I am deeply honored to present the sixth annual William A. (Tex) Frazier Lecture. My participation allows me to join ASHS in recognizing the outstanding contributions that Frazier made to the world of horticultural science. Everywhere Frazier worked during his long and remarkable career, he left a definite contribution to horticultural crop production technology. This includes the two years he spent in Arizona, where he helped establish a strong vegetable industry and gave Arizona potato production a boost.

I am proud to join the previous Frazier lecturers in calling attention to the important contribution that horticulture can make in improving the quantity and quality of food available to feed the world. In 1989 David Hopper defined the role of horticulture in the economy and food supply of developing countries. In 1990 Frank Salisbury took us on a trip to the moon to discover how to produce food in space. And last year, E.T. York discussed the importance of agricultural sustainability as farmers try to increase food production while maintaining natural resources and the quality of the environment.

THE CHALLENGE-THE CONQUEST OF HUNGER

I mention these timely contributions because they are directly related to one of the most critical challenges confronting the world today: Will this planet be able to feed a rapidly growing population? A positive answer is possible only if world population stabilizes by 2100 at about 12 billion. An equally challenging question is: Can we feed this growing population while establishing a sustainable agriculture that will preserve the quality of our environment? The answer depends on our ability and discipline as citizens of one world to: 1) define and accept realistic goals and priorities; 2) use or develop the needed technology; and 3) establish strategies and international cooperation to implement the program. During this decade and as we enter a new millennium, this campaign to feed the world and preserve the quality of our environment may be the most critical struggle for survival in the history of mankind.

GOALS AND PRIORITIES

The goal is simple, clear, and inspiring: end hunger and malnutrition in the world while preserving the quality of the environment and maintaining our natural resources. The priorities, more complicated and controversial, are to: 1) produce enough food; 2) distribute it equitably; and 3) establish a sustainable agriculture.

World food production

Obviously, the production of enough food is basic to any solution of hunger. Much has happened to increase world food production during the past 40 years. The Green Revolution in wheat and rice production in Asia and Latin America has been followed by significant breakthroughs in other food crops, such as sorghum and potatoes. By the 1980s nearly 4 billion tons of grain was produced worldwide, almost double the amount two decades ago. Today 2.3 kg of food is produced per person per day in the world. This increased production has allowed more grain to be stored, even in India and China, which have 40% of the world’s population. This is in great contrast to 30 to 40 years ago, when great famines occurred every 2 to 3 years in these countries. Despite these encouraging data, an alarming paradox is emerging: food surpluses have grown worldwide, but so has hunger. The United Nations Food and Agriculture Organization (FAO) reports that, today, more than 700 million people are classified as hungry. The figure for those that are undernourished is much higher.

Accordingly, adequate food production does not make an automatic solution to hunger. Why? Food production in developing countries. Although world food production has increased, many developing countries do not produce enough food to feed their populations. For example, due to rapid population growth, annual per capita food production is decreasing in large regions of Africa and Latin America. The resulting economic burden of importing food contributes to hunger.

Feeding a world population of 12 billion in 2100, even if it has stabilized, will be a monumental task. Even more alarming is the fact that 90% of this total population will inhabit the world population during the next century, it is imperative that more food be produced in the developing countries, and by higher productivity rather than simply by more area planted.

Private incentive and food production. Attempts to socialize agricultural production have been unsuccessful. The production of food crops is subject to too many unpredictable variables and individual, spontaneous decisions. Whenever the food producer (the farmer) is directly rewarded for higher yields—either in quantity, quality, or both—private incentive is stimulated and food production and productivity increase.

For example, during the past decade, the conversion of Chinese agricultural communes to groups of individual family holdings has sparked a spectacular rise in crop productivity. In Poland, more than 80% of the agricultural land has remained in small holdings in the private sector since 1945. Consequently, yields of important food and forage crops have been substantially higher in Poland than those in neighboring countries with state-controlled agricultural production systems.

Technology. Many believe that a lack of technology is the limiting factor in agricultural production, resulting in hunger. This is rarely the case. We do have the technology to increase food production dramatically in most
parts of the world, but we lack the economic resources to use it efficiently in developing countries. We know how to put our farm lands on a sustainable base. However, a field-proven technology for increasing food productivity, while establishing and maintaining a sustain-
able agriculture, is still our greatest need and technological priority. This is true for all coun-
tries, developed and developing, but perhaps most critical in the latter.

Government policy. The use of available technologies is often made more difficult by contradictory government policies or the apa-
dy of the decisionmakers. Inefficient coordi-
nation among official agencies and institutions can suppress or confuse the most worthy of production-oriented projects and prevent the wider use of new or established technologies. Again, this is true of both developed and de-
velling countries. In affluent countries, for example, policymakers may decide they are not interested in disease-resistant cultivars or integrated pest management and may simply apply more chemicals to control pests. In poor countries with scarce resources, unstable gov-
ernments and the lack of continuity in policies governing agricultural production and distri-
bution can be potent contributors to hunger.

Distribution and availability of food

Poor distribution and reduced availability of food can result in hunger even when food is abundant. This is true of any country. Even in the United States, the largest food-exporting country in the world, about 12% of the people are hungry, and an even larger percentage is undernourished.

Any economic, political, or social factor that contributes to a lack of purchasing power in any sector of society is an important cause of hunger. These factors include poor marketing opportunities, postharvest losses, and inadequate transportation and storage facilities. Finally, and most importantly, an inescapable link exists between poverty and hunger.

Sustainable agriculture

We cannot continue to expand the area planted to food crops as a way to feed the increasing world population. The pressure on marginal lands is already at the danger point. The more pessimistic observers believe that we have already gone too far and that our planet is doomed.

If we merely continue to use more chemi-
cals to fertilize our crops and control diseases and pests, the dangers to a sustainable agricul-
ture are obvious. Any strategy to feed the world’s population during the coming century must maintain environmental quality and natural resources. And, as York stated in 1991, “A truly sustainable agriculture must also be productive, and profitable.”

CURRENT ROLE OF THE POTATO AS A WORLD FOOD CROP

In the remarkably short period of four cen-
turies, the potato has emerged from the central Andean region of South America and become one of the four major food crops of the world, along with rice, wheat, and maize. Today the potato is a staple food in developed, industri-
alized countries and is becoming more impor-
tant in developing countries.

Annual per capita consumption of potatoes in Europe, Russia, the United States, and Canada is several times higher than in the Third World countries of Asia and Africa. In Latin America, with the important exception of the Andean region where the cultivated potato originated, annual per capita consump-
tion is also well below that of industrialized countries (Fig. 1).

Let us examine some of the recent trends in potato production and use, first in developed countries and then in developing countries.

Developed countries

Although the area planted to potatoes in developed countries has steadily declined dur-
ing the past 40 years, productivity has signifi-
cantly increased. As a result, total annual pro-
duction has tended either to rise slowly or level off in these countries.

Canada and the United States are good examples of this trend. Annual potato produc-
tion has been gradually rising during the past 20 years in both countries due to a steady increase in yield per hectare, while the area planted has remained fairly stable.

In several European countries, the potato is not only an important daily food for the people, but also a livestock fodder, particularly for swine: a source of starch; and a crop for pro-
cessing. Any future decline in total potato consumption in Europe will probably be due, not to a reduction in human consumption, but to a shift from potatoes to cereal grains, both for starch production and livestock feed.

In Europe, the potential demand for pro-
cessed potatoes has not been exploited; until recently, less than 20% was processed. In the United States, however, more than half the potato crop is processed and consumed as snack food.

Developing countries

During the past 45 years I have had the privilege of collaborating with colleagues in national potato programs in 78 countries, mostly in the developing world. In each coun-
try our main objectives were to 1) improve national potato production and productivity, thereby increasing per capita consumption of this valuable food crop; and 2) establish a strong national potato production program, with the resources and trained personnel to provide an operating base for continued con-
tributions. These programs have been highly effective, and the potato has significantly in-
creased in importance in many Third World countries. Potato production in these countries has been rising at a faster rate than that of any other food crop, due both to more hectares planted and higher yield per hectare.

Forty years ago the developing countries produced only 7% of the world’s potato crop; today they produce more than 25% (Table 1). This dramatic increase in potato production was the result of dedicated efforts by national potato program personnel, with the enlight-
ened support of national decisionmakers who appreciated the potential contribution of the potato to the diet and economy of their people. These countries used their own resources to apply advanced, production-oriented technol-
ogies for the development of better seed, more

![Fig. 1. World potato consumption (in kilograms per capita per year) from 1979 to 1981 (from the United Nations Food and Agricultural Organization).](image-url)
productive cultivars, more efficient fertilizers and cultural practices, and effective disease and pest control (Fig. 2, Table 2).

A significant indication of the value and impact of a new staple food is the price consumers are willing to pay for that food. In urban Asian markets, the relative price of potatoes compared to that of rice had dropped substantially by 1980 (Table 3), due primarily to impressive increases in production and productivity. Thus, the potato was more available economically and was evolving from an expensive vegetable to a staple food.

The opening of markets for processed potato foods in Third World countries has been an important development in the past decade. Although the processing facilities may be installed by foreign investors, the potatoes are produced locally. This development could profoundly affect future potato production and consumption patterns in developing countries. However, the national potato programs and production trends in developing countries probably would be unaffected.

**POTENTIAL ROLE OF THE POTATO AS A WORLD FOOD CROP**

Let us examine some of the reasons for this dramatic increase in the importance of the potato in the nutrition of the Third World. Since the potato still is considered a horticultural crop in this region, could it serve as an example for other potential food crops? Could any of the strategies and programs responsible for this successful potato story be of value to you, Members of ASHS, as you attempt to increase the worldwide importance of the horticultural crops with which you are working. These other crops, as the potato, have great potential to contribute to the quest of hunger, particularly in the sustainable agricultural systems of subsistence farmers in developing countries.

Table 1. World potato production (data from the United Nations Food and Agricultural Organization production yearbooks).

<table>
<thead>
<tr>
<th>Year</th>
<th>Area (million ha)</th>
<th>Yield (t ha⁻¹)</th>
<th>Production (1000 t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1948-52</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>World</td>
<td>23</td>
<td>10.7</td>
<td>244</td>
</tr>
<tr>
<td>Developed</td>
<td>20</td>
<td>11.4</td>
<td>224 92</td>
</tr>
<tr>
<td>Developing</td>
<td>3</td>
<td>6.4</td>
<td>20 8</td>
</tr>
<tr>
<td>1969-71</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>World</td>
<td>20</td>
<td>13.8</td>
<td>277</td>
</tr>
<tr>
<td>Developed</td>
<td>16</td>
<td>15.0</td>
<td>242 87</td>
</tr>
<tr>
<td>Developing</td>
<td>4</td>
<td>9.0</td>
<td>35 13</td>
</tr>
<tr>
<td>1979-81</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>World</td>
<td>19</td>
<td>14.2</td>
<td>270</td>
</tr>
<tr>
<td>Developed</td>
<td>13.5</td>
<td>15.5</td>
<td>209 78</td>
</tr>
<tr>
<td>Developing</td>
<td>5.5</td>
<td>11.0</td>
<td>61 22</td>
</tr>
<tr>
<td>1986-88</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>World</td>
<td>18</td>
<td>15.5</td>
<td>281</td>
</tr>
<tr>
<td>Developed</td>
<td>12</td>
<td>17.4</td>
<td>209 74</td>
</tr>
<tr>
<td>Developing</td>
<td>6</td>
<td>11.8</td>
<td>72 26</td>
</tr>
</tbody>
</table>

Table 2. Increases in potato production from 1950 to 1980 (data from the United Nations Food and Agriculture Organization production yearbooks).

<table>
<thead>
<tr>
<th>Year</th>
<th>Country</th>
<th>Area (1000 ha)</th>
<th>Yield (t ha⁻¹)</th>
<th>Annual production (1000 t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1948-52</td>
<td>Bangladesh</td>
<td>50</td>
<td>5</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Colombia</td>
<td>55</td>
<td>9.2</td>
<td>506</td>
</tr>
<tr>
<td></td>
<td>India</td>
<td>277</td>
<td>6.8</td>
<td>1,547</td>
</tr>
<tr>
<td></td>
<td>Mexico</td>
<td>30</td>
<td>4.5</td>
<td>134</td>
</tr>
<tr>
<td></td>
<td>Turkey</td>
<td>79</td>
<td>7.7</td>
<td>605</td>
</tr>
</tbody>
</table>

For Bangladesh from 1948 to 1952 listed under East Pakistan.
Security of production under stressful environmental conditions. This is a subtle advantage not often given much consideration. For example, in the Andean region of South America, resistance farmers often plant small plots of frost-resistant, wild potato species (e.g., Solanum jacqosuicuii and S. acaule) beside their fields of higher-yielding potato cultivars. In a severe frost during the growing season, the wild species will still yield a modest crop, while the other potatoes will be destroyed. Also, farmers in Poland have noted that an untimely frost or drought in the latter part of the season can destroy a grain crop, but the damaged potato will produce a partial crop.

Short crop season. The potato has a shorter growing cycle than most other food crops, especially in the tropics, and thus can be more easily incorporated into rotations and cropping systems. Agricultural officials and scientists in India report that the area planted to potato in the Punjab (a major potato production area) would shrink to less than half the area now planted if they did not have potato cultivars that could be harvested in 90 to 100 days, thus fitting into the annual rotation between winