PLANT BREEDING AND THE CONQUEST OF HUNGER

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by

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PLANT BREEDING AND THE CONQUEST OF HUNGER

MR. VICE-CHANCELLOR:

We live in a world where large segments of humanity suffer from chronic malnutrition and frequent famines. Malnutrition and hunger have persisted throughout history, from the time when man lived as a hunter and gatherer of food and only a few million inhabited the globe, until today when around four billion occupy the earth's land surface.

The reasons and remedies for such persistent problems as hunger and malnutrition are complex and often interrelated. We can define the term hunger to mean insufficient supply of food to cover calorie requirements and malnutrition to mean inadequate consumption of proteins, vitamins and essential minerals.

FAO, on the basis of a survey made for sixty-four developing countries, suggested that the physiological per capita requirements of 2,260 calories/day is on an average 94 percent satisfied by the available food supply in these countries, with regional variations between 85 and 111 percent. The average physiological protein requirement of 61 g/head/day is 93 percent satisfied, with fluctuations between 68 and 106 percent. The survey further indicated that approximately 450 million human beings suffer from hunger (undernourishment) and over 700 million are malnourished[1]. FAO's former Director-General, A.H. Borema, said, "Rough as these figures are, the order of magnitude should be sufficient to strike at the conscience of every civilized man and woman."

Countries such as Australia, Canada and the U.S.A. produce great surpluses of food, while many of the developing countries are in constant deficit. An analysis of total world food production and food needs leads one to the conclusion that at present, the problem is seemingly that of distribution rather than production[2]. On a regional basis, however, hunger and malnutrition resulting from serious famines have occurred, somewhere on the earth,

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practically every year throughout recorded history and even since the end of World War II. (See table 1.)[3]

The primary causes which lead to shortages in the supply of food are natural catastrophes, cultural and socio-economic constraints, inefficient farming systems and last, but the most important, overpopulation.

Natural catastrophes such as wars (for example, the World Wars, the Indo-Pakistani and Arab-Israeli conflicts), civil disturbances (such as the Nigerian, Congolese, Angolan, Lebanese and Portuguese civil disorders), droughts (for example, the Dust Bowl droughts of southern and western U.S.A. in the 1930s and the Sahelian drought of the late 1960s and early 1970s), earthquakes (such as in Japan, Latin America, the Middle East and Guatemala), locusts (in, for example, the Middle East), and recurrent crop failures due to disease and pest epidemics, have caused and will continue to cause serious dislocations in regional and global food supplies. Man, with his present technical know-how, is unable completely to control the operation of most of these factors.

A vast array of cultural and socio-economic factors limit food production, particularly in countries characterized by subsistence farming and, unfortunately, the great majority of the human race lives in such countries. The compilation of an all-embracing list of these factors is outside my competence and, in any case, would vary from country to country and from one continent to another. However, mention can be made of political instability, mass illiteracy and ignorance, the high costs of modern technology, fertilizers, pesticides and other agricultural chemicals leading to their underuse, the lack of fair and adequate credit facilities and price incentives necessary to encourage better yields, the problems of poor distribution and storage facilities, absentee land ownership and other land tenure problems, extended family systems and an almost fatalistic attitude to life. The success of our efforts to combat and curb exploding population growth and significantly increase agricultural productivity through more efficient farming systems will depend almost entirely on how quickly and effectively the political, administrative, technological and educational machineries succeed in creating an environment of mass literacy, where the small farmer previously toiling to feed himself and his family wants to grow more food because he and his family can then look forward to better things in life.

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TABLE 1
Post-World War II Famines

Names of Countries and Years Where a Famine Existed				
Europe	*Latin America*	*Africa*	*Middle East*	*Asia*
1945 — Western Holland	1949 — Ecuador	1958 — Tunisia	1945-49 — Syria-Palestine	1945 — Japan
1945-50 — Areas of Eastern Europe and Soviet Union	1951 — El Salvador	1960 — Morocco Mauritania	1954 — Iraq	1945-49 — China
	1954 — Haiti	1960-61 — Republic of Congo	1962 — Iran	1946 — Vietnam
	1960 — Chile	1962 — Algeria	1969 — Syria	1950-56 — Pakistan
	1967 — Colombia	1967-70 — Nigeria-Biafra		1950-55 — India
	1970 — Peru	1971-74 — Angola Chad Mali Niger Mozambique		1950-57 — Korea
	1972 — Nicaragua	1971-74 — Mauritania Upper Volta Senegal Dahomey Togo Ghana Nigeria Central African Republic		1954 — Vietnam
		1972 — Burundi		1959 — Korea
		1973 — Sudan		1960 — Pakistan
		1973-75 — Ethiopia		1961 — Vietnam
		1974 — Egypt		1964 — Vietnam
				1965-67 — India
				1968 — Vietnam
				1970 — Cambodia
				1970-75 — Bangladesh
				1971-73 — Pakistan
				1971-72 — Afghanistan
				1972 — Philippines
				1975 — Cambodia and Vietnam

Source: Mayer[3]

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Chapter 1 of the book *The Limits to Growth*[4] which forcefully brings out a message of inevitable gloom and doom, possibly within our lifetime, if the accelerating pace of demographic and material growth is not checked and if rapid transition from growth to global equilibrium is not brought about, starts with a quotation:

> People at present think that five sons are not too many and each son has five sons also, and before the death of the grandfather there are already 25 descendants. Therefore people are more and wealth is less; they work hard and receive little.
>
> Han Fei-Tzu, *ca.* 500 B.C.

When Han Fei-Tzu uttered the above statement there were probably fewer people on the face of this earth than there are in West Africa today. Some twenty-three centuries later, in the year 1789, world population had reached close to one billion and Thomas Malthus[5] said:

> That food is necessary to the existence of man...
> That passion between the sexes is necessary
> and will remain nearly in its present state...
> I say that the power of population is indefinitely
> greater than the power in the earth to produce
> subsistence for man.
> Population when unchecked increases in a
> geometrical ratio. Subsistence increases only
> in an arithmetical ratio...
> By that law of our nature which makes food
> necessary to the life of man, the effects of
> these two unequal powers must be kept equal.
> This implies a strong and constantly operating
> check on population from the difficulty of
> subsistence...
> The race of plants and the race of animals
> shrink under this restrictive law. And the
> race of man cannot, by any efforts of reason,
> escape from it. Among plants and animals
> its effects are waste of seed, sickness and
> premature death. Among mankind misery and
> vice...

