THE ROLE OF CHEMICALS IN THE PRODUCTION OF FOOD FOR A GROWING POPULATION. Dr. Norman E. Borlaug, Distinguished Professor of International Agriculture, Texas A & M University, College Station, Texas.[1]

It's a pleasure for me to be here today to try to give you some insights into some of the changes that I've seen in food production during these last forty years in developing countries. I think that at the present time many of us are suddenly shocked by what we see on our television screens in the evening news by the hunger and famine in Africa, and especially in Ethiopia. Now let's turn back the time clock about 25 years and we will see that that situation, similar to the one today, prevailed at that time in Asia, South Asia especially. I would like to point out how the world looked at the situation in Asia in the early 1960's and up through '67 or '68 so that we can recapture a bit of the philosophy of many of the learned people in the most distinguished universities. For example, we began to transfer the technology in the case of wheat, mostly which was developed in Mexico where wheat was not an important crop, to India and Pakistan first. Many of the scientific social philosophers said that we were simply making the rich richer and the poor poorer. There were those also that said to forget about it; India is a hopeless case and Pakistan almost certainly nearly as bad; and these were among our most distinguished scientists. We were accused of accelerating the migration of rural, miserable peoples to the cities. And if we look at history we know that has been so, without any science and technology. There has been a slow gradual evolution of agriculture from the time of discovery of agriculture which has made it possible for people for the first time to settle down in villages and to try to strive for a little better life, one of learning, of forming some kind of governments, and eventually crafts and trade which have evolved, after all of this time into a complex of world civilization such as we see today. So with that in mind, let us relfect again on the situation in Africa today. Can we do something about it? Is there a chance that we can make similar breakthroughs?

Before going further, let me refresh our memories on where this food, the first necessity for life, comes from. Somewhere between 98 and 99% comes from the land and less than 1% comes from the ocean and inland waters. It's likely to remain that way for the next several decades at least. So what we do to improve the productivity of the land will largely determine the future of mankind. When we talk about food we have to consider two problems: one, to produce enough, and secondly, to distribute it equitably. On the distribution problem we run into poverty and lack of purchasing power. It is ironical today that when we have overproduction of food again in this country, depressed prices, and many farmers going broke, just the opposite situation is happening in Africa - many starving because of lack of food.

Having grown up on a small farm, and having studied forestry, I became interested in land use in the broadest context. I worked briefly in the chemical industry where I probably would have spent my career if it had not been for just some funny strokes of luck. I accepted a job in Dupont after I got my degree, about six months before Pearl Harbor. The contract was to work on

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[1]From a recording made of Dr. Borlaug's presentation.

agricultural chemicals, probably weed killers, as well as some of the other pesticides. It turned out that Pearl Harbor came along and this laboratory was converted into a microbiological laboratory, where I was frozen under the War Manpower Commission, to carry out various kinds of research for the armed forces. I had a chance to join this first foreign assistance program in 1944.

The first foreign technical assistance program in agriculture was started in Mexico through the joint undertaking of the Rockefeller Foundation and the Mexican government. At the time when that program was started there were only two or three people moderately well trained in scientific agriculture in Mexico. It took us seventeen years to train enough scientists in the different disciplines to be able to turn over the responsibilities for research. There was no extension service whatsoever in existence when we started. The first extension service was established with young people who were trained in research. The National Institute of Agricultural Research of Mexico was formed in 1960.

There were several of us who were there, then serving in the transfer of responsibilities, when the hunger crisis broke in South Asia. We were asked to see what we could do in transferring this technology. Before that happened, however, based on the positive results of the wheat program in Mexico, and with the hunger crisis worsening in Asia, two foundations, Rockefeller and Ford, decided that there would have to be some other kind of approach. The foundations did not have adequate money to establish programs similar to the Mexican one in many countries. And they hit on the idea that they would establish an international center in one location. The first was the International Rice Research Center (IRRI) in the Philippines. And since that time, the International Maize and Wheat Improvement Center (CIMMYT) came into being. CIMMYT and IRRI today, are two of the thirteen international agriculture research institutes that are set up and administered under what we call the Consultative Group on International Agriculture. These two centers have been in existence longest and they've had big advantages in that they had a core of experienced staff from the time they started. The Consultative group last year had a budget for the thirteen institutes of about 184 million dollars. That sounds like a lot of money, but really it is about a million and a half tons of wheat.

