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COURSE NOTES

FEEDING TEN BILLION PEOPLE: HEADACHES OF AN AGRONOMIST

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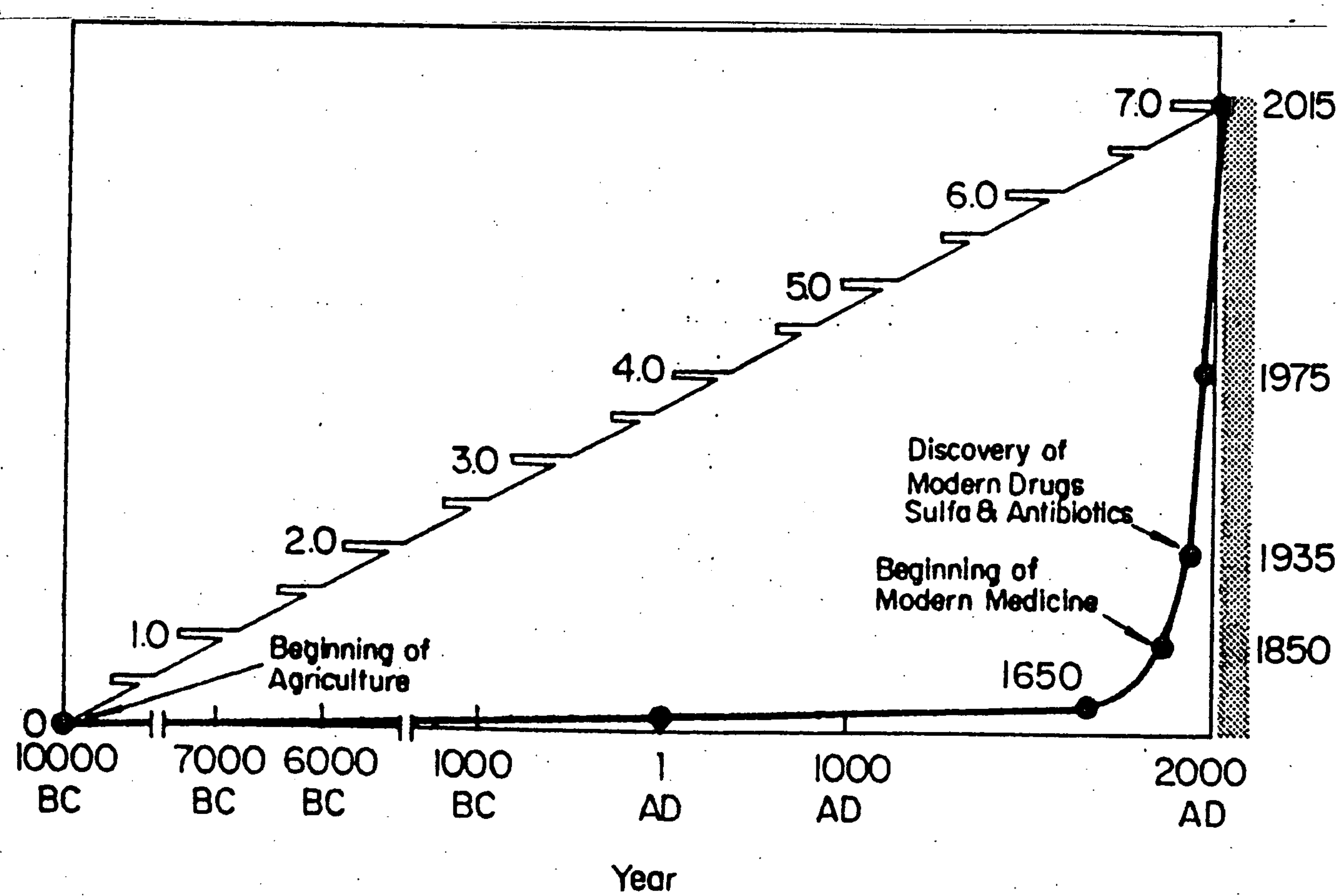
Feeding a Hungry World

Although many of you probably dream of becoming doctors, engineers or mathematicians and do not really see the need why you would spend your time on agricultural research, I believe that agricultural sciences face some of the biggest challenges on earth. How can we keep on adequately feeding all the people in the world?

Population experts now estimate world population to have been about 250 million 2000 years ago (Figure 1).



1. World population growth.

The first doubling of the population appears to have occurred by about the year 1650. It looks thus 1650 years to double the population from 250 million to 500 million. However, within only another 200 years, by about 1850, population doubled to 1 billion. A short span of only 80 years passed till 1930 to reach 2 billion and after even a shorter 45 years, population reached 4 billion in 1975. Experts project that by the year 2015 the world population will have doubled again to 8 billion people.

So, early in the year 2015, 8 billion people will be living on the earth. Within 25 years from today, there will be one and a half times as many people to feed as there are now. Not only the number of people will increase, also the demand for diets that are more nutritious and varied will be much greater as a result of the higher standard of living that many more people will have at that time. The implication is formidable.