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I see no way by which man can escape from
the weight of this law.[6]

The increase in world population has followed the Malthusian rate fairly closely and world population is now at the four billion mark. However, Malthus, at least in the short run, underestimated man's capacity to increase food production.

Migrant populations, mostly from Europe, settled and brought into cultivation vast acreages of virgin land in North and South America and Australia. Acreages under cultivation in Asia and Africa increased with increasing pressure of population. Rivers were harnessed and large-scale irrigation facilities brought about quantum leaps in food production by multiple cropping and by controlling, to a significant extent, the vagaries of nature.

As Malthus was spelling out his prophecy of doom, European agriculture was entering the age of modern technology. Pre-Mendelian plant breeders started producing improved varieties of crop plants with much higher yield potentials. These have been followed by modern plant breeders with sound training in genetics, evolution, biology and related areas. Machine farming became popular and production per unit of labour increased several fold, thus enabling large segments of mankind to work in the production and distribution of other material goods and services. The importance of mineral nutrition of plants was recognized in the early part of the 19th century. This was followed by the invention of fertilizers by Liebig and others. World consumption of fertilizers within a century increased from almost nothing to over 70 million tons of nutrients annually[7] and almost doubled crop yields. Pesticide and herbicide use became increasingly popular and produced gratifying results.

These and similar technological breakthroughs coupled with vastly increased acreages under the plough caused a series of agricultural revolutions, the last being the so-called Green Revolution, which have inspired mankind to seek for and find ever-increasing quantities of food from mother earth. Thus while the human population grew approximately eight times from about 500 million in 1650 to 4,000 million today, total food production during the period has, in fact, increased by about ten to eleven times. From 1875 until today, crop yields in countries with intensive and profit oriented farming systems have gone up about five times and

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food production on a global basis has approximately doubled since the end of World War II. Even in the last decade, increases in food production have generally been in line with population increases. (See table 2.)

It is therefore obvious that as of now in the life and death race between food and population, the world's food production has stayed a step ahead of the population's food needs. Why, then, so much concern about population explosion? Why so many pessimistic predictions of disaster ahead? Why the necessity to hold two World Conferences, one on 'Food' and another on 'Population' in 1974?

Contrary to what is generally believed, an average person's diet today in most countries is better than ever before in terms of both quality and quantity. It is also equally true that vast numbers of people, particularly in Asia and to a considerable extent also in Latin America and Africa, still live on an insufficient supply of protein and energy. The margin of safety between survival and starvation which was never too wide in the past is still too narrow today. World statistics on population growth and food production for the past two decades and future projections show clearly a widening gap between the Western industrialized nations and the low income group of countries. Thus while the annual increase in food production in both the developing and developed countries has been around 2.8 percent, the rate of population increase has been disproportionate, being 2.5 percent in the former and less than 1 percent in the latter. With 86 percent of world population growth occurring in the low income countries, most people are born in areas where improvement in per capita food production is insignificant. Disruption of food production in these areas can and does cause widespread hunger or famine for millions of people[8] as was painfully evident in the recent droughts of Ethiopia, Sahelian Africa and South Asia.

Since we live in a finite world and since many of the earth's resources are non-renewable, it is therefore obvious that in order to win the battle against hunger and famine decisively and permanently, mankind will have to intensify further its efforts leading to still higher increases of food production *per unit area* and simultaneously curb drastically the rate of population growth (70 million annually — that is, over 8,000 per hour) with the eventual aim of quickly reaching the desirable zero population growth.

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TABLE 2
Comparative Data on Population (1974) and Change in Population, Food Production and per caput Food Production (1961—65) = 100)

	World	*Developed Countries*	*Developing Countries*	*Centrally Planned Economies*	*Africa*	*Nigeria*
Population Millions (1974)	3904	750	1925	1228	384	61
Index Nos. for:						
(i) Population	124	111	133	118	132	132
(ii) Food production	132	128	131	141	127	104
(iii) Per caput Food Production	107	115	99	119	96	79

Source: FAO Production Yearbook, 1974

Then, and only then, will it be possible to bridge the gap between the fortunate few and the many living a hand to mouth existence. Rampant population growth not only causes food shortages but is also the primary cause of unemployment and urbanization crises, pollution crises, energy crises, resource crises, water crises and many other social, political and economic crises which bedevil societies and nations.

Modern medicine and sanitation, while succeeding admirably in their noble goals of freeing individuals from pain and agony, reducing infant mortality and increasing the individual life span have also, as a natural consequence, contributed to the present population crisis. However, modern medicine also has given us the tools effectively to control population growth and it is left to us whether population growth is checked painlessly now or painfully in not too distant a future.

Glimmers of hope have started appearing on the horizon. Several countries in Western Europe are close to achieving the ideal of zero population growth. Birth rates have started dropping fairly rapidly since the 1960s in many overpopulated and underdeveloped countries and the trend in these countries appears to be very much similar to, and in fact faster than that which started in the latter part of the 19th century in the industrialized countries and which has led to population stability in these countries (fig. 1). Man with his technical know-how and a will to survive may yet prove Malthus wrong in his dire projections of population growth as he has been proved wrong in estimating the limits of human ingenuity towards increased food production. Lester Brown, in his book *In the Human Interest*[9] has visualized that, in spite of present pessimism, stable world population at 5.8 billion is feasible.

Having outlined the problem of hunger and malnutrition, and having briefly discussed the causal factors which have accentuated the problem, let us now examine the various avenues open before us for increasing agricultural production. The two most obvious ways by which total food production can be increased are:

(i) bringing additional land under cultivation.
(ii) raising agricultural productivity per unit area.

Recent estimates[10] have suggested that there are about 3.2 billion hectares of land available for food production in the world and only about half of them are currently under cultivation. However, they are the better half. The distribution of potentially available land is uneven, with much of it being in the form of hilly

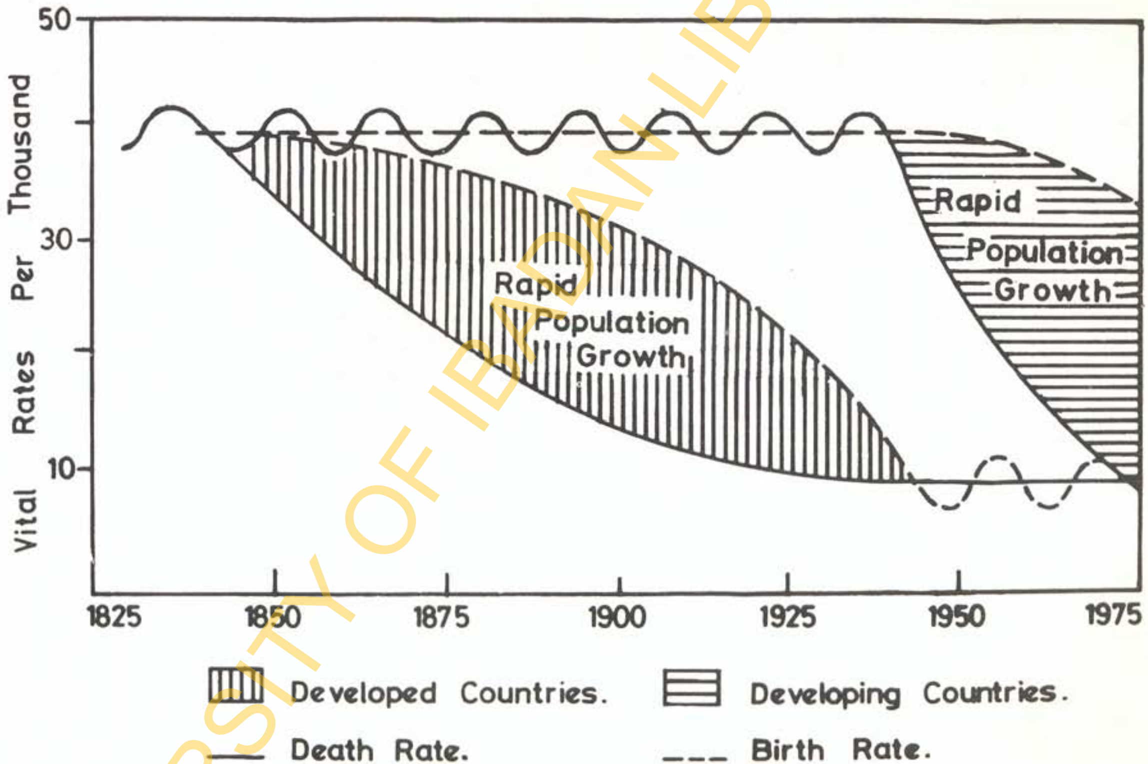

Fig. 1
The demographic transition schematized
Source: Data from Poleman[5]

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terrain, semi-desert or dense tropical rainforest in the under-populated and underdeveloped parts of Africa and Latin America. (The statistics regarding Nigeria's land use are presented in table 3.) Bringing such lands into cultivation will require massive capital outlay and technical know-how and realization of the fact that if not properly planned and managed such grandiose programmes could result in large scale erosion, massive and irreversible loss of soil nutrients through leaching, silting up of rivers and dams and flooding of the low lands.[11]

Tropical rainforests are an important asset and the countries which possess them cannot afford the short-sighted policy of putting them under the plough because to do so without developing the technology to maintain the soils would end in transferring this wealth into an unproductive burden.[12] Jon Tinker[11] has said, "Stalin's virgin lands and the dust bowls of *The Grapes of Wrath*, the eroded and abandoned Inca fields in the Andes, the deserts of Babylon and Egypt, the sands of North Africa which once fed the Roman Empire – there are too many examples both ancient and modern of agricultural systems which ruined their soil".

Let us therefore, at least for a while, not depend too much on the optimistic estimates of potentially available land for food production made by surveyors sitting in their airconditioned offices in Rome and New York or by international consultants jetting from one continent to another but instead devote our efforts and energies primarily towards raising the productivity from the land already under the hoe and the cutlass.

Notwithstanding the phenomenal advances made in agricultural technology in the 19th and the 20th centuries, most of the farming practised in the low income countries is still at the subsistence level.

The annual input of solar radiation on earth's agricultural lands varies from 70 to 210 kcal/cm^2. One ton of dry matter production per acre fixes a miniscule 0.1 kcal/cm^2; that is, less than one day's input of solar radiation is utilized by most of the crops in their entire growing season of several months. On theoretical grounds the expected possible efficiency of growth has been calculated to be around 8 to 10 percent of the energy received but in actual practice even under the best conditions crops rarely fix solar energy with an efficiency of over one percent. Under subsistence farming the efficiency of utilization of solar energy by cereal crops has been

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TABLE 3
Estimates of Land Use in Nigeria

Use	*$x10^3$ Hectares*
Total Area	92,377
Cropped	21,795
Forest and Woodland	31,069
Pasture and bush	20,720
Other	18,793

Source: FAO Production Yearbook 1974

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calculated to be around 0.04 to 0.1 percent (with 0.08 to 0.2 percent as probable best) but in countries with intensive farming the average value ranges between 0.25 to 0.35 percent (with 0.6 to 1.0 percent as probable best.[13])

Comparative data on present yields of some important crops (kg/ha) in different parts of the world are presented in table 4. Returns of food per unit land area are at least two to three times higher in the developed countries as compared to the developing. Crop yields in Africa are generally 25 to 50 percent lower than the average for all developing countries. Cereal and grain legume yields in Nigeria are significantly lower than the average African yields but root and tuber yields are comparable. Let us also note that the cereal and legume yields in Nigeria are only about half to one third of average world yields.

Therefore mankind's salvation from hunger and malnutrition rests almost entirely, at least in the near future, on the ability of the African, Asian and Latin American peasant farmer significantly and continuously to increase food output from the land he is tilling. This will undoubtedly depend to a certain extent on enlightened leadership providing necessary incentives to the farmer. However, in the final analysis the rate of progress will be dependent on the research outputs of dedicated teams of agricultural scientists who, working together, will make available (i) the high yielding varieties and (ii) a package of realistic recommendations conducive to maximizing the high yield potential of the *newly* released varieties. The former is the task of plant breeders and the latter the responsibility of agronomists, soil scientists and biologists working towards the determination of optimum inputs in terms of seeding rates, time of planting, cultural practices, fertilizer rates and time of application, irrigation, methods of controlling weeds and disease and pest attacks, etc.

All of us present here have heard of the 'Green Revolution' but many of us do not know much about it except that it has increased the quantities of available food in parts of Asia and Latin America. The 'Green Revolution', a catch phrase popularized and praised by the world press, often with the help of charitable foundations and aid-giving Western organizations, and now increasingly criticized by the same world press and played down by those who got on the bandwagon is nothing but the application, with minor modifications, of modern technology mostly developed during the later

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TABLE 4
Comparative Crop Yield (kg/ha)

Crop	*Year*	*World*	*Developed Countries*	*Developing Countries*	*Centrally Planned Economies*	*Africa*	*Nigeria*
All cereals	1961–65	1462	2341	1102	1338	760	732
	1974	1818	2805	1279	1846	813	639
Wheat	1961–65	1209	1737	973	1013	701	2690
	1974	1603	2138	1168	1522	728	2000
Rice	1961–65	2048	4913	1626	2744	1283	1140
	1974	2363	5580	1872	3193	1307	1249
Maize	1961–65	2171	3507	1136	2272	934	825
	1974	2510	4008	1280	2951	108	846
Millet (Gero)	1961–65	573	1134	523	624	606	391
	1974	675	978	551	806	567	393
Sorghum (Guinea corn)	1961–65	934	2692	643	879	757	803
	1974	1103	2724	800	1107	655	620
Roots and Tubers							
Sweet potatoes	1961–65	8320	17246	6377	8441	4604	11940
	1973	8762	13378	6165	9338	4218	12059
Cassava	1961–65	8580	–	8581	8471	7000	9377
	1974	8831	–	8835	8473	7330	10000
Cocoyam	1961–65	5581	12805	5075	5839	4875	5762
	1974	5711	14198	5219	8080	5022	5651
Yams	1961–65	8902	–	8902	–	8975	9458
	1974	9689	–	9689	–	9815	11111
Pulses	1961–65	621	740	517	814	430	273
	1974	666	952	487	1074	389	191
Cowpeas	1961–65	284	664	272	–	266	265
	1974	207	661	201	–	197	184
Groundnut (in shell)	1963–65	872	1412	799	1183	806	935
	1974	931	2287	797	1236	664	500
Soybeans	1963–65	1145	1603	757	783	339	334
	1974	1277	1581	1407	808	392	382
Other crops							
Benniseed	1963–65	299	449	281	390	302	270
	1974	314	482	257	405	381	295
Seed cotton	1963–65	989	1548	686	1364	349	456
	1974	1170	1349	838	1913	514	464
Sugarcane	1961–65	49529	80341	47184	55447	50969	30159
	1974	53424	80631	50698	60796	59744	51538

Source: FAO Production Yearbook, 1974

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part of the last and early part of the present century for intensive farming to the *newly* developed varieties of wheat and rice in the less developed countries. The 'Green Revolution' therefore is simply one of a series of yield breakthroughs generated by large-scale acceptance of newly released varieties of crop plants. It is a revolution the seeds of which were sown by the plant breeders.

What is plant breeding? Vavilov[14] described it as "evolution directed by the will of man". Frankel[15] referred to plant breeding as "the genetic adjustment of plants to the service of man". These, and many other statements, clearly and concisely define the term plant breeding. Burton[16] in six simple verbs described a plant breeder's activity:

Variate ←
Isolate → Intermate
Evaluate ↗

Multiplicate

Disseminate

Plant breeding, originally an ancient art, is now recognized as one of the most exacting of the biological sciences. The origins of plant breeding can be traced back to the very origins of cultivated plants themselves.[17] Our first major victory in the battle against chronic hunger occurred when man abandoned his nomadic life as a hunter and gatherer of food and instead became sedentary and chose to grow food. He surveyed the plant kingdom, which comprises over one quarter of a million species of higher plants, identified some 3,000 which he considered useful and decided to cultivate extensively about 150 of them.[18] Neolithic man, though we call him a primitive plant breeder, did his job of domesticating plants so well that nothing really significant has been added to the human diet ever since.[17] He accelerated and directed the evolution of the plant species chosen by him and moulded them into what we now know as cultivated crops. He carefully examined the highly variable populations growing around him and selected only those types which he considered most useful to him. He profitably

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utilized the spontaneously occurring desirable mutant forms as well as the better recombination products arising from natural inter- and intra-specific crosses.[18] He continuously looked for, found, and multiplied forms which possessed several to many of the desirable characteristics which we normally associate with cultivated plants, such as vigorous plant growth, larger and fleshier roots or fruits, larger seeds, non-dehiscent fruits or non-shattering of seeds in cereals and legumes, absence of toxic or unpalatable substances, absence of spines and thorns, shorter life span or annual growth habit and self pollination. He thus ended up some 3,000 to 5,000 years ago, that is, even before most societies started keeping historical records, successfully changing the wild progenitors of our cultivated species to such an extent that in many cases we are not even sure of their identity and do not know whether they exist any more or not.

Burton[16] paid tribute to the primitive plant breeder. These are his words:

> Let us take a look at this man. He knew nothing about genetics, sex in plants, metabolic pathways, DNA, RNA, etc. He had no microscopes or any of our sharply honed tools. He had no written language, no libraries... What did he have? He had his plants, but probably a much more restricted germ plasm than most of us have at our disposal. He lived with his plants and knew them as few of us know ours. He had his hands and used them. He had to, for they were about all the tools he had. He had a tremendous motivation. He worked as if his life depended on it. It did, and I suspect we would get more done if we were similarly motivated. Finally he had time — more time than a hungry world will give to you and me. We must be more efficient than he. Primitive plant breeders took what they had, worked hard, and made tremendous advances in plant improvement.

The primitive plant breeder, instead of squandering the enormous natural variability without which any effective genetic

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improvement of crop plants is absolutely impossible and which is now being rapidly eroded due to the adoption of a few improved varieties over very large areas, in fact aided and added to the build-up of a reservoir of genetic diversity by his movement from place to place carrying seeds of his crop plants, by forming crop-weed-man complexes which permitted intermittent transfer of small amounts of germ plasm into the cultivated species due to natural crossing with adjacent weed races and wild relatives and by his wide practice of growing varietal mixtures. On this legacy of variability left by our forefathers all modern plant breeding work depends.[17]

In the modern sense, plant breeding implies maintenance of types and production of new types through direction and control of the natural processes of self-and cross-fertilization. The plant breeding methodology is based on a knowledge of sexuality in plants.

On 25th August 1694 Camerarius, Professor of Natural History in the University of Tubingen in south Germany wrote a fifty page letter entitled "De Sexu Plantarum Epistola" (The Sex of Plants) to his friend Professor Valentin of the University of Giessen. The letter contained information regarding his experiments with spinach, hemp, hops and maize which clearly showed the functions of ovules and pollen and an idea was put forward of crossing to get new types. However, several decades elapsed before his discovery regarding sex in plants received any recognition.

Koelreuter, generally recognized as the first scientific plant breeder, wrote: "From the 25th August, 1694 when Camerarius wrote his letter concerning his experiments upon sex in plants, until September 1, 1761 there has been no real progress in the scientific knowledge which underlines plant breeding".[19]

Crop improvement by intensive application of hybridization methods (to induce increased variability) along with the ancient art of selection was carried out during most of the 19th and the early part of the 20th century by several men of genius.[20] Mention can be made of Knight and Herbert (horticultural crops) in England, Shirreff (wheat and oats) in Scotland, the Vilmorins (sugar beet) and Sagret (cucurbits) in France, Le Couteur (wheat) in the Isle of Jersey, Van Mons (fruit trees) in Belgium, Burbank (potato) in the U.S.A., as well as the Saunders brothers in Canada, Farrer in Australia and Michurin in Russia. They developed varieties which yielded higher than ever before and several of them are still grown in many parts of the world because they are still the best available

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while others have been important parental materials in plant breeding programmes which have eventually yielded the present day high yielding varieties. This was the period when plant breeding emerged from an art to a science and increasingly took into account the findings and theories contributed by eminent contemporary hybridists, scientists and naturalists. These included among others, the works of: Lamarck, 1801 — inheritance of acquired characters; Gauss, 1812 & 1820 — theory of least squares, law of error; Amici, 1830 and Hofmeister, 1849 — pollen tube growth through the style to the ovule; Brown, 1831 — discovery of nucleus; Schleiden, 1837 and Schwann, 1838 — cell theory; Gordon, 1844-63 — sterility in interspecific and fertility in intraspecific hybrids; Strasburger, 1875, 1877 & 1888 — description of chromosomes, definition of gamete and reduction division in plants; Weismann, 1885-87 , and Boveri, 1887-88 — reduction of chromosome number; Navashin, 1898 — double fertilization in higher plants and, above all, the works of Darwin during the later part of the 19th century.[21]

Until the end of the 19th century plant breeders depended on their subjective judgement and intuition in choosing parents for their improvement programmes and grew enormous populations which enabled selection of superior types.[22] This required a very high degree of perception and considerable luck. The rediscovery of 'Mendel's Laws' by Correns, De Vries and Tschermak at the turn of the 19th century brought to an end, almost overnight, the haphazard, hit-or-miss approach to varietal improvement.

The present methods of plant breeding are based on our clear understanding of the laws of heredity and recognition of the fact that genes situated in the chromosomes control hereditary differences between individuals. The phenomenon of segregation and recombination of genes in higher plants resulting from sexual reproduction which involves alternation of two generations (viz., the diploid organism and the haploid sex cells) has enabled breeders to plan and create new types more or less at will.

Progress in plant breeding in the 20th century has paralleled the progressive development of genetics. The relationship has been symbiotic and in innumerable instances one has contributed significantly in advancing the frontiers of knowledge in the other.

Knowledge in the broad areas of genetics, cytogenetics and population genetics particularly in respect of polygenic inheritance, genotype-environment interactions, heterosis or hybrid vigour,

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host-parasite relationships, polyploidy, genomic reconstruction, genetic lethals and regulation of the breeding system as well as advances in other fields of biology, particularly plant physiology and radiation biology, and the availability of greatly refined statistical methods have enabled breeders to develop sophisticated methods of production, crossing and selection, thus enabling them to control to a great degree the evolutionary mechanisms and thereby equipping them in their tasks of directing the internal energy of the plant into desired channels: for example, high yield, disease and pest resistance, better nutritive quality, early maturity, adaptation to changing agricultural technology, etc.

While the primitive plant breeder was primarily interested in the domestication of plant species, the modern breeder is mainly interested in the domestication of genes in the species already under cultivation.[18] Permit me to say that he is succeeding quite well and never before have so few genes satisfied the hunger of so many.

The concept of centres of origin of cultivated plants[14] and the actual location of the centres for most crops by plant geographers, explorers and students of evolution[14,23] have facilitated the identification of the major areas of genetic variability for each of the main food crops. Plant breeders searching for specific genes for specific character improvement have found the collections of plant types originating from these areas to be most rewarding. This has prompted the formation of large gene banks or germ plasm pools by national and international organizations. An urgent need to strengthen the existing gene banks and formulate new ones has arisen in order to insure ourselves against future irreversible loss of existing genetic variability which will surely occur[24] before the turn of the century, due to the large-scale abandonment of existing countless genotypes by farmers in favour of a few high yielding varieties even in the remotest corner of the world.

After my feeble efforts to go over with you some 10,000 years of plant breeding history in ten minutes, let me for a moment refer to the research tools required by plant breeders as well as others interested in increasing agricultural productivity. I can do no better than quote Jennings:[25]

> In contrast to today's fever for ever more
> complex and recondite equipment in much of

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> science, the requirements for a sustained attack on unsatisfactory food production are disarmingly simple. These include a team of scientists dedicated to a common goal, a comprehensive collection of germ plasm, abundant labour, land and power to till it, assured water supply, a sprinkling of simple seed rooms and greenhouses and money for massive training of young researchers in materials and methods.

Plant breeding requires time. The development of an improved variety rarely takes less than ten years and often up to twenty or more years. However, among all areas of agricultural research, investment in plant breeding gives the best value for money expended. The total cost of plant breeding research in Sweden from 1886 to 1948 was estimated to be less than two million naira for the *entire period* and the *annual* returns in terms of increased productivity were valued at over 12 million naira.[26] The total cost of development of the rice varieties by the International Rice Research Institute in the Philippines was less than 16 million naira but the value of the resultant increased income to farmers growing the improved varieties in 1969 alone was estimated to be over 200 million naira.[27] In Colombia, with the release of three new varieties of rice since 1967, yield per hectare increased from about 3 tons to 5.4 tons in 1972, thus adding over 60 million naira to the total monetary value of the crop. This amount was more than sufficient to pay for the total government investment in research, extension and education for all crop and animal programmes during that period.[25]

Now, with a few specific examples, I will attempt to underline the importance of plant breeding in the conquest of hunger. But first let me re-emphasize, what I said a few moments before, that higher productivity per unit area is achieved not only by the genetic manipulation of available variability but also by a combination of other important inputs of modern agricultural technology such as better cultural methods, better water and soil management, and a greater application of fertilizers, insecticides, and fungicides. However, allow me also to emphasize that the other inputs of agricultural technology when viewed objectively by the energy and

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economy conscious world have been found to be expensive and the profitability accruing from their usage is much reduced because the local age-old varieties of crops do not often possess the genetic potential effectively to utilize and convert the added inputs of energy, nutrients and water into products desired by man (fig. 2).[28]

Cooperative and co-ordinated research involving plant breeders and other production-oriented agricultural scientists is the only way successfully and continuously to increase agricultural productivity. Thus breakthroughs in yield occur as a result of improvement in the genetic properties of the crop as well as in the production environment. It is difficult and often impossible to qualify exactly the contribution of each factor because here laws of mathematics have failed and 2 + 2 + 2 instead of adding up to 6 add up to an unknown quantity significantly higher than 6.

Ishizuka[29] presented the results of a study wherein a series of popular improved varieties of rice grown during different periods from 1890 to 1959 were grown under uniform conditions and in common experiments to assess plant breeding accomplishments. Data presented in table 5 (as summarized by Frey)[30] show gradual but consistent improvement in yielding ability through breeding. Over sixty percent increase in yield was due solely to better varieties during the period.

Japan is one of the most overpopulated countries in the world. Arable cropland available per person is only 0.04 hectares (that is, a considerably smaller area than this auditorium) and rice is the staple diet. The nation's survival has depended on this crop and the data presented in table 6[31] show how well the scientists have responded to the challenge. The average yield of paddy rice (rice in husks) has increased from less than 1,300kg/ha in the 8th century and is now approaching 6,000kg/ha. No doubt better agricultural technology has played an important role but without varietal improvement other inputs would have been quite ineffective.

Data presented in table 7[31] present a similar story of achievement for wheat in England.

The most outstanding achievement in the field of plant breeding during this century has been the development of disease and insect resistant varieties. There is hardly any nation which has not reaped the fruits of this significant contribution by plant breeders who, in collaboration with pathologists, virologists, nematologists or entomologists, have developed a large number of varieties which

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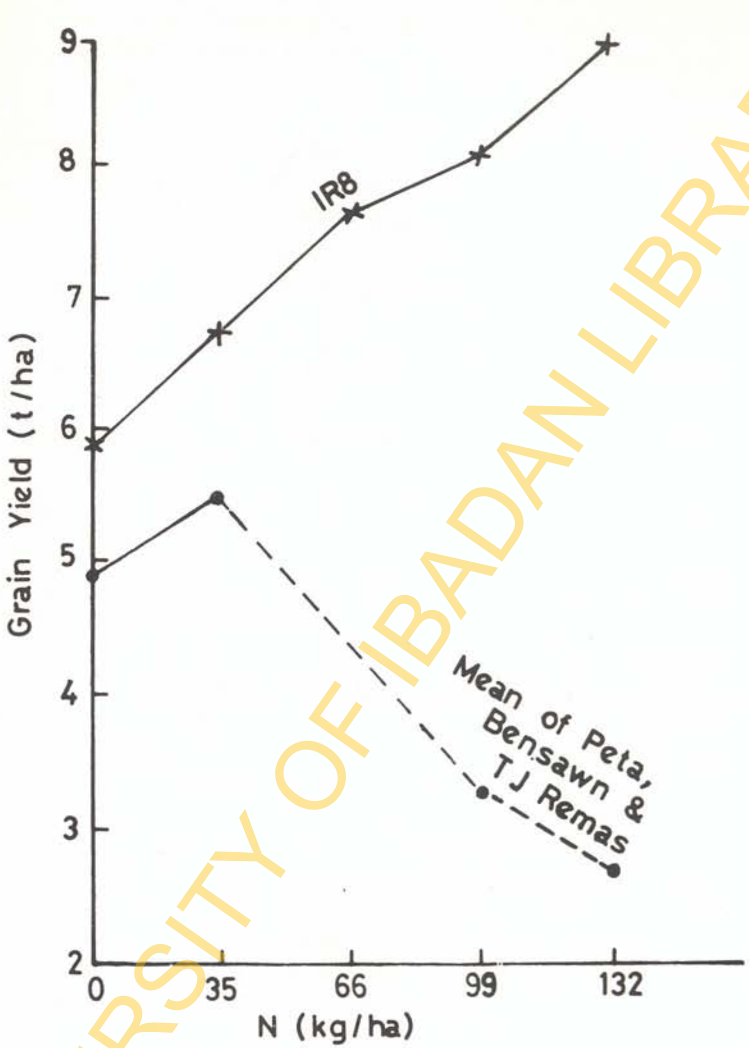

Fig. 2
Yield response of IR.8 and typical tropical rice varieties at Los Banos, the Philippines.