The following will illustrate some inkling of what the pay off has been from that one little beginning program in Mexico. The Rockefeller-Mexican program, where the total expenditures on all agriculture, in seventeen year's of time was 8 million dollars, resulted in not only a research program, but also the establishment of the extension services, and a graduate school, the first in Latin American agricultural sciences. Why did this little program have such a big impact? The real reason was the way we approached the breeding program. It is a mountainous country and the dogma at the time was that you had to select the varieties, if they were to be successful, in the same environment in which you were to grow them. There had been three disastrous stem rust epidemics a few years before I arrived in Mexico, and with conventional methods it would have taken somewhere between nine to eleven years to produce a rust resistant variety and to get it into the hands of farmers to avoid another disastrous epidemic. I knew that with conventional methods and the time required my luck wouldn't hold out that long and I would be thrown out of the country as a complete disaster, so I decided to grow two generations a year using widely different sets of environment. Planting was done in November when the days were getting shorter at the Northwest Institute of Agriculture Research at about 29 degrees latitude and 30 meters above sea level in the irrigated agriculture. Stem rust is one of the main problems, but leaf rust is also a problem. We would harvest the best plants, after selecting strictly for good seed, as well as healthy and productive plants. We would then take the seed to the high valley area near Mexico City, the Toluca Valley, at 19 degrees latitude, and plant them in May when the days are getting longer. At 2600 meters or about 8500 feet elevation where it rains nearly every day, there's a whole series of other diseases. There we would harvest in October and shuttle the seed back to Sonora.

By doing this we produced the first varieties with rust resistance in three and one-half years. They were tall strawed, but better yielding than any that had been seen before. They were widely grown within five to six years. That turned out 25 years later to be the key to why you could move whole shiploads of seed, after adequate testing, halfway around the world into India, Pakistan, and into many other countries. In other words, the plant material was subjected in the process of selection to very different environments and selected for a range of diseases that were the most important.

At the time when this program was begun it was not known that the major cereal crops were photoperiod sensitive. The original idea in all foreign technical assistance was that the United States and Western Europe knew what was needed to be done to transform agriculture of the third world developing nations. There was a lot of nonsense in this, because the diseases were different, but especially because they failed to recognize the photosensitivity of many of the crop species. Wheat was one that was thought not to be very photo-sensitive. And yet when we tested the varieties with good disease resistance, good milling, and baking quality, that came from the spring wheat regions of Minnesota, North Dakota, South Dakota, Montana, and Canada, not only were they low yielding in Mexico but also in all the third world countries close to the equator or in the semi-tropics. It turned out, after we unscrambled this, that it was light sensitivity.

Of course, there were many other factors. Once we got disease resistance, the tall straw or the harvest index ratios (grain to total dry weight) were so bad that they were using a lot of moisture and fertilizer to grow more straw but not very much more wheat grain. When we finally got the dwarfing genes put into the package, which didn't happen until about 1962, we were in business, improving the productivity for each pound of nitrogen or any other fertilizer applied, and in the process we produced much more grain.

As we looked around the world, I was still not satisified, first in Mexico and then elsewhere, about only producing a good variety. There is no magic in a high yielding variety if it can't express its potential because of lack of soil fertility, or competition with weeds, or with diseases. You have to be able to put the pieces together. Worn out soils are a common scene in many parts of the world even today. You have to find out what is wrong, what is the limiting nutrient, correct it as cheaply as possible, be it with chemical fertilizer or organic or a combination, and go on from there.

Wheat yields in developed countries didn't start going up until relatively recently, within the last 40 or 50 years, and especially since the end of World War II. In Mexico, by 1975, average yield was 3.4 T/ha, and today it's about 4.5 T/ha. When I began, in 1944, the average yield was 800 kg/ha. The total production of wheat in Mexico at that time was 340,000 tons. This last harvest it was close to 5,000,000 tons.

All down through time, the way to restore soil fertility was with organic matter. The Chinese have done an excellent job of maintaining a moderate level of fertility by the use of organic wastes, but since 1959, they've begun to recognize they had to have chemical fertilizer to go with organic materials if they were going to produce food for the large number of people in the growing population they are confronted with.

