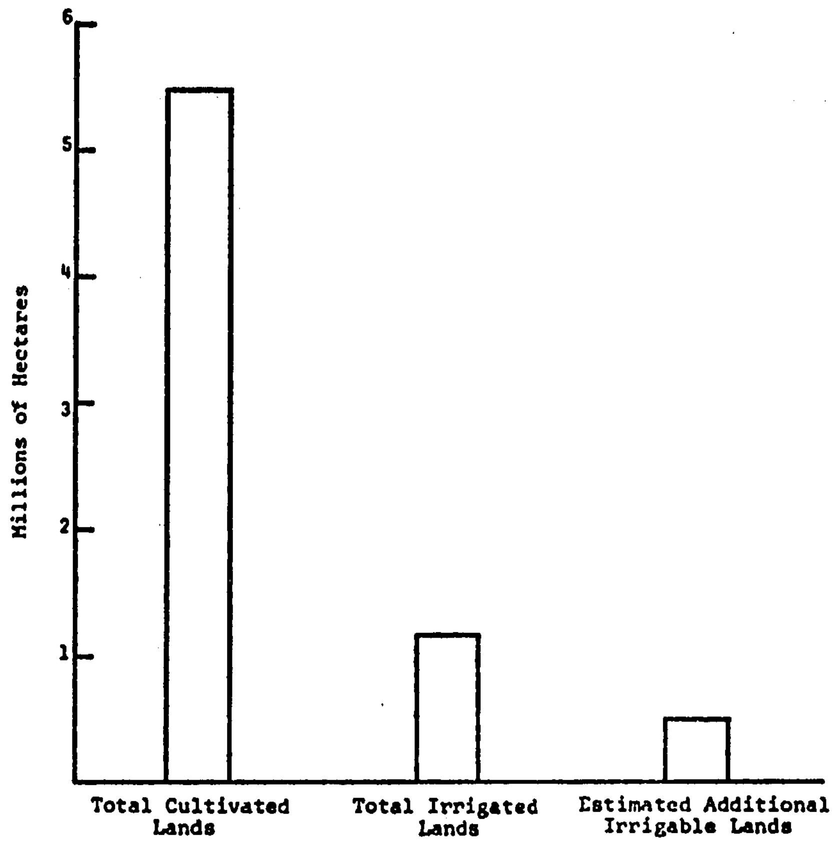


Figure 1. Agricultural Land Use in Chile.

The presently irrigated 1,171,000 hectares of land includes a wide range of soils and topography. For the most part they are alluvial soils along rivers which originate in the high Andes mountains. These soils are generally low in nitrogen and phosphorous, with adequate levels of potassium for crop production. There are some volcanic soils in the southern part of the irrigated region which have special problems with regard to phosphorus.

As is common with alluvial soils, there is also a wide range of textures from loamy sands to clays. Available water holding capacities for the majority of these soils range from 6 to 15 cm. of water per meter of depth. Because of the prevailing cultural practices, structure tends to be poorly developed. Soils with textures such that they would normally be expected to have adequate water infiltration rates often exhibit reduced ability to absorb irrigation water because of their poor physical condition.

Approximately one half of the area planted to corn in recent years is in the central provinces of Santiago, O'Higgins and Colchagua. This area is responsible for more than one half of the corn production in the country. About 85% of the corn is planted in the 9 provinces from Aconcagua south to Ñuble. The 86,000 hectares of land devoted to corn production represents about 7.4 percent of the total irrigated land.

Climate

Climate and, more specifically, precipitation vary across the narrow width of Chile because of the influences of the coastal range of mountains and the high Andes; there is an even greater variation from north to south.

In the northern part of the country, commonly referred to as "Norte Grande" there is a desert climate with very little or no rainfall except in the high mountains. Farther south in "Norte Chico" the climate becomes semiarid with a slight increase in precipitation. All of the Central zone has a typically temperate climate (8).

In general, rainfall, increases from north to south, from the very low average annual precipitation at Tocopilla of 3 mm. and 11 mm. at Antofagasta to 344 mm. at Santiago to as high as 2,470 mm. at Valdivia. Most of the precipitation falls in the winter months, so there is little if any precipitation available for crop growth during the summer months except in the southern zone. As a result, there is a heavy dependence upon irrigation for agricultural production.

Water Requirements

Based on climatological data the evapotranspiration by corn has been estimated for five locations in the irrigated corn production zone of the country (9). These are shown in Table 1 along with average annual precipitation and 85% dependable annual precipitation (annual precipitation to be expected in 17 out of 20 years). It must be remembered that except for limited precipitation in April at Linares and Chillan, none of this precipitation occurs during the growing season for corn.

Table 1. Typical Evapotranspiration for Corn and Annual Precipitation for Five Locations in Chile (9)

Location	Precipitation: Average Annual mm	Precipitation: 85% Dependable mm	Evapotranspiration mm
Los Andes-San Felipe	305	106	750
Santiago	344	185	680
San Fernando	770	470	654
Linares	966	690	643
Chillan	1,033	785	637

The irrigation water requirement depends not only upon evapotranspiration, but also upon the irrigation method and its efficiency. For example, taking the estimated evapotranspiration for corn in the Los Andes-San Felipe area and the recommended method of irrigation (furrows), irrigation water requirements can be estimated. With some improvement in current furrow irrigation, a reasonable efficiency to expect is 65%. The irrigation water requirement at the farm level is 1,150 mm. depth or 11,500 cubic meters per hectare. This requirement would be reduced by the amount of soil moisture stored in the root zone, depending upon winter rains. In many years, however, this stored moisture is neglible.

Irrigation Water Supply

As would be expected, the water supply for irrigation also varies directly with the precipitation, and thus increases from north to south. The Chilean Institute of Engineers has divided the country into various regions with regard to the relationship of land to water supply (see Figure 2) (6). The first of these is the region from the Aconcagua to the north and includes the four northern provinces of Tarapaca, Antofagasta, Atacama and Coquimbo. In this region the limiting resource is water, since there is more land than water available to irrigate, even if water were used with maximum efficiency. This region includes the area "Norte Grande" with 12,600 hectares of irrigated land and "Norte Chico" with 89,470 irrigated hectares.

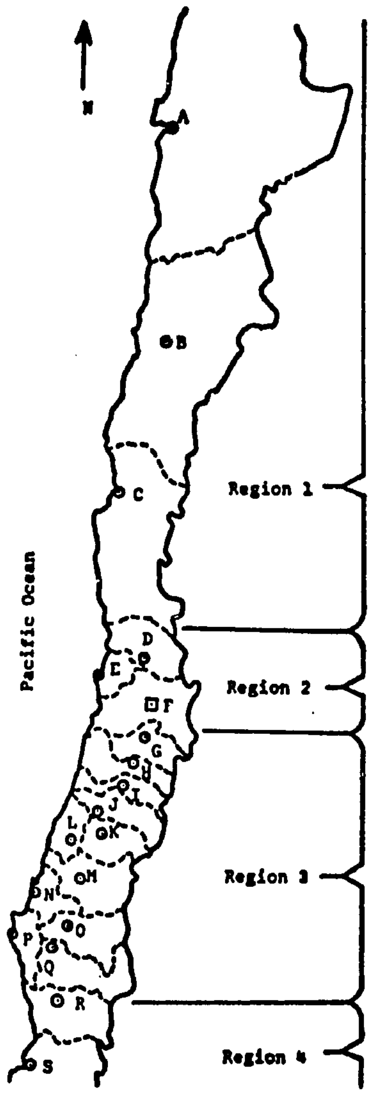
The next region to the south, consisting of 303,500 hectares of irrigated land, includes the valleys of Aconcagua and Maipo and is the most important region in the country because of its development. If the potential water supply is utilized efficiently, the demands for irrigation can be met on all irrigable lands. The region is comprised of the provinces of Aconcagua, Valparaiso and Santiago.