Source: Data from Chandler[28]

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TABLE 5
Grain Yields of Rice Varieties from Different Eras
(Tested in Common Experiments) in Japan

Variety	*When Grown*	*Yield (t/ha)*
Akage	1890 – 1930	3.4
Bohzer - 5	1910 – 1935	4.1
Fukoku	1935 – 1940	4.7
Elkoh	1940 – 1959	5.1
Toyokikari	1950 – –	5.0
Mimasari	1959 – –	5.5

Source: Ishizuka[29] as summarized by Frey[30]

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Table 6
Paddy Rice Yields in Japan

Period (*A.D.*)	8th Cent.	16th Cent.	1883-1887	1898-1902	1918-1922	1938-1942	1948-1952	1961-1965	1974
kg/ha	1270	1890	2450	2850	3590	3790	4000	5010	5840

Source: Richardson,[31] updated by author

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Table 7
Wheat Yields in England

Period (A.D.)	C.1250	C.1350	C.1550	C.1750	C.1850	C.1900	C.1950	1961–65	1974
kg/ha	425	560	1050	1410	1840	2120	2630	4045	4890

Source: Richardson,[31] updated by author have stabilized yields and reduced to a large extent widespread hunger due to disease and pest epidemics. The procedure involves finding a source of resistance and then combining the resistant characteristic with other desirable crop characteristics by appropriate breeding methodology. Thus, for example, in Nigeria, the plant breeders in the Federal Department of Agricultural Research have developed a variety of maize N.C.B.Rb, resistant to rust and blight, the two most important diseases of maize in West Africa. This variety has been one of the most outstanding in regional trials. Our current okra improvement programme at this university aims to develop varieties with resistance or tolerance to mosaic virus and nematodes, the two most important constraints to okra production. Cooperative work with scientists in the Department of Agricultural Biology has resulted in the identification of lines potentially useful as parental materials in the breeding programme for resistance.

Another spectacular plant breeding success has been the development of hybrid maize followed by hybrid varieties of many other important crops such as guinea corn, millet, cotton and a number of vegetable, fruit and forage crops as well as asexually reproducing crops such as cassava. Regulation of breeding systems as a result of the discovery of cytoplasmic, genetic and cytoplasmic-genetic male sterility systems has facilitated the commercial production of hybrid varieties in several of the above mentioned crops.

The production of good quality hybrid seed is a highly technical enterprise. The lack of an efficient production, processing, sale and distribution network which is absolutely vital for large-scale adoption of a hybrid variety has caused hesitancy among plant breeders in Nigeria to develop and release hybrid varieties for annual crops such as maize, guinea-corn and millets. However, hybrid varieties for some perennial crops and vegetatively reproducing crops are available within the country. Thus the hybrid *tenera [dura x pisitera]* palm varieties yield 10 to 12t/ha of bunches with an oil yield of 2.5t/ha when compared with 6 to 8t/ha of bunches with 0.6 to 1t/ha of oil production by the unselected native palms [32] The Agronomy Department of this university has released two hybrid varieties of *Cynodon,* IB.8 [33] a natural intraspecific hybrid form of *C. nlemfuensis* var *ulemfuensis* and IBX.7 [34] an interspecific (*C. nlemfuensis* var *nlemfuensis x C.*

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dactylon var *aridus*) hybrid. These improved varieties, because of their high yielding potential and good response to fertilizer application and management coupled with superior nutritive value, have the capacity to double beef production per unit area[33] when compared with local cultivars of *Cynodon* (fig. 3). The Department has also successfully combined the high yield characteristic of elephant grass with the good nutritive value of 'maiwa' millet and produced a perennial hybrid variety.[35] Our recent work using cytoplasmic-genetic male sterility has clearly demonstrated the feasibility of large-scale seed production of this hybrid variety.

An elegant and gratifying testimony to support my theme that plant breeding has played and will continue to play an important role in the conquest of hunger was provided when Dr. Norman E. Borlaug, a world renowned plant breeder who led the development of the now famous semi-dwarf, photo-sensitive, very high yielding Mexican wheat varieties which made the 'Green Revolution' possible, was awarded the 1970 Nobel Peace prize.

Borlaug's breeding of the new Mexican wheats involved the bringing together of genes from around the world. Varieties of wheat from the U.S.A., Canada, Australia, North Africa, East Africa, Italy, Japan, Korea, Brazil, Argentina, Peru and other countries were brought in as breeding materials.[36] These contributed genes for dwarfism, high yielding ability, rust resistance, spring habit, nonsensitivity to photoperiod, desirable seed colour, good milling and baking qualities and higher protein content. The end product, a group of varieties collectively called 'Mexican Wheats' have such wide adaptability that they are now grown in very large areas in more than twenty-five countries and yield 30 to 100 percent higher than the local varieties.[37]

Let us now briefly turn our attention to the Nigerian scene. Plant breeding programmes geared towards increasing food production in the country are relatively recent and it will be some time before the benefits are fully realized. A review of existing literature on the subject originating from the country indicates considerable progress.