Unfortunately, in many countries such as India or Pakistan, there is inadequate fuel and organic waste is used for fuel. Cow pies, like the buffalo chips that were the fuel for the pioneers going across the great plains of this country, are burned for fuel because there is inadequate coal, gas, or wood. Even though it may be present, it's not distributed out to the village level, so soil fertility is lost.

The first so called chemical fertilizer came from Chilean nitrate from the desert in Northern Chili. They had a monopoly and it wasn't broken until shortly before World War II when the Haber-Bosch synthetic ammonia process was developed. We then moved essentially into the system of fertilization as done today. But it doesn't do any good to fertilize the soil if the weeds are the robbers that utilize a good share of it. Weeds not only rob nutrients, but also the water, which is the number one limiting factor in the production of food in the world.

When the hunger was at its worst, in the early 60's, I was told to go over to Pakistan and India and see what I could do. We began to bring many young students, especially from the near and middle east countries, to work with us in Mexico. And they took back many small samples of wheat seed. We started to get reports back from them that some of these looked very good. The door was opened after three years of testing on small plots. Then during the worst hunger and famine crisis in 1965, 300 tons of seed were brought in. It was tested on hundreds of farms, on half-acre plots. The results were very positive in India during the worst crisis. The late Mrs. Ghandi and her minister made the tough decision to import 18,000 tons of seed. We could have multiplied the new seed to this amount from the small samples in over five years of time, but this importation saved at least 3 to 5 years. There were many who said we were playing with the lives of millions, but see what happened.

The technology alone is worthless unless you can hitch up to an economic policy which will permit the small farmer to adopt that technology. That implies that there has to be available production imputs, in this case, fertilizer. We should have had herbicides, but you've got to play with the cards that you have in your hand. At least, we insisted that the fertilizer of the right kind be imported and distributed down to the village level at least six weeks before planting, with credit for the farmer to buy it. Also, the farmer had to have assurance of a floor price announced before planting that reflected the international price for that commodity, wheat. At harvest with this system, some fields of the introduced wheat from Mexico, grown as we suggested, yielded 85 bu/A. The results by 1968 were dramatic, and the late prime minister, Mrs. Ghandi, put out a commemoratory stamp to the wheat revolution before harvest that year. Wheat was piled everywhere because they had not built warehouses. When it started to rain they had to close schools in order to put the wheat in the school rooms.

Another thing that we were accused of was that what we were doing would lead to mechanization. Yet today, the vast majority of the wheat is still cut with the sickle and it's not a pleasant task. Believe me, when it is about 105 degrees and you're cutting wheat, it is not a wonderful experience.

There were many that said that dwarf wheats would cause a shortage of straw. Straw is the main feed that keeps the bullock and the buffalo alive during the long, dry winters. Generally, before harvest, the price of ground-up straw was worth more than the price of wheat. But after two years with proper fertilization and other practices, you couldn't sell all the straw. It was one of the happiest days of my life showing how there was even enough straw left over for the people, myself included, to eat had we wanted to.

The transfer of technology was much broader than just wheat. It brought in multiple cropping and many other indirect benefits. In the period of 1961 to 1966, total wheat production was 400 million bushels in India. Last year, 1984, wheat production was about 1.65 billion, more than a four-fold increase. That additional production provided 65% of the calories and protein for an additional 250 million people. It increased the gross national product by about 5.5 billion dollars over that of the early 60's base period. Does research pay? Not just research, it is how you put all the pieces together.

In Pakistan there has been more than a three-fold increase as a result of all this transferred technology. Once you get a couple of touchdowns a lot of people want to play the game. Then it is relatively easy to get other countries started. The result is that out of the so called Mexican-Rockefeller materials, there were 40 million hectares grown in the developing countries, and 10 million hectares in developed countries, including southwest U.S.A. Conservatively, it added ten million tons annually to global wheat production. That is probably an under-estimation because it includes only the genetic part. When you put all the pieces together it is quite different. In Argentina, for example, everything is ready now except for chemical fertilizers.

Competition from weeds continues to take a heavy toll from crop yields and production, especially in the developing nations where the use of herbicides is still in its infancy. In traditional agricultural production systems, little attention is given to weed control because weeds apparently are not highly competitive with the crop plants, because they, too, are suffering from nutrient deficiencies. However, when fertilizer is applied to correct nutrient deficiencies with the hope of increasing crop yields, weeds grow more rapidly too and compete with the crop species for nutrients, moisture, and sunlight and greatly depress the anticipated increase in crop yield that was sought through investments in fertilization. Over the past two decades the use of phenoxy herbicides for the control of annual broadleaf weed species has become quite commonplace in wheat production in many developing countries including Argentina, Brazil, Chile, China, India, Mexico, Pakistan, Turkey, etc. Even in these countries that have experienced a revolution in wheat yields and production there are still many farmers who do not use herbicides at all, or use them inefficiently.

Currently, grassy weeds such as wild oats (Avena spp.), tall canary grass (Phalaris major), rye grasses (Lolium spp.), and brome grasses (Bromus spp.) are causing severe losses in many areas. The former two weeds are widespread and often reduce yields by 25 to 50 percent in both the irrigated and rainfed areas of the Near East, the Indian sub-continent and Mexico. Although there are herbicides that will control these weeds effectively, they are still unavailable in most parts of Asia and Africa.

The rye grass and brome weeds are particularly destructive in the rainfed areas of North Africa and the Near East. In years when the onset of the rains are delayed into December, and sowing is made in dry soil, weeds may reduce yields by 50 percent, or destroy the entire crop. In all probability, the widespread use of a herbicide that would effectively control wild oats and tall canary grass in India and Pakistan, would increase wheat production by 25 percent.

In low-yield, traditional agriculture, it is only in unusual years that ecological conditions are sufficiently favorable for diseases and insects to reach ravaging proportions. When these conditions do occur, however, the losses are severe, for there are no organized disease or insect control programs to advise and assist the farmer. In most years, however, pathogen and insect pest species, like host plants, are all struggling for survival under difficult and unfavorable environmental conditions. The situation in high-yield, intensive agricultural systems, changes this equilibrium dramatically; fertilized soils and improved agronomic practices result in the development of thick lush stands of crops. The ecology within these fields then becomes very favorable for weed, pathogen and insect pests. Weeds become aggressive, and unless controlled, will greatly reduce yield. Disease and insect-resistant varieties must be used to minimize the risks of crop losses. Moreover, an integrated pest control program must be adopted, insofar as possible, including crop rotation, proper dates of planting, biological control, and the regular monitoring of the pest population combined with the timely application of pesticides when necessary, in order to reduce crop losses to acceptable economic levels.

In most western advanced agricultural nations, the distribution of production inputs, such as improved seeds, feeds, fertilizer, herbicides, insecticides, fungicides, equipment and machinery, is provided to farmers by an efficient highly competitive private agro-business sector. By contrast, in most developing nations, the private sector supply system is either weak or non-existent, and these services are assumed by government.

In many developing countries, production inputs are either unavailable or are available only in a few large cities far removed from agricultural production areas where they are needed. All too often the production inputs are adulterated. It is necessary to establish an effective network to distribute these inputs down to the village level if production is to increase. The timeliness of distribution and appropriateness of the products being distributed are of primary importance, but all too often they are hopelessly entangled in a web of bureaucratic inertia which adversely affects production.

Agricultural research and extension programs in most developing nations are weak. They are handicapped by a shortage of trained people, inadequate budgets, and low prestige associated with agriculture. In reality, even though 50 to 85 percent of the total population in most developing nations is involved in agriculture, this profession often occupies the lowest rung on the socio-economic ladder. Consequently, the majority of the most talented young people with a rural background want to forget about the hard work and low income of agriculture. They seek careers in medicine, dentistry, law, engineering or business.

It is impossible to transform traditional agriculture into modern agriculture without the assistance of a large group of well motivated and well trained scientists and technicians. My experience in a number of countries, where research and training programs were initiated with only a few trained people, indicates that it takes 20 to 30 years to identify, train and provide research experience for enough young scientists and technicians so that a national research institute can be organized and staffed effectively.