The third region is made up of the 12 provinces from O'Higgins south to Cautin, and has an irrigated area of 761,730 hectares. Here, the limiting factor is land suitable for irrigation. Even if all of the suitable land were brought under irrigation (esimated to be an additional 600,000 hectares), there would still be excess water for other uses.

In the southern region which extends from Cautin south, irrigation is scarcely practiced because of the abundant precipitation. The irrigated area is only 3,360 hectares.

The major source of water for irrigation is surface streamflow in rivers that originate in the Andes and flow westward toward the Pacific. The snow pack in the mountains serves as important storage for precipitation and is released for irrigation during the summer months. Seasonal water shortages are likely to occur during the early part of the growing season before temperatures become high enough to melt the snow pack and again during the latter part of the season as the snow pack becomes depleted or temperatures drop.

Although the great majority of the water supply is from surface sources, ground water is utilized to a limited extent. There are some 130 wells, irrigating about 5,500 hectares in the Santiago Province (2), with possibly an equal number in Aconcagua Province. Activity in ground water development increased during the severe drought of 1968-69.



	Province	Capital
A	Antofogasta	Antofogasta
B	Atacama	Copiapo
C	Coquimbo	La Serena
D	Aconcagua	San Felipe
E	Volparaiso	Volparaiso
F	Santiago	Santiago
G	O'Higgins	Rancagua
H	Colchagua	San Fernando
I	Curico	Curico
J	Talca	Talca
K	Linares	Linares
L	Maule	Caugenes
M	Nuble	Chillan
N	Concepcion	Concepcion
O	Bio Bio	Los Angeles
P	Arauco	Lebu
Q	Malleco	Angol
R	Càutin	Temuco
S	Valdivia	Valdivia

Figure 2. Partial Map of Chile Irrigated Regions.

Water quality is generally good and even excellent in the southern irrigated regions. In the Santiago Province some of the waters are moderately salty and in a few cases toxicity has been reported. The salt concentration tends to increase to the north and waters in the northern region are generally of lower quality but still usable for irrigation. One of the principal problems in the central provinces of Aconcagua, Santiago and O'Higgins is the large amount of sediments carried by the rivers and the subsequent high maintenance requirements and operation difficulties in the delivery canals and at the farm level.

INCREASING CORN PRODUCTION

There are two obvious alternatives for increasing corn production in Chile. Present yields per hectare can be accepted and additional land area planted to increase the total production. In contrast, corn acreage could be maintained at approximately present levels and an effort be made to increase the yield per unit area. A third alternative might be a combination of these two.

The first alternative presents at least two major difficulties; production costs would also increase, and corn would be competing with other crops for the limited water resources.

In view of the relatively low average yield (33 quintales per hectare) of corn in the country, it seems logical to attack the problem through increasing yield per unit area alone or perhaps in combination with some increase in acreage rather than trying to increase total production only by increasing acreages planted. The discussion here on corn production will emphasize the increase of corn production by intensive methods as opposed to extensive methods, that is, to increase the yields per hectare on present corn acreage.

Many factors are involved in the production of corn; any one of many could be given attention in an attempt to increase production. Among the more important factors are water, fertility, plant population, variety, cultural practices, disease and pest control, weed control, etc. In the experimental work conducted in the Aconcagua Valley during the three crop years previously mentioned, the first four of these were studied as variables and observations made with respect to weed control and cultural practices.

For the purposes of this bulletin, emphasis will be placed on and recommendations given for irrigation, land management, population and variety, and fertility. Other factors such as disease and pest control are omitted, as they were not a problem during the experience in Chile. These, of course, have to be controlled for the stated recommendations to produce maximum increases in yields.

Water Management

Principles. In irrigated agriculture no one single factor is as important as water. This importance is generally recognized, but often only in terms of whether or not water is available. However, if water is to fulfill its role, it must be considered as a manageable input like seed or fertilizer. In addition to total amounts, methods of application and timing or scheduling should also be considered.

The importance of adequate soil moisture and its influence on corn production was clearly shown by research results in the Los Andes area on Fundos El Castillo and Condoroma. Table 2 shows average corn yields in relation to water applied for various years and location. These same data are shown graphically in Figure 3. Production increases sharply with an increase in applied water up to the level at which the water requirements of the corn are satisfied.

Table 2. Average Yield of Shelled Corn in Relation to Depth of Water Applied

Location and Year	Corn Yields qq/ha	Water Applied cm
El Castillo 1970-71		
High soil moisture	122	92.1
Low soil moisture	111	68.8
Condoroma 1970-71		
High soil moisture	93	75.4
Low soil moisture	61	48.8
Condoroma 1971-72		
Interaction	63	53.3
Infiltration	44	44
Condoroma 1972-73	52	46

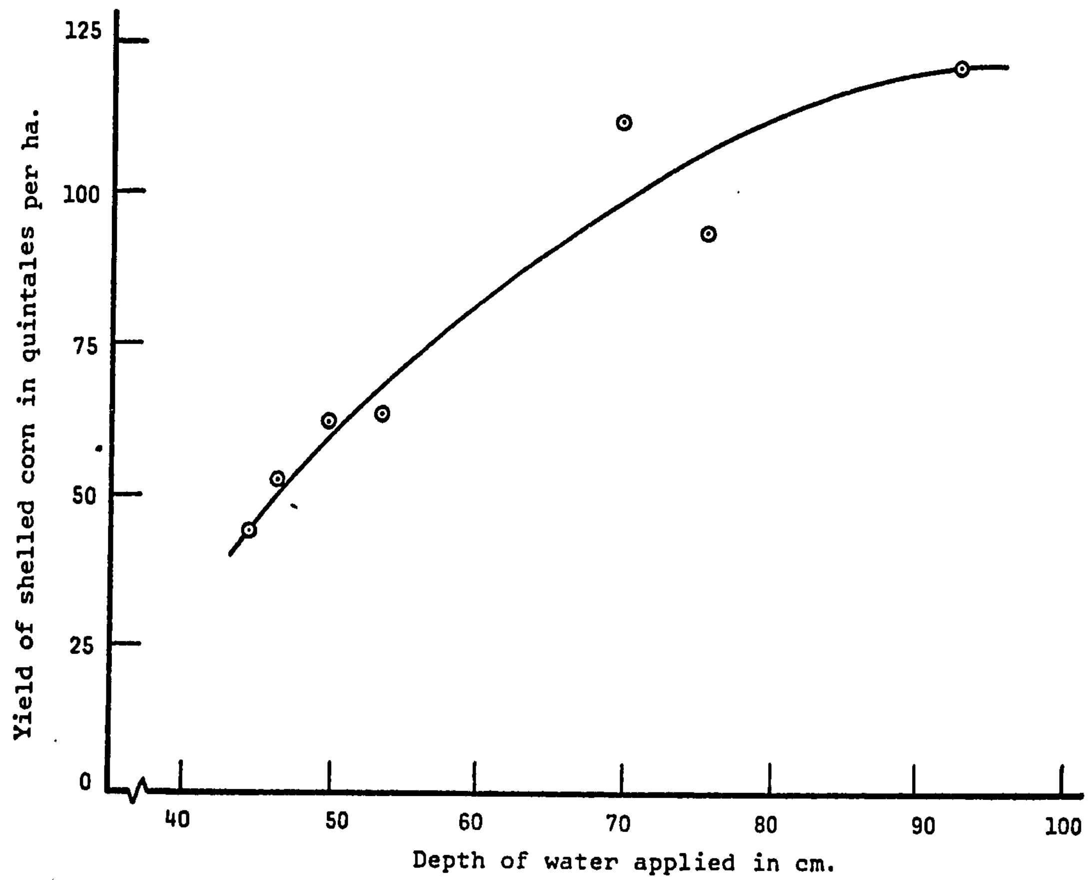


Figure 3. Average Relationship Between Yield and Water Applied During Three Year Irrigated Corn Research in Chile.