Farmers, livestock keepers and food processors and distributors will not only have to produce, process and distribute twice as much food as they do now. They also will have to change the mix among cereals, meats and vegetables as well as increase production and distribution by perhaps as much as another 100% to satisfy the greatly expanded demand in developing countries for other than the simplest of diets based primarily on the major cereals like rice, wheat and maize.

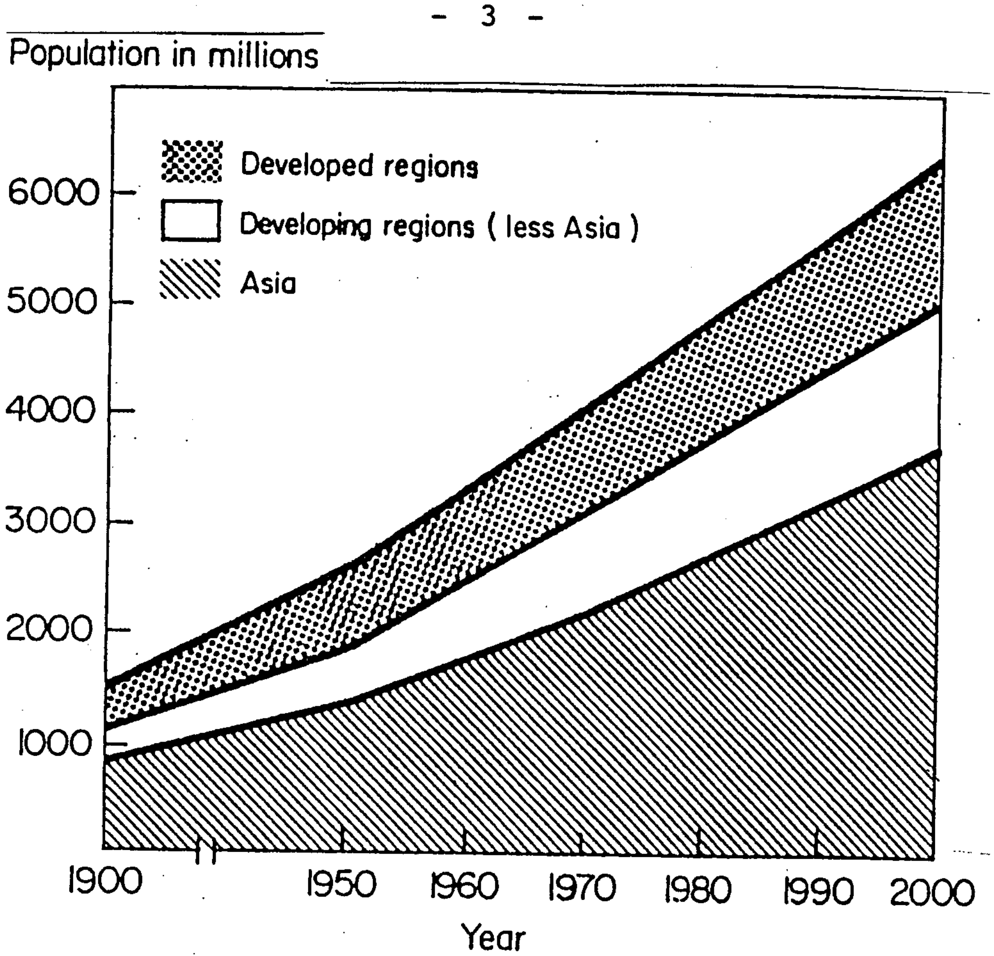


Figure 2 illustrates that our problem is even more complicated than that. If the increased demand for food would be evenly spread all over the world there would be a good chance that agronomist could meet the challenge.