Maintaining creativity and viability in research organizations, once effectively staffed and launched, is equally frustrating and complex. Research organization in developing nations - even more than in developed nations - are vulnerable to the disruptiveness of political winds, inadequate funding, corruption and the viruses of bureaucratization and scientific fossilization.

As I look ahead at the magnitude and complexities of the world food needs for the next half centry, I am apprehensive. In 1975, when world population reached 4 billion, the world produced an all time record harvest of 3.3 billion metric tons of all kinds of food, e.g. grains, pulses and grain legumes, tubers, oil seeds, sugar, vegetables, fruits, nuts, eggs, milk, cheese, meat and fish. It took from the beginning of agriculture and animal husbandry, some 12,000 to 14,000 years ago, up until 1975 to gradually increase production to the aforementioned level. If human population growth continues at the 2 percent level of 1975 it will double up to 8 billion in about 40 years or by the year 2015 A.D.; consequently food production must be doubled (and more equitably distributed) in the same period. There is evidence that world wide population growth is beginning to slow somewhat, especially in the developed countries; but it continues to grow at a frightening rate in most of the developing countries.

But even if we assume that this reduced rate will prevail and that the time to double to 8 billion will increase by 50, 60 or even 80 years to 2025, 2035, or 2055 A.D. respectively, (which I feel is optimistic) - the necessary food production increases are staggering. In essence these projections mean that within the next 40 to 80 years, depending on how population growth changes, world food production must again be increased at least as much as was achieved during the 12,000 to 14,000 year period from the beginning of agriculture up to 1975 just to maintain per capita production at the inadequate 1975 level. Moreover, most of this increase in production in the future, must come from increase in yield from land already under cultivation, since in most of the densely populated countries there is little additional land suitable for agriculture that can be brought under cultivation without huge investments in irrigation, which is both extremely costly and also slow to bring on stream.

I am cautiously hopeful that world food production can be doubled within the next doubling of world population provided that world governments give high enough priority and continuing support to the agricultural sector in their development programs. It can not be achieved with the miserly and discontinuous support that has been given to agriculture and forestry in the past 50 years. Today, the horror of the famine and human misery in Ethopia, shown on the television screens around the world, shock the general public and political leaders, but tomorrow it will be forgotten by most viewers.

To double food production will require a change in focus in development programs and an upgrading of the effort in agriculture and forestry, especially in the food deficit developing nations, where crop yields are still low. We must train more and better agricultural scientists, expand our scientific knowledge and improve and apply better technology if we are to make our finite land and water resources more productive. If our foreign technical assistance programs, designed to assist third world developing food deficit nations, are to be effective, administrative procedures must be stream-lined. Bureaucracy and paper work must be drastically reduced while field-oriented, action-type production programs are greatly expanded. This must be done promptly and in an orderly manner if we are to meet the growing needs for food. We must educate the public to realize that producing more food and fiber and protecting the environment can, at best, be only a holding operation while the population monster is being tamed. Moreover, we must recognize that, in the transition period, unless we succeed in increasing the production of basic necessities and more equitably distributing the benefits to meet growing human needs, the world will become more and more chaotic, and social and political systems will collapse.

In recent years the "human rights" issue has generated much interest and debate around the world. It is a utopian issue and a noble goal to work toward. Nevertheless, in the real world, the attainment of human rights in the fullest sense can not be achieved so long as hundreds of millions of poverty-stricken people lack the basic necessities for life. The right to dissent does not mean much to a person with an empty stomach, a shirtless back, a roofless dwelling, frustrations and fear of unemployment and poverty, the lack of education and opportunity, and the pain, misery and loneliness of sickness without medical care. It is my belief that all who are born into the world have the moral right to the basic ingredients for a decent, humane life. How many should be born and how fast they should come on stage so that the world can provide them with the basic necessities is another matter.

Those of us who work on the food production front, I believe, have the moral obligation to warn the political, religious and educational leaders of the world of the magnitude and seriousness of the arable land, food population problem that looms ahead. If we fail to do so in a forthright unemotional manner we will be negligent of our duty and inadvertently contribute to the pending chaos, of incalculable millions of deaths by starvation. A solution to this complex problem is imperative. The imminence of the disaster is before us. It is closer than most people realize, or are prepared to admit. The problem will not vanish automatically and to continue to ignore it will ultimately make its solution more difficult.