The soil in the root zone of a crop acts as a reservoir to store the applied irrigation water. During the periods between irrigations, plant roots extract this stored moisture. It is important to recharge all of the storage capacity to avoid too frequent irrigation. This is done by adjusting the water application time to the water intake rate so that the reservoir is full after each irrigation.

For example, the approximate available soil moisture holding capacity of four different soil textures is shown:

	Field Capacity	
Soil Texture	Approximate Available Moisture in 30 cm of Soil	Approximate cm of Available Water in 120 cm Depth
Fine sandy loam	3.5	14
Silty loam	4.5	18
Silty clay loam	5.0	20
Clay loam	5.7	23

Assume that a silt loam soil at the end of the irrigation season has no available moisture. Assume further that during the winter there is an accumulation of 30 cm. of precipitation of which 50% is lost by evaporation and surface runoff. Thus, there will be 15 cm. of available moisture stored in the soil. Then 3 cm. of water must be added by irrigation for the soil moisture to reach field capacity at 120 depth. Further, this same soil has an approximate infiltration rate of 1 cm. per hour.* Assuming no soil structure problems, it will take 3 hours of irrigation to add the 3 cm. of water.

It should be pointed out that the irrigation to recharge the soil moisture reservoir before planting might be made well in advance of planting. The importance of starting the corn crop off with a full reserve of soil moisture cannot be overemphasized. Experience has demonstrated that this practice can extend the period before the first irrigation after planting is necessary by as long as three weeks.

Determining the water requirement during the crop growing season might be accomplished in a similar way. One probably will desire to irrigate or replace the soil moisture when 50% of the available stored moisture has been depleted. For this it is necessary to determine a rate of depletion per day for the crop. In the Los Andes area for corn, this use (evapotranspiration) is estimated to be about 1 cm. per day during peak crop use. Again using the silt loam soil as an example which holds about 18 cm. of water in 120 cm. of depth, if 1 cm. per day is used by evapotranspiration then it will be necessary to irrigate every 9 days. Irrigation needs to be 9 hours in duration (1 cm. per hour infiltration for 9 hours).

The corn crop itself, if observed carefully can be used to predict irrigation frequency. If the plants during midday are showing symptoms

*See page 11, Infiltration.

of wilting it is generally time to irrigate. These symptoms are observed as the edges of the top leaves fold inward into a "v" like appearance. The upward leaves hang noticeable limp. Scheduling irrigation by this method takes experience and carful observance of the crop. Another methcd used by some farmers is called the "touch" or "ball" method. This simply consists of taking a hand full of soil from the 20-30 cm. depth. If the soil will hold its form when molded together, it is usually considered moist, if not, it is time to irrigate. This ability to form a ball depends somewhat on soil texture.

Figure 4 illustrates a soil column with its "reservoir" at three different stages of stored water. It should be noted that this reservoir is filled from the top and when it is only partially filled, the water is contained in the upper portion; as the water moves down through the soil pores a part of it is retained. The lower part is filled only as the storage reservoir above approaches its field capacity. If additional water is applied after the reservoir "overflows" the water continues down through the soil beyond the root zone.

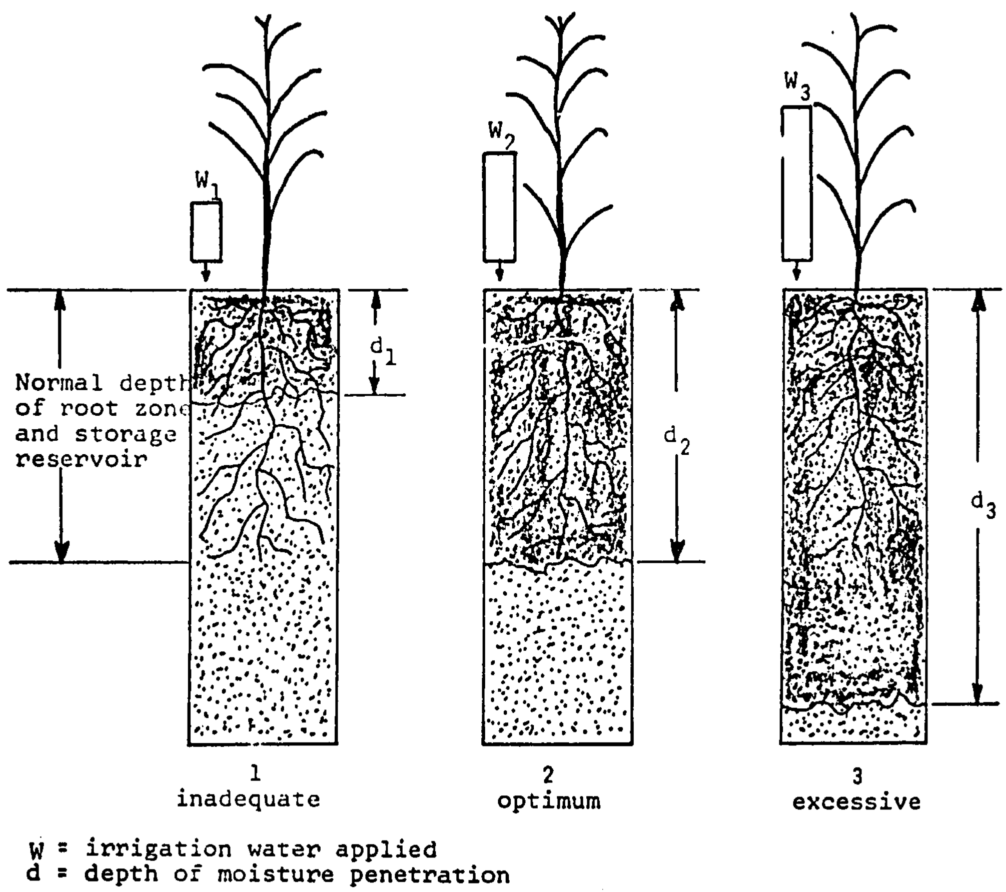


Figure 4. Typical Soil Columns Showing Moisture Storage Reservoir and Three Irrigation Applications.

Case 1 of Figure 4 represents a light, inadequate irrigation which utilizes only a portion of the storage capacity of the soil in the normal root zone. A limited amount of soil moisture is available for crop use between irrigations, which have to be repeated frequently. These light, frequent irrigations are generally less efficient, as well as inconvenient from a management and labor point of view. The root zone of the crop is artificially restricted, and crop yields may be reduced due to limited available soil moisture.

Case 3 represents a deep irrigation where the amount of water applied by irrigation is more than can be stored in the reservoir and the excess moves below the root zone. This excess is lost for plant use because it is no longer available for extraction by the crop roots. Not only is the water lost, but it also carries nutrients beyond the reach of the roots.

Case 2 represents the ideal or optimum irrigation where the entire soil moisture storage reservoir in the root zone is filled to its capacity, but with only "enough excess to maintain a salt balance in the soil". This assures that moisture will be readily available to the plants during periods between irrigations (which can be less frequent), and that the crop will be fully utilizing its normal root zone.

<u>Methods</u>. The traditional method of irrigation for corn, as well as many other crops, is a type of flooding, locally known as "tendido". The method consists of running a series of approximately parallel ditches across the field at intervals of from 20 to 50 meters and diverting the water from these ditches to flood the areas between them. Water comes in direct contact with the plants and serious erosion may take place. The method generally results in a nonuniform light application, similar to that illustrated by Case 1, because the water is held on the field only for a short time. Labor requirements are high and because there is so little control over the water, the method does not lend itself to improving irrigation techniques (see Figure 5).