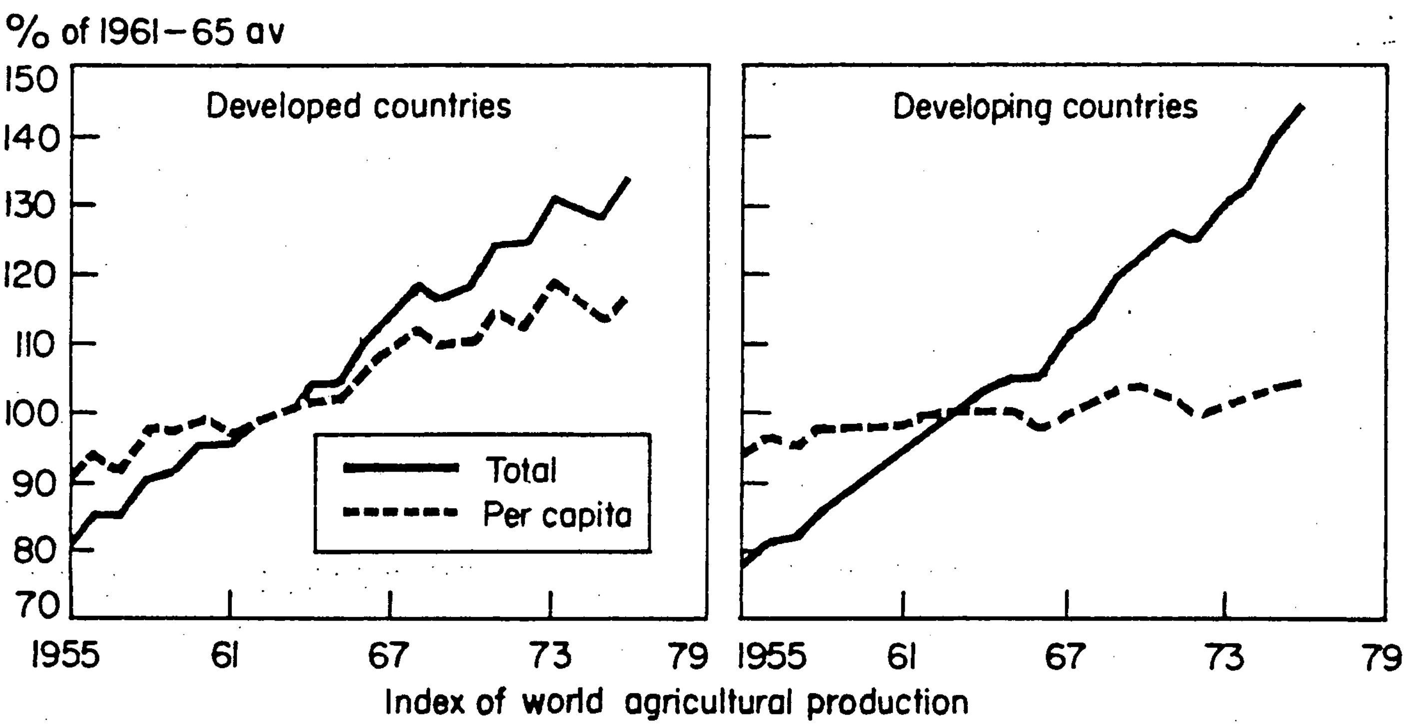
However, world population growth rates are unfortunately the highest in areas where production growth rates are lowest (Table 1).

Developing countries which find it now already difficult to produce enough food will have in the future even more difficulties to become self-sufficient (Figure 3).

Table 2. Projections of food demand[a] and extrapolations of food production to 1985.

	Volume growth rate (%/year)		Overall volume increases (1969-71 = 100)	
	Demand	Production	Demand	Production
World	2.4	2.7	144	150
Developed countries	1.5	2.8	126	151
Market economies	1.4	2.4	124	143
Eastern Europe and USSR	1.7	3.5	130	168
Developing market economies	3.6	2.6	170	146
Africa	3.8	2.5	176	145
South and Southeast Asia	3.4	2.4	166	143
Latin America	3.6	2.9	170	152
Near East	4.0	3.1	180	157
Asian Centrally planned economies	3.1	2.6	158	146
All developing countries	3.4	2.6	166	146

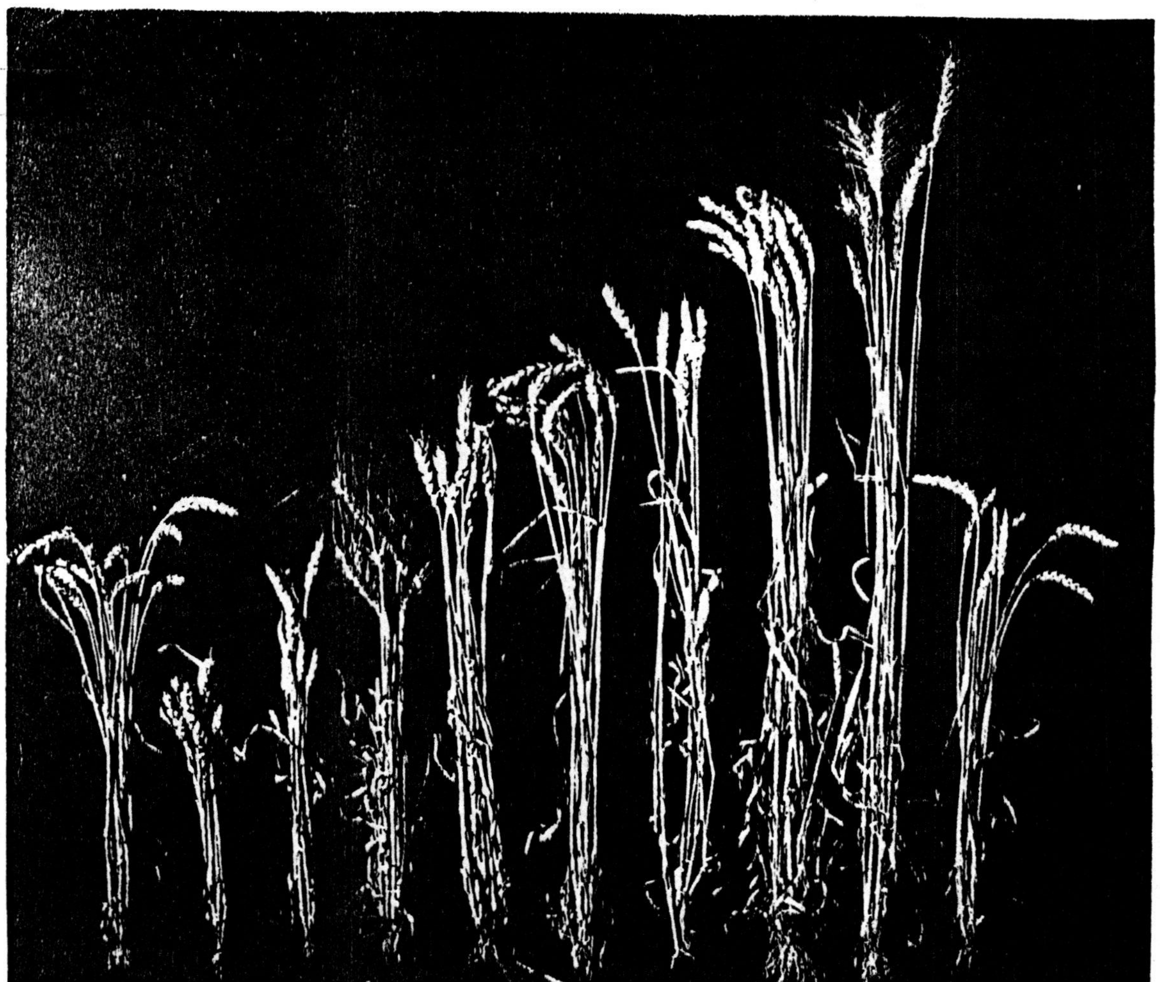
[a]All food, including fish. The base period of extrapolation of food production was 1961-1973. A full description of the methodology of demand projections is given in FAO (1971).
Source: UN 1974.



2. Index of world agricultural production (source: Palacpac 1980).

However, the situation is not desparate. Scientists from different agricultural disciplines are working very hard to ensure that food production growth rates keep pace with the population increase.

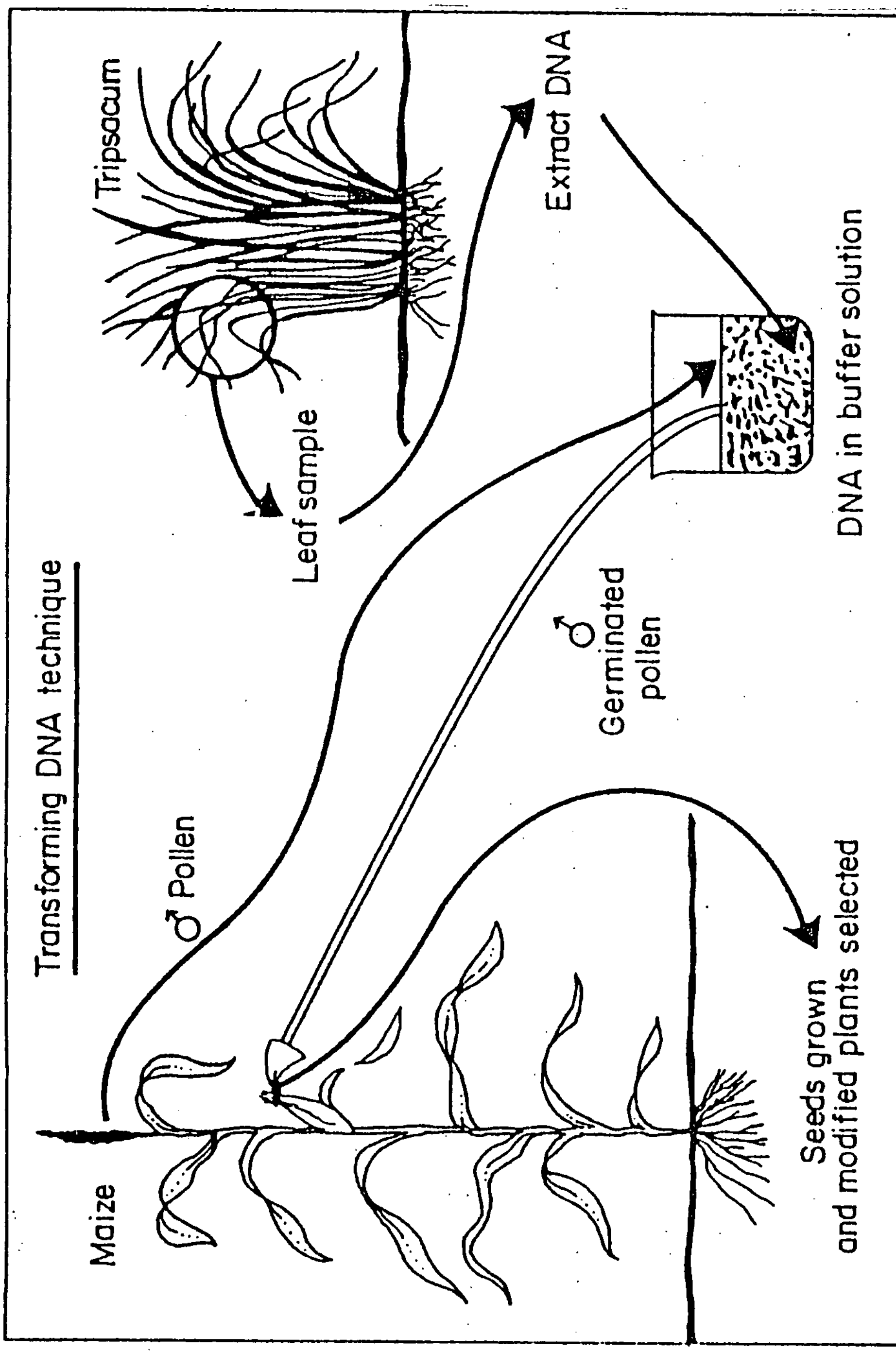
1. Good opportunities for providing production gains of 50% and more lie in the fields of plant genetics. Traditionally, hybridization has been the technique for improving plants to get high yields (Figure 4).