Improved varieties of almost all major cereal, root and grain legume crops as well as forage crops and commodity crops such as cotton, cocoa, oil palm and groundnuts are available within the country. Experiment station trials involving improved varieties of major food crops with adequate inputs and management indicate

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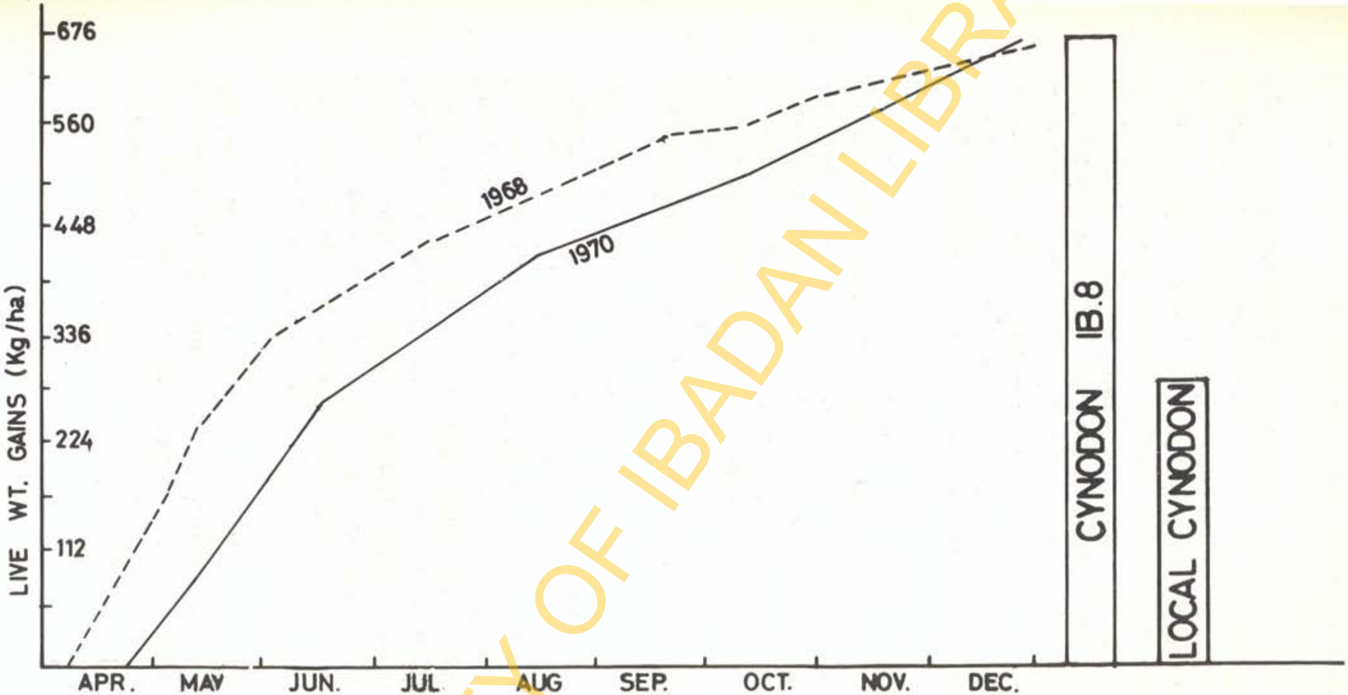

Fig. 3

Cumulative live weight gains during the wet season from a rotationally grazed *Cynodon* IB.8 pasture. The vertical bars show comparative performance in terms of beef production from IB.8 (grazed April to December) and local *Cynodon* cultivar (grazed for one year).

Source: Data adapted from Chheda[83] and Ogor and Hedrick.[39]

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yield increases of 3 to 6 times more than the average farmers' yields.[38]

However, many of our research recommendations ignore the basic facts of Nigerian peasant farming. They assume that high yields are important but often ignore consumer preferences. They assume monoculture and largely ignore mixed cropping. They assume highly mechanized farming conditions and ignore the cutlass and hoe agriculture. They assume ready availability of fertilizers and agricultural chemicals and ignore economic considerations of their use. In short they aim to convert the present farming systems overnight into Western types of energy-dependent highly complex business enterprises. This, I suspect, the average farmer will not buy and to a certain extent I have to agree with him.

I should now like to ask myself, my colleagues and my employers: what path does the University of Ibadan wish to follow? Should we be content with fulfilling our functions as producers of agriculture graduates and post-graduates and devote the rest of our efforts primarily towards publication-oriented research only? Or should we also participate actively in trying to move a stagnant agriculture by providing leadership, by modifying our research outlook and by working with and for the peasant farmer rather than for ourselves?

Undoubtedly we have succeeded quite well in the former task and Nigeria today has more agricultural scientists than any country in Africa, south of the Sahara. Agricultural scientists from Nigeria probably contribute more research publications than all the agricultural scientists working in the rest of Africa. My faculty alone has been contributing over one hundred good quality research publications to the scientific world annually, in the past several years, and the pace is rapidly increasing. However, I cannot find many really good examples which I could proudly quote as being already incorporated in the Nigerian farming systems and which really had their origins in the laboratories and farm of this university.

I am not a pessimist. We have with us in this university a large body of ambitious, well-trained and well-qualified agricultural scientists second to none in Africa and as good as any in the rest of the world. Teaching and publication-oriented research is what we have demanded from them and they have more than satisfied our

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demands. We can and should demand along with the so-called basic research more of problem-solving and mission-oriented research at the grass roots, more of medium and long term research, more research in mixed cropping, more research towards modification of the existing farming systems rather than their wholesale replacement — any and all kinds of research the results of which are of immediate practical value to the peasant farmer. By giving enlightened leadership and better farming facilities and by finding ways of adequately rewarding those teams of scientists who do such research we can and must make a greater contribution to the society which we serve.

The late President Kennedy, in his inaugural address, made a stirring plea for the abolition of hunger and malnutrition. I should like to end this lecture with his words:

> So long as freedom from hunger is half achieved, so long as two-thirds of the nations have food deficits, no citizen, no nation, can afford to be satisfied. We have the ability as members of the human race. We have the means, we have the capacity to eliminate hunger from the face of the earth in our lifetime. We need only the will.

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