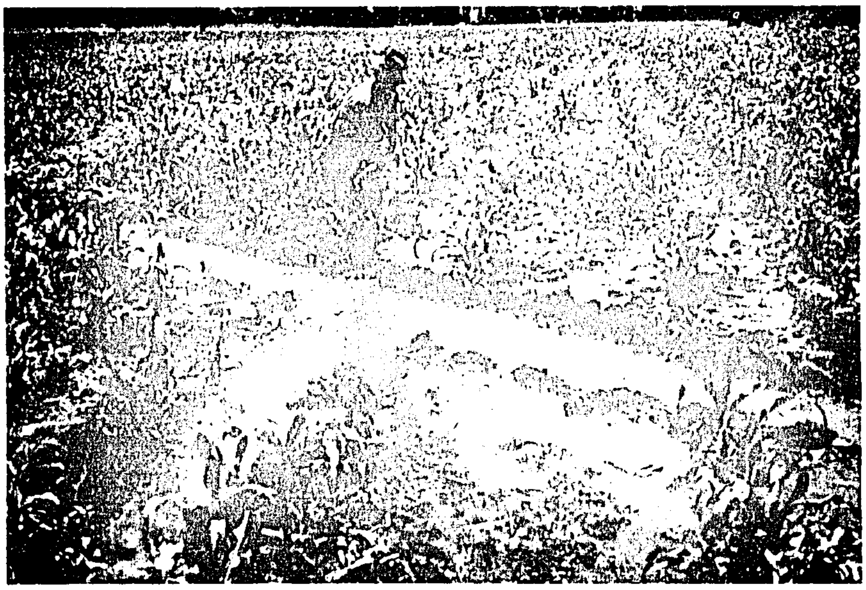


Figure 5. Traditional Flood Irrigation.

During the research and demonstration experience in Chile, corn was irrigated by the furrow method. Siphon tubes were used to distribute the water to the furrows and control stream sizes. This method offers several advantages over the traditional method. The water can be controlled to prevent erosion, and the water can be left on the field as long as required to permit it to penetrate the full depth of the root zone with the resulting irrigation like that illustrated in Case 2.

The importance of adequate irrigation, not only during the season but also the preplant irrigation, was demonstrated during the research on Fundo El Castillo. A 21 cm. depth of water was applied prior to planting which completely filled the entire root zone. Only three additional irrigations, with an average application depth of 15 cm., were required to produce a very respectable yield of 111 qq. per hectare. Even though the irrigations were infrequent, there was adequate soil moisture available for crop growth during the periods between irrigations because the storage reservoir was completely filled each time. Figure 6 and Figure 7 show irrigations.

Of course if the water is left too long on the field, an application similar to that in Case 3 will result, particularly at the upper end of the field. However, with adequate land preparation and the proper combinations of furrow stream sizes, furrow lengths, and irrigation times, losses can be minimized and adequate, reasonably uniform irrigation applications can be achieved. Furrow irrigation is recommended for corn as adequate appplications can generally be made with a minimum of erosion and labor requirements.

Infiltration. Even with furrow irrigation where irrigation times can be controlled, water penetration may be limited because of slow intake rates.

Some of the soils used for corn production in Chile have these slow intake rates either because of soil texture or poor soil structure and physical condition. This problem was particularly apparent on the soils at Condoroma during the research. At this site even after 18 hours of irrigation, water did not penetrate to the 45 cm. depth. This limited the root zone to approximately one third the depth that corn would normally occupy, and resulted in the need for frequent irrigation to assure adequate moisture for the corn between irrigations. The effect on the yield was a 25% reduction from that of El Castillo where water intake and penetration was not a problem.

An even more striking example of yield differences due to increased soil moisture availability was caused by slope differences on other research plots on Condoroma. Nitrogen rates, plant populations and varieties were studied as controlled variables on plots with slopes that varied from 0.0 to 1.05%.

It was observed during the growing season that corn growth was more vigorous in the flatter plots. After harvest, the yield data were evaluated in relation to slope groups. The relationship is shown in Figure 8. Yield decreased with increasing slope and increased among slope groups with increasing nitrogen rates.

The difference in corn yields as related to field slope is explained entirely in terms of moisture availability. Moisture penetration increased as the field became flatter, apparently the result of decreased velocity and a larger wetted area in the furrow, giving a greater opportunity for infiltration to occur.

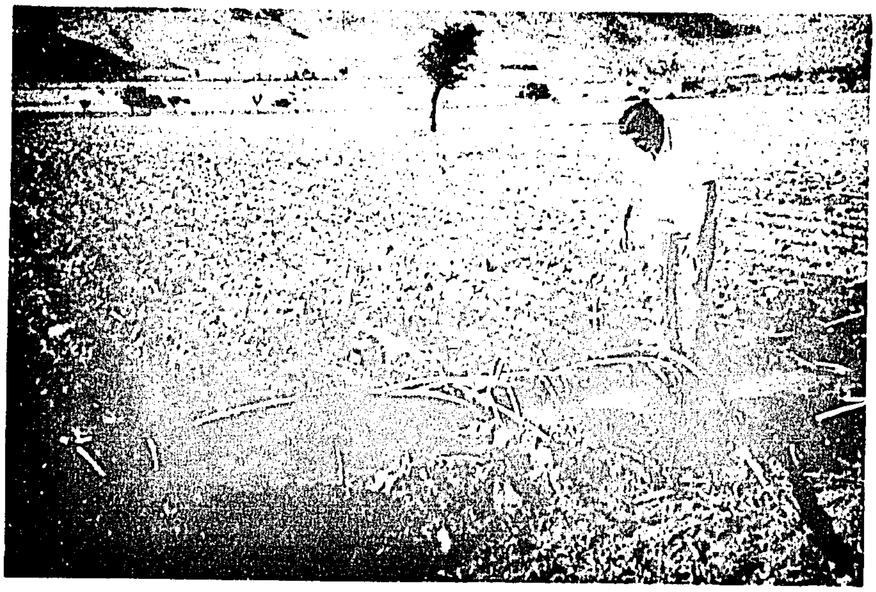


Figure 6. Furrow Irrigation with Siphon Tubes.

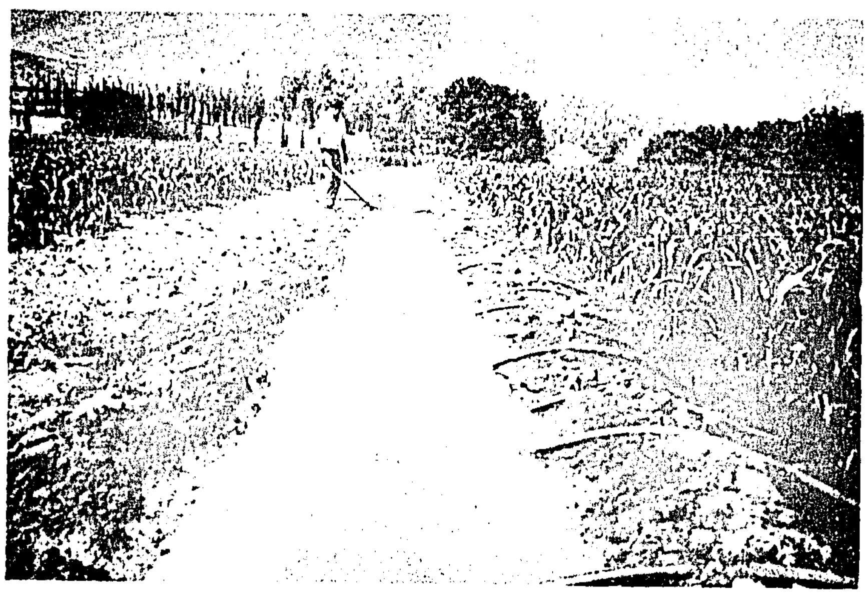


Figure 7. Furrow Irrigation with Siphon Tubes.

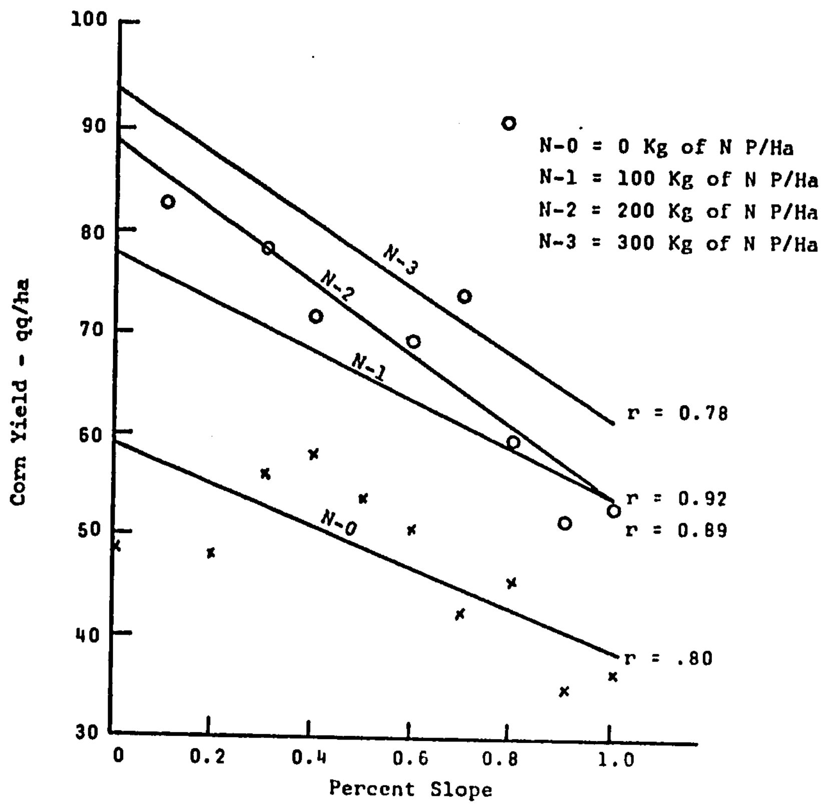


Figure 8. Yield of Corn as Influenced by Slope of Plots and Nitrogen Rate.

These examples clearly show the effect of low water intake rates and limited moisture penetration in reducing yields. Then the question must be asked: What can be done to improve the water intake rate of these soils? Since it is the common practice in Chile to remove the residue of the previous crop from the field before beginning land preparation, an experiment was conducted at Condoroma to evaluate the effect of incorporating the crop residue to improve soil physical condition and water intake rate.

Two levels of corn stalk residue were incorporated in a field previously planted to corn. The first level was that which was left after pasturing over the winter. The second level was double the first level and approximated the full crop residue before pasturing. The check plot had all of the residue removed before land preparation to simulate the current practice.

During the growing season the control plots showed signs of moisture stress whereas most of the plots which had the double crop residue showed the greatest plant development, as illustrated in Figure 9.

Yield results showed an increase of 38% or from 40 quintales/hectare on the check plot to 55.5 quintales/hectare on the plots with double level of crop residue. This increase reflects the increased moisture availability which resulted from the improvement in water infiltration by incorporating the crop residues. It showed that the problem of slow infiltration rate can be overcome at least in part by soil management. Incorporation of crop

Figure 9. Corn Residue Treatment Plots.

residues is recommended in place of removal. It should not be incorporated too deeply, but kept near the surface where it can have a maximum effect on irrigation water intake.

The following table can be used as a guide to help determine the infiltration rate for different soil textures.

Soil Texture	Approximate Infiltration Rate Per Hour in cm.
Fine sandy loam	1.27
Silt loam	1.0
Silty clay loam	0.76
Clay loam	0.5

The soil texture cannot be changed, but the structure is largely a product of management. The incorporation of crop residues into the soil surface and avoiding practices that cause soil compaction will help maintain good soil structure.

Land Management

Land management is important in corn production and consists of several important practices, all of which must be carefully executed for maximum corn production. These practices in general are:

1. Preparing crop residues for plow-down
2. Plowing
3. Irrigation
4. Seedbed preparation
5. Planting and
6. Cultivation

The best method for preparing crop residues for plow-down is by disc-ing. Where crop residues are too rank, a field chopper or roto beater might be more efficient. Burning should not be practiced. Crop residues should be returned to the soil to help maintain the organic matter content and soil structure. Both are important factors in irrigated agriculture from the standpoint of maintaining or increasing water infiltration rate and retention of soil moisture for crop use.

Plowing should be completed before irrigation. Under conditions where the field is too dry and large dry clods result, it is helpful to irrigate with a light uniform application of water before plowing. Depth of plowing should be sufficient to adequately cover plant residues so that they will not hinder the planter or the cultivator in their perform-ance. The plow depth should be sufficient, perhaps 25-30 cm. to allow the roots to grow and expand without restrictions caused by soil compaction. These restrictions often occur from machinery running over the field during the previous harvest, or from winter grazing of cattle.

Irrigation, as has already been stressed, is simply a means of main-taining a favorable moisture level in the soil reservoir. Irrigation by furrow helps assure uniform distribution of water over the field (Figure 6). The furrows for irrigation can be made using a tractor cultivator with ditcher shovels spaced to fit the corn rows (Figure 10).

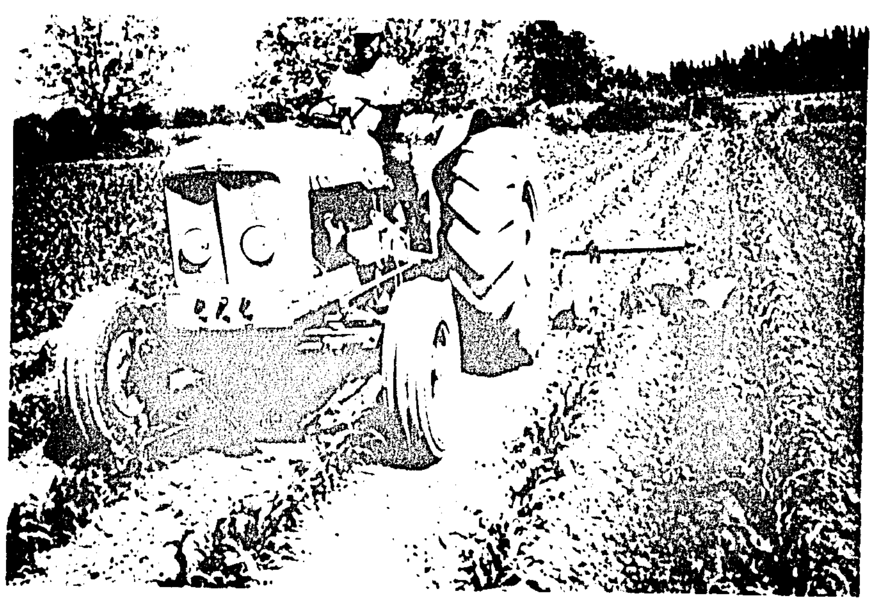


Figure 10. Cultivating and Forming Furrows for Irrigation.

Seedbed preparation is begun, following irrigation, usually by discing It is important that this operation be carefully timed. To cultivate an irrigated field too soon after irrigation, that is, before the field can support the weight of the tractor without causing deep wheel marks, will usually result in soil compaction. It is helpful to attach a spike-tooth harrow behind the disc to break down the slices of soil left on the surface by the disc which, upon drying, cause a cloddy condition (Figure 11).

Following a discing, a land plane should be used. Two passes in opposite directions are usually necessary to assure a level field. This will facilitate the field operations which must follow, such as planting, cultivation and irrigation. As with the disc, here again it can be helpful to attach a spike-tooth harrow behind the land plane. This will help to make a surface soil mulch of fine dry soil. A fine dry surface soil mulch will help prevent rapid soil moisture evaporation. This will usually place many weed seeds in an environment where they cannot germinate, and facilitate cultivation for later weed control, after crop emergence (Figure 12).

Planting is considered to be the most important single operation in corn production. Its success depends upon how well all of the previous operations have been performed. It therefore should be carefully planned giving consideration to the following items.

Seed. Very good hybrid seed varieties are available in Chile; both short season and long season varieties. Extension agents and seed company representatives are available to help a grower choose a variety that will best suit his needs.

Planter seed plates. Corn seed size varies, but it is packaged according to seed size. Seed plates must be selected for the planter that will accomodate the size of seed and to some degree adjust the seeding rate.

Seeding rate. Most planters are adjustable for seeding rate. A calibration can be made by pulling the planter over a hard surface such as a roadway, and counting the seed drop for a measured distance.

Seeding depth. The planter should be adjusted in the field to place the seed in moisture below the dry soil surface 5 to 7 cm. deep.

Functioning of the planter. The planter should be carefully examined and put in the best possible repair to insure trouble-free planting.

Cultivation for control of annual weeds is most effective when the corn is 25 to 30 cm. high. Good practices to this point will allow the corn to grow rapidly, and it will normally be much taller than most weeds. The dry surface soil mulch can be pushed up around the corn plants in ridges of sufficient height to cover the growing weeds. This can be accomplished using cultivator shovels or discs or a combination of the two. The shovels will leave the field furrowed for the irrigations to follow (Figure 10).

Fertility

The only plant nutrient deficiencies identified in Aconcagua Valley have been associated with nitrogen and phosphorus. For this reason no other fertilizer elements are recommended. Recommendations for nitrogen

Figure 11. Seedbed Preparation.

Figure 12. Soil Moisture Storage.

and phosphorus are based on soil analysis and cropping history. There is a residual effect from nitrogen and phosphorus applications to crops with nitrogen carrying over into the second year and phosphorus into the third and fourth year.

The effect of nitrogen applications made in previous seasons is illustrated by the data in Table 3. The results are from two experimental sites that received various rates of nitrogen fertilizer. The data indicate that plots receiving no nitrogen yielded essentially the same as with plots varying from 100-400 kg. per hectare. This simply says that there was enough residual nitrogen left from previous seasons to meet the corn crop requirements. This happens because of repeated generous nitrogen applications. On the other hand, experience has shown that many fields in Aconcagua are not well supplied with nitrogen and therefore respond favorably to nitrogen fertilizer applications. Figure 13 illustrates the average response to fertilizer nitrogen applications at 13 sites during two years. Figure 14 shows the effect of nitrogen at one of these sites. The stunted yellow plants are in a control plot which received no nitrogen fertilizer.

Table 3. Average Yield in Shelled Corn at Standard 15% Moisture Content

	Yield in Quintales/Hectare	
N in Kg/Ha	El Castillo	Condoroma
0	121.34	70.23
100	114.32	76.19
200	116.89	70.69
300	114.10	81.09
400	115.70	71.14

N = Kg. of elemental nitrogen per hectare.

The amount of fertilizer nitrogen necessary for increasing profits depends upon the amount of carry-over nitrogen from previous seasons. Figure 13 illustrates that the third increment of N (the increase from 200 to 300 kg. per hectare for the 1971-72 crop year) gave a yield increase of about 300 kg. per hectare of corn. Since the cost of 100 kg. of nitrogen in urea fertilizer, at that time, was about E° 350 and the value of 300 kg. of corn at the same time was about E° 200, the return in yield of corn for applications of nitrogen above 200 kg/ha was not profitable.

It might be assumed from Figure 13 that the average corn field in Aconcagua will respond best in yield to about 200 kg. of nitrogen per hectare. All of the corn fields are not average, but differ in relation to a past cropping history and fertilizer practices.

The following table serves as a guide for nitrogen fertilizer recommendations under some of these varying conditions.

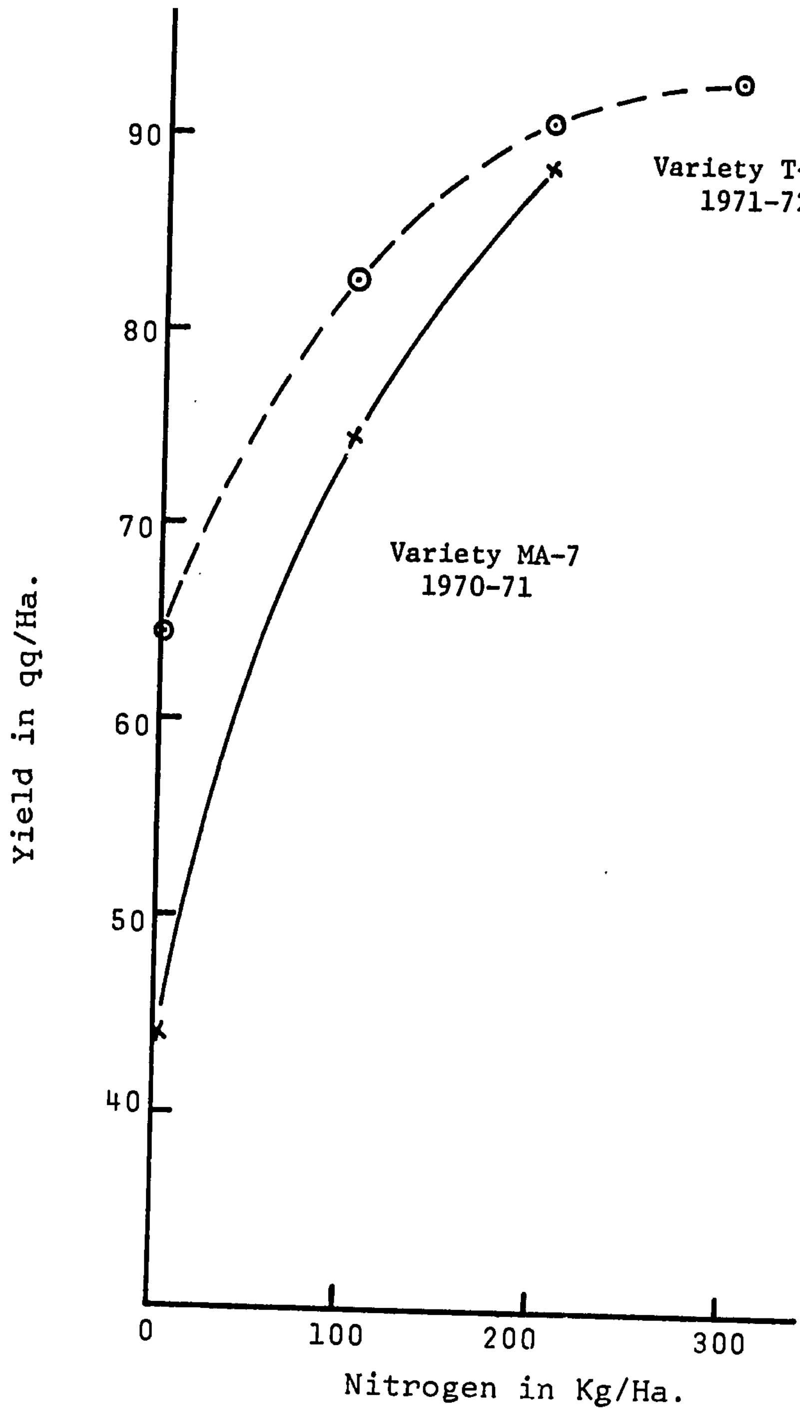


Figure 13. Average Yield of Shelled Corn for 13 Demonstration Plots in Aconcagua as Influenced by Nitrogen Rates.

Figure 14. Nitrogen Treatment Plots with Check Plot Showing Deficiency Symptoms.

Previous N Applications		Requirements of N in kg. per Hectare
Heavy	(200-300 kg. per ha.)	0-50
Moderate	(150-200 kg. per ha.)	100-150
Light	(50-100 kg. per ha.)	200

The form of nitrogen that should be used, of those that are available, is the one which has the least cost per kg. of elemental nitrogen.

Phosphorus is generally used at the rate of 70 to 75 kg. of P_2O_5 per hectare for corn production in Aconcagua. Soil tests for the area verify the validity of this practice. Soil samples for phosphorus analysis should be taken every 2-3 years to assure that adequate levels are maintained. Assistance can be obtained through the extension services for this kind of analysis.