2. Variation in plant height in SC_3 progeny of somaclones from a double dwarf wheat variety. Parental plants are at extreme left and right.

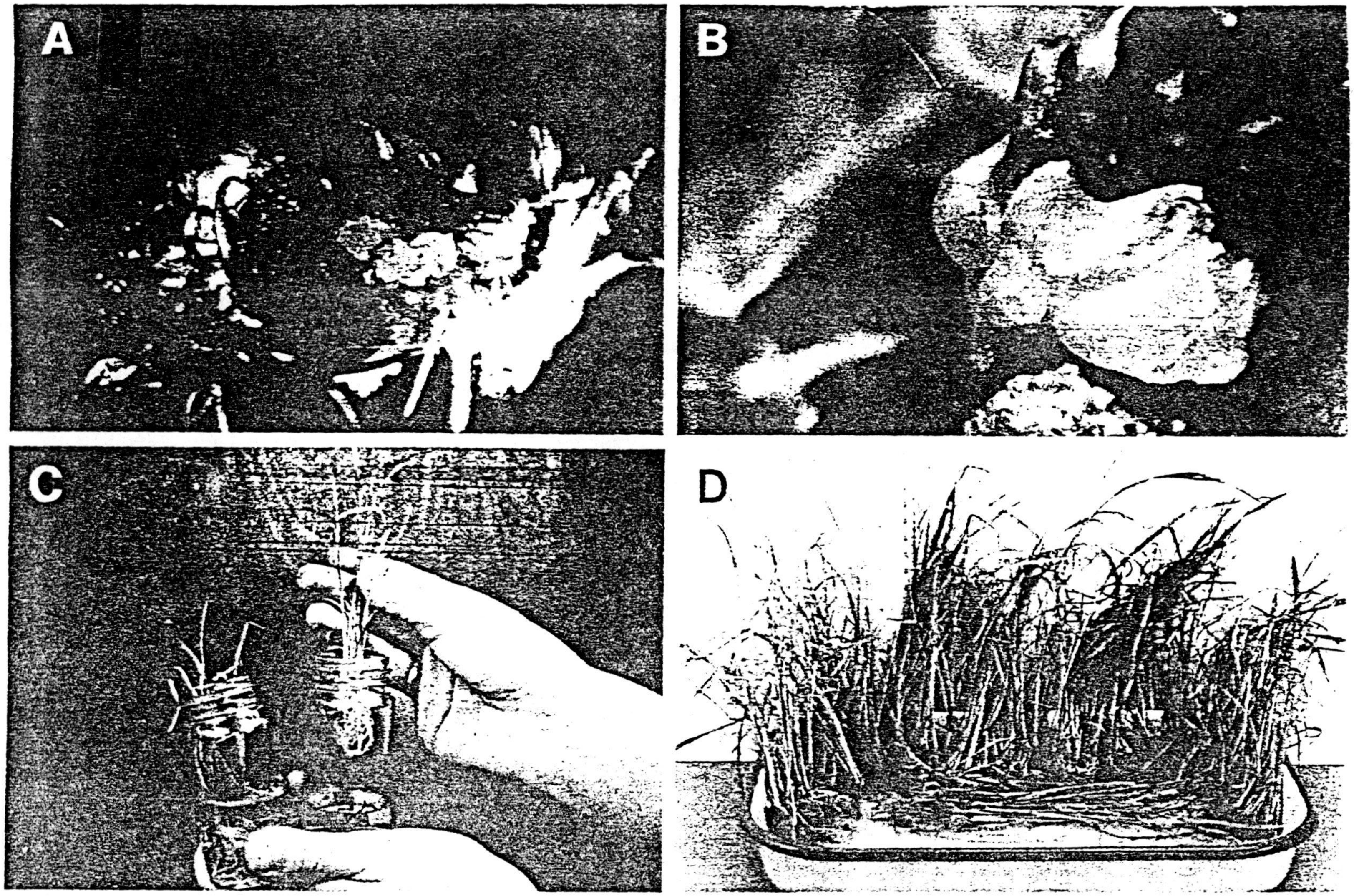
The traditional approach of increasing strains with desirable characteristics will continue. However, in very recent times, the new technique of genetic engineering has been developed.

Highly refined techniques now permit to isolate genetic material, identify formation of genetic molecule responsible for specific characteristics and then splice the portion on to genetic molecules from another strain (Figure 5).



3. Diagram of the method used for incorporating alien material by the transform ing DNA technique.

When the technique becomes broadly applicable to plants, the time needed to develop new strains of crop will be shortened dramatically (Figure 6).



6. A. Embryogenic Mahsuri rice callus with a number of regenerating plants. B. A single embryo of Giza-159 rice showing the shoot and root regions enveloped by the scutellum. C. Regenerating plants are removed from culture and placed in vials of distilled water to encourage root elongation. D. A tray containing several hundred regenerated Pokkali rice plants.

On the otherhand, genetic engineering will open the door to the production of amino acids and vitamins to supplement foods and to vaccine production, a major way to control animal disease.

2. A second way in which agricultural research can lead to large gains is through plant physiology studies.

The study of plant physiology includes the isolation of chemicals present in very minute amounts during different growth stages of the plant. The molecular structure of these plant growth regulators has been determined so that methods can be developed to apply these regulators to enhance or modify plant characteristics as yields, resistance to lodging, growth rate etc. Some of the well known growth regulators are indole acetic acid, abscisic acid, gibberelic acid and ethylene (Figure 7).

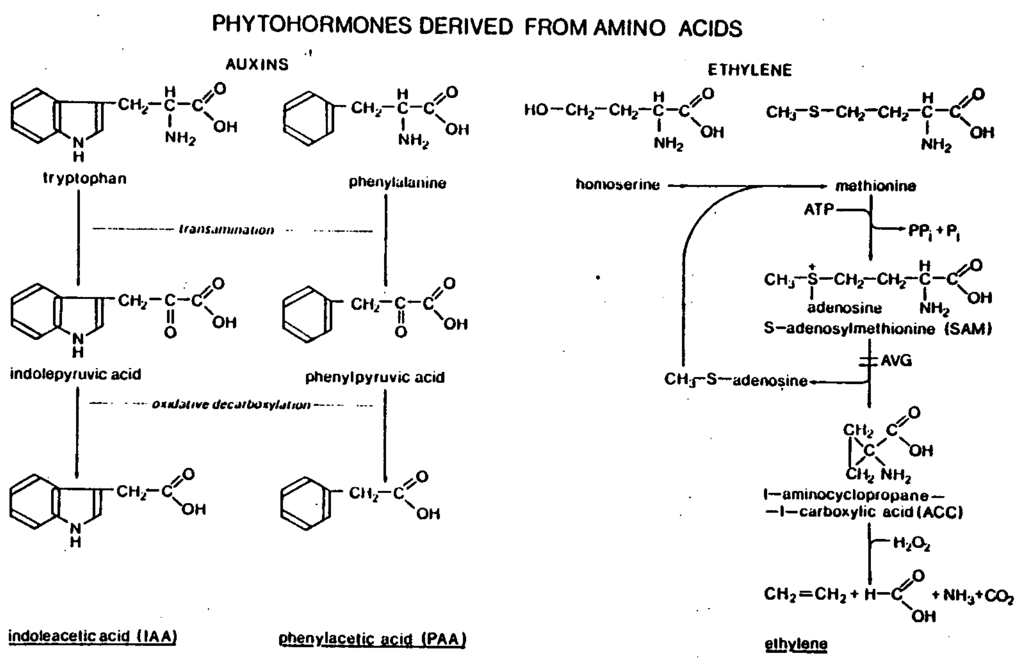


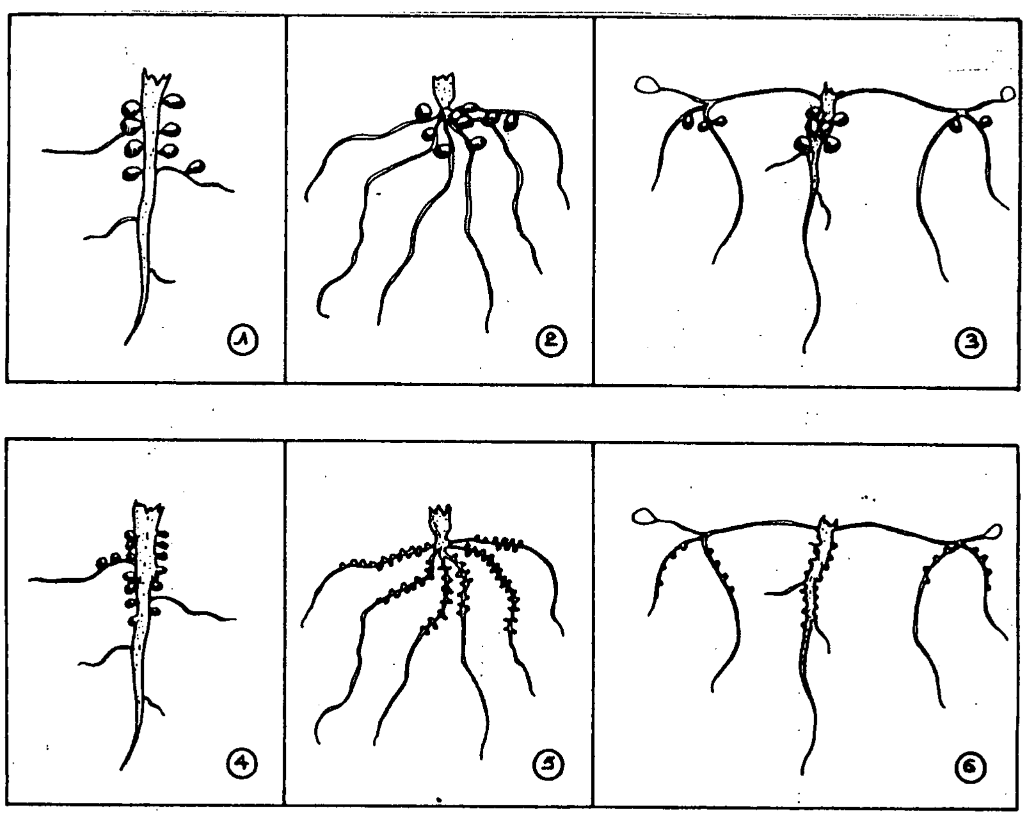
Figure 2

3. To increase food production rapidly in all countries in the short term, the next effective technology is increased use of fertilizers and increasing the efficiency of the fertilizers that are used.

Leaching of soluble nutrients out of the root range of crops is a major concern in tropical farming under heavy rainfall and high temperature conditions. As much as 2/3 of applied chemical nitrogen may then be lost.

Therefore, a great challenge to research in the field of plant nutrition is to improve the processes for fixing nitrogen into a form that plants can use. Although 80% of the air consists of N_2 gas this nitrogen form is not available for plants. Plants take up nitrogen only as ammonium or as nitrate. However, some bacteria or algae can transform N_2 gas to nitrogen forms which are readily available to plants. This process is called biological nitrogen fixation. These bacteria, are known as nitrogen fixing bacteria, can live in very close contact with the roots of legumicous plants.

On these roots one can observe tiny round shapes which are called nodules (Figure 8).



These nodules contain the bacteria which live in symbiosis with the plant. Both the plant as well as the bacteria are benefitting from the close association. The bacteria provide nitrogen to the plant, which is the most essential plant nutrient. In return, the plants provide sugars to the bacteria, so that these can survive.

If two different species live in close contact with each other and if both benefit from that association this is called symbiosis.

4. There are millions of hectares of land suffering from toxic soil conditions. Research to diagnose the problems and to devise solutions will prove very essential. The different types of problem soils and possible solutions will be presented in the following lecture.

5. Animal Husbandry.

A very promising way to increase food production in developing countries is by combining animal husbandry and crop cultivation into an integrated agricultural system.

Animals not only provide food as well as draft for crop cultivation, but they are also essential parts of a recycling system, consuming organic matter that people cannot or will not eat. Feeding systems for ruminants must be organized to take full advantage of their capability to use cellulosic products and non-protein nitrogen to produce proteins and dung for biogas and fertilizer for the field. Also the value of animals as food stores should not be ovelooked.

It is well recognized that the developing countries should not adopt the capital-intensive cattle production systems of the developed countries, but modern technology can be applied to less intensive systems to produce milk, meat, cheese etc., successfully.

Continued efforts by vetenary scientists to determine host-pathogen relation and to develop cures or preventive measures deserve the strongest support. Otherwise animal diseases will remain a major impediment to animal production. In Africa, 1 billion ha of land cannot be used for grazing because of trypanozomiazis carried by tsetse flies.

6. Food production alone cannot solve the problem of malnutrition. Food processing technologies should follow the trend of large scale production, since the trend to urbanization cannot be stopped. Research and development projects for small and medium scale processing will have to be adapted from country to country and from region to region since great differences exist in food resources, food habits and food availability.

Some of the stratagies to solve the hunger problem in the world have been summarised above. However, we must not forget that the increase in food production will have to come mainly from the developing countries. The potential in these countries for increasing food production is great, but difficulties are great as well.

Developing countries continuously lose croplands because the fertility is exhausted, erosion removes the fertile top soil and salination makes land unsuitable for cultivation. In addition, farmers have to invade virgin lands that have inadequate rainfall, steep slopes or other factors which makes them only marginally suitable for cultivation. As a result, great areas of forest are being destroyed and converted into upland so that serious shortages of wood for fuel can occur.

It is thus obvious that the problem of feeding 10 billion people is a complex one. This makes it essential for scientists from different fields to collaborate successfully to solve our problem.

1. Health workers and parasitologists will mention that we have to combat parasites and diseases specially in children. If not, the agronomist will feed parasites instead of people.

2. In order to achieve a better food conversion rate, certain food habits will have to be adapted or even changed. Nutritionists have shown that this is not impossible. In Sri Lanka, 30 years ago nobody thought about eating bread. Now you can find bread even in the smallest village. Bread is obviously a good alternative for rice since it provides large number of compounds which were essential for human nutrition.

3. The positive impact of press, massmedia and extension workers in the promotion of high protein vegetables like winged bean and soya is abvious. So, agricultural scientists also need the help of these people to inform the people of the reseach findings.

Institutes, like IFS are aware of the necessity of multidisciplinary research to win the difficult battle against poverty and hunger. When agronomists, health workers, veterinary surgeons, chemists and other specialists work closely together, it should be possible to eradicate hunger and malnutrition.

SOIL-RELATED CONSTRAINTS TO FOOD PRODUCTION IN THE TROPICS

In the first lecture I tried to give a general overview of the problems which agronomists face.

Furthermore, it was suggested how different agricultural disciplines can contribute to overcome some of these problems. Since the main goal of our project at the IFS, is to improve food production on problem soils, I would now like to restrict myself to introduce to you the different types of problem soils and suggest to improve the yield of the problem soils.

There is no clear cut definition of a problem soil. A soil is called a problem soil if a crop suited to a particular climatic zone and landscape cannot be grown with economic inputs or there is danger of soil degradation when cultivated.

Probably all of you know that there is a big difference between the rice yields of some districts in the Dry Zone compared to those of the wet zone. Where a farmer in Amparai easily gets 5t/ha (100 bushels/acre) it is for a farmer in Matara already quite difficult to obtain half of that yield. This difference is mainly explained by the fact that the soils on which rice is grown in these two districts have other characteristics. Soils in Ampara are rich in essential plant nutrients, they have a high pH, and have other characteristics that promote plant growth like a high carbon content, high nitrogen content etc...

On the otherhand, Matara soils are producing much less rice due to a variety of essential plant nutrient deficiencies so that we can call these soils, problem soils.

Soil problems fall into three main classes :

1. Mechanical
2. Hydrological
3. Chemical

CHEMICAL PROBLEMS

The main chemical problems include :

1. Salinity
2. Alkalinity
3. Strong Acidity
4. Iron Toxicity
5. Excess Organic Matter
6. Nutrient Deficiencies

Saline Soils

These soils contain too much salts for normal plant growth. Soils with an electrical conductivity (EC_e) exceeding 4 dS/m are harmful to most plants. Above 15 dS/m only salt-tolerant plants can grow. Salinity may be due to influx of sea water regardless of climate or to accumulation of salts in dry areas. The remedy is to prevent the entry of salts, wash out the salts, and grow salt-tolerant crops. Salt-tolerant rice varieties such as Pokkali and IR 36 are widely grown in saline tracts.

Alkalinity or Sodicity

Alkali or sodic soils usually have a pH greater than 8.5 and a high percentage of sodium. They usually occur in dry areas. Growth-limiting factors are excess sodium and deficiences of calcium, phosphorus, nitrogen, and zinc. The remedy is to remove the excess sodium by applying gypsum ($CaSO_4 2H_2O$), leaching the soil, correcting nutrient deficiencies, and growing alkali-tolerant crops.

Strong Acid Soils

These include Ultisols, Oxisols, Spodosols, and acid sulfate soils. The pH value of these soils is less than 5.5. The main growth-limiting factors for dryland crops are aluminium and manganese toxicities and phosphorus deficiency. Most of the tea and rubber lands of the Sri Lanka are strongly acidic. Fortunately, tea, rubber and coconut are acid-tolerant crops. But because these soils are deficient in calcium and magnesium, use of dolomite ($CaCO_3MgCO_3$) is advisable.

Iron Toxic Soils

Iron toxicity of wetland rice is common on the Ultisols and Oxisols of Sri Lanka. It occurs in the wet zone from Mirigama to Matara. Iron toxicity is caused by excess water-soluble iron in the soil solution. Nutrient deficiencies make it worse. The remedy is to apply lime, manganese dioxide, and grow resistant varieties. The Department of Agriculture has bred many tolerant rice varieties and the International Rice Research Institute has identified many iron-tolerant varieties.

Excess Organic Matter

This is a problem on Histosols. The main problems are deficiencies of nutrients, especially nitrogen, phosphorus, potassium, zinc, and copper. Some organic substances are also believed to interfere with nutrient uptake or to poison the plant directly. The remedy is to fertilize the soil and grow adapted varieties.

Nutrient Deficiencies

Sandy soils are deficient in all nutrients. Besides they lose fertilizer fast. They need complete fertilizer in small doses.

Most soils of Sri Lanka especially those of the Dry Zone are deficient in nitrogen. Because of heavy phosphate fertilization of tea, rubber, coconut and vegetables, phosphorus deficiency may not be common. Phosphates applied to soils are held in the top soil for several years whereas nitrogen and potassium are easily lost. Zinc deficiency is likely to occur on high-pH soils and on soils high in organic matter. Iron deficiency is likely to occur on high pH, dryland soils.