Variety and Population

Excellent corn varieties are available to growers in Chile. Both "Tracy and Co." and "Funk" have been increasing good hybrid varieties within the country. A good seed improvement program under the Ministry of Agriculture and Livestock also exists and fairly good varieties of corn are now available from this source.

Three varieties of corn were used during the three years of investigations in Chile. They were Tracy Co. varieties T-133 and T-90 and Chilean hybrid MA-7.

The longer season variety T-133 gave higher yields than the shorter season variety T-90; and both varieties produced higher yields at 90,000 plants population density per hectare than at 60,000 plants, during the first year's experiments.

The experiments of 1970-71 at El Castillo and Condoroma resulted in higher average yields with corn variety MA-7 at 60,000 plants per hectare than at 90,000 plants per hectare. These data are shown in Table 4.

Table 4. Average Yield in Shelled Corn at Standard 15% Moisture Content. Corn Variety MA-7

Population	Yield in qq/Hectare	
	El Castillo	Condoroma
60,000 plants per hectare	118.8	82.07
90,000 plants per hectare	114.12	65.56

The 1971-72 investigations at Condoroma show that higher yields of both T-133 and MA-7 were obtained at 65,000 plants per hectare than at 50,000 or 80,000. This is shown graphically in Figure 15. The data from the three years of investigations indicate that different varieties of corn respond somewhat differently to population densities. However, corn

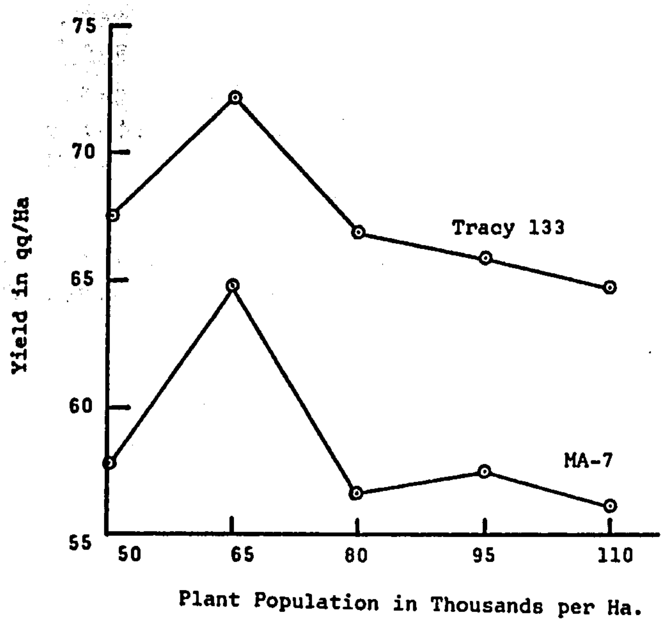


Figure 15. Yield of Shelled Corn as Influenced by Population and Variety.

population densities are estimated by SAG to average about 40,000 plants per hectare. This is much too low regardless of variety (see Figure 16). Both T-133 and MA-7 appear to respond best between 60,000 and 70,000 plants per hectare. Perhaps T-133 would yield best near the upper range and MA-7 near the lower range. However, the yield differences are not so great and planting populations in this range for T-133 and MA-7 appear to be a good recommendation.

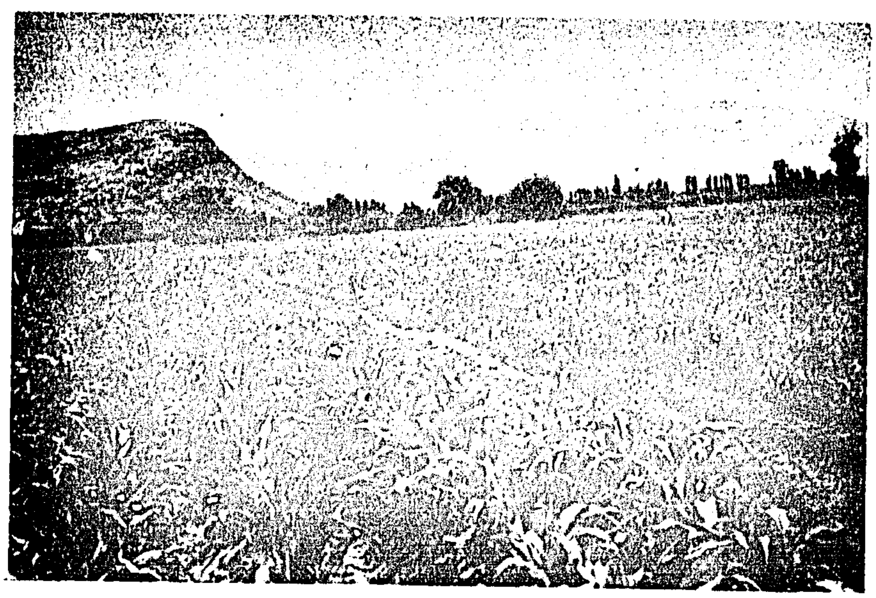


Figure 16. Plots Showing Differences in Plant Population.

The plant densities studied were at row widths of 86 cm. and 100 cm. Spacings within the row were determined as dictated by the desired population density. These row widths are common for the area and accommodate machinery used for planting, cultivating, and harvesting.

The choice of long or short season hybrids is usually based on two considerations. The first is the availability of irrigation water. If water is limited, a short season hybrid may be used with greater assurance that enough water will be available to bring the crop to maturity. If irrigation water is not limited then, of course, the long season hybrid will produce higher yields. The second consideration is time. Varieties vary in the total number of days required to mature the crop. A variety can therefore be chosen within reasonable limits to fit the time available. For example, an early vegetable crop might be grown and then followed by a short season hybrid corn variety that would fill in the balance of the growing season. Another consideration might be to grow two short season hybrids, one following the harvest of the other, rather than one long season hybrid. A short season hybrid might very well have an important place in a double, or even multiple cropping program.

Costs and Returns

As an example of potential yield increases and their economic significance to corn producers, the average cost of production was computed by the San Felipe Office of SAG using the data from the 1970-71 demonstration experiments (3). These cost figures were based on average corn yield of 45 qq/ha. for the period 1967-70. Total production cost per hectare, excluding nitrogen fertilizer, was E° 4,251. The corn yield results, shown in Figure 13 for the 1970-71 crop year, were evaluated in terms of production costs. Figure 17 shows the relationship between production cost and returns. The average price for corn in 1971 was about E° 100

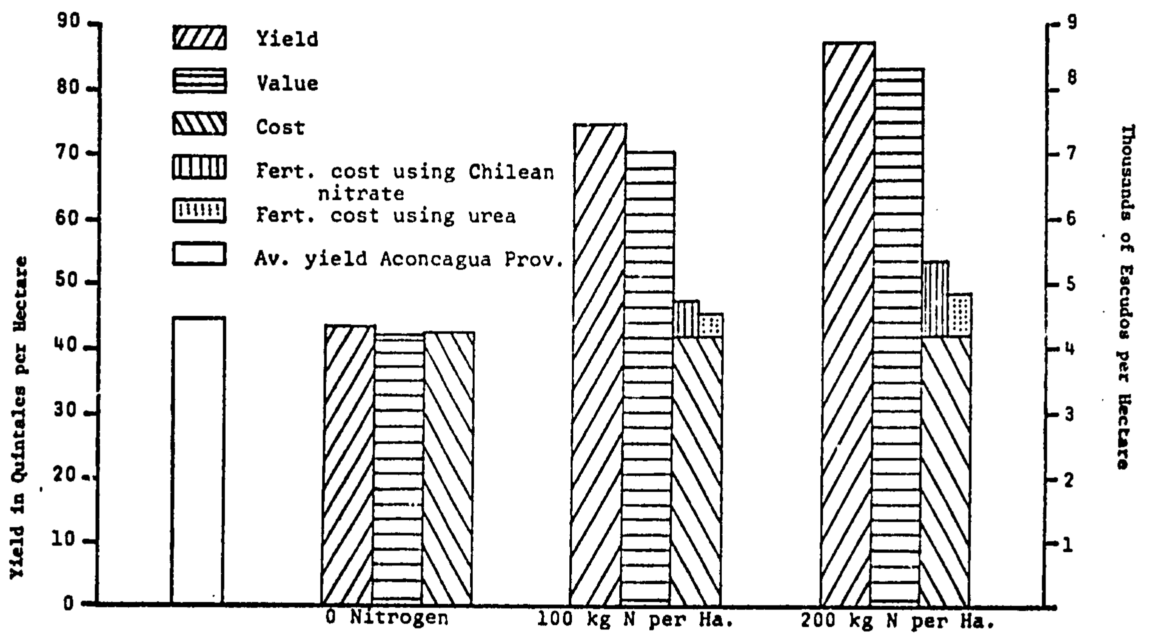


Figure 17. Average Yields, Production Costs and Gross Value of Corn Produced on Demonstration Plots - Aconcagua.

per quintal. Accordingly, the gross return per hectare and the cost of production are nearly equal at the 0-nitrogen level. At the 100 kg. of N per hectare there was an increase of 64% in yield of corn with only a 9% increase in production costs. At 200 kg. of N per hectare there is an increase of 96% in yield of corn with an increase of 21% in production costs.

It should be emphasized that the increase in corn yields presented here were obtained not only under controlled experimental conditions, but also under existing conditions of private farms and agrarian reform centers. While the program activities were limited to corn in the Aconcagua Province, the recommendations may be applied in the other corn producing areas in Chile, and many of the management techniques can be applied to other crops as well.

The recommendations given here, based on the concepts of intensive irrigation agriculture, will increase production 150% above present levels.

SUMMARY AND RECOMMENDATIONS

A three year program involving research and demonstration on modern concepts of irrigation management for corn was conducted in the Aconcagua Province. Irrigation, land management, fertility, corn variety and plant population were emphasized. Results proved that yield potential of corn is well above the current level of production. By adopting the practices in this bulletin, corn producers can increase yields at least 150% with the resources they currently have available. While all of the research was conducted in the Aconcagua Province, the technology can be transferred to other provinces in the corn producing area with slight modification or adaptation.

Based on the results of the project, the following recommendations are made for increased corn production in Chile.

Irrigation

Proper timing and amount of irrigation is essential for increased production, since corn is very susceptible to moisture stresses. Even short periods of moisture stress, particularly during the critical stages of tasseling and silking, will sharply reduce yields.

Perhaps the most important single irrigation is one prior to planting. Enough water should be applied to the soil to completely fill the root zone to the field capacity. Part of this moisture will come from rain during the winter months. The remainder must come from irrigation. If water for irrigation is limited, irrigation might be accomplished during the winter months when irrigation demand is low. This would have the effect of relieving the water demand during the planting season. For most soils, this will require several hours, and the furrow method is recommended so that application times and amounts can be controlled. An adequate irrigation at this time will insure good moisture for seed germination, early crop growth and will postpone the first irrigation after planting.

In subsequent irrigations, depths of water applied should again be adequate to completely replace the moisture extracted from the soil reservoir. By completely filling the entire root zone at each irrigation the periods between irrigation can be extended and the number of irrigations reduced. This also reduces labor requirements and management problems associated with light, frequent irrigation. Incorporation of crop residue will enhance water infiltration and thus increase yields.

When to irrigate is an important management question. Experienced farmers will use the corn plant itself as an indicator of moisture stress; when the plant wilts in midday the soil moisture supply is getting low and needs to be replenished. The "ball" method can be correlated with corn wilt symptoms in order to anticipate drought stress before it actually occurs. There are instruments, such as soil moisture tensiometers, that can be placed in soil to obtain a more precise estimate of available moisture conditions.

Another method that might be used to schedule irrigation involves evapotranspiration rates (evaporation of water from the soil plus the water used as transpiration by the crop). (This was about 1 cm. per day in the Los Andes area during the peak water demand for corn.)

Land Management

Plowing should be done prior to irrigation at a 25-30 cm. depth to adequately incorporate residue from previous crops. A preplant irrigation should then be applied. Seedbed preparation can be done after soil is dry enough to prevent undue compaction by equipment. The tandem disc should be followed by a spike-tooth harrow to break up clods and leave a fine surface mulch.

The seed should be planted in moist soil so it can germinate. This will be 5-7 cm. deep. A carefully calibrated and adjusted planter should be used to insure uniform seed drop and depth.

Weeds can be controlled by cultivation after corn is 20-30 cm. high. This operation will also prepare the furrows for subsequent irrigations.

Fertilizer

A recommendation of 200 kg. of N per hectare would be adequate for most soils in Aconcagua. In the event that the field has a history of heavy use of nitrogen fertilizer, smaller applications may be sufficient.

Soil test for phosphorus taken in the Los Andes-San Felipe area indicate that about 60-70 kg. per hectare of P_2O_5 should be applied to insure adequate levels of soil phosphorus. If phosphorus fertilizer has been applied to a crop in the rotation during the previous crop season a soil test can be made to determine the level that might be needed.

Variety and Plant Density

Several good varieties of corn are available in Chile, including short and full season hybrids. If water is limited, a short season hybrid may be used with greater assurance that enough water will be available to bring the crop to maturity. If irrigation water is not limited then the long season hybrid will produce higher yields. An early vegetable crop might be grown and then followed by a short season hybrid corn variety that would fill in the balance of the growing season. A short season hybrid might very well have an important place in a double, or even multiple cropping program.

Recommended plant density is 60,000 to 70,000 plants per hectare. The plant densities are based on field experimentation at row width of 86 cm. with plants spaced at 18 cm. within the row, and 100 cm. with plants spaced at 15 cm. within the row.

It must be emphasized that the recommendations made here for growing corn are based on the assumption that all of the crop growth factors are maintained at near optimum levels for maximum crop yield as far as possible. If for example, nitrogen is not applied in sufficient quantity to obtain maximum yields, but variety, plant density, irrigation, crop management, etc., are maintained at appropriate levels, the yield of corn will be lower than the maximum potential. The same will be true also if irrigation or any other crop growth factor is limited.

The recommendations given here, based on the concepts of intensive irrigation agriculture, will greatly increase production above present levels.

REFERENCES

1. Indicadores Agroeconómicos. Publicación No. 4, ODEPA y SAG, Ministerio de Agricultura. Santiago, Chile, 1970.

2. Investigations of the Water Resources of the Maipo Basin. Final Report 1970. Prepared by: Rendel, Palmer and Tritton, Chartered Civil Engineers, London, England, for: Irrigation Directorate, Chilean Ministry of Public Works.

3. Kidman, Don C.; R. Kern Stutler. Interim Report of Water - Soil - Crop Interaction Experiments in Chile. 1970-1971.

4. Kidman, Don C.; R. Kern Stutler; and David W. James. On-Farm Water Management Research in the Aconcagua Valley, Chile. Third Annual Report 1971-72.

5. Kidman, Don C.; R. Kern Stutler; and David W. James. On-Farm Management Research in Chile: Increasing the Efficiency of Soil Moisture Use for Increasing Crop Production. 1973.

6. Política Nacional de Riego; Comisión de Utilización de Recursos de Agua; Instituto Ingenieros de Chile.

7. Reyes M., Rodrigo. Interacciones de Riego en Variedades de Cultivo, Poblaciones de Plantas y Fertilizantes. Tesis, Universidad Católica de Valparaiso. 1970.

8. Seminario Sobre Uso de los Recursos de Agua en Chile, Dirección de Riego, MOPT. Junio, 1972.

9. Tosso, Juan. Analysis of Chilean Meteorological Data to Estimate Evapotranspiration and Irrigation Requirements. M.S. thesis. Utah State University. Logan, Utah. 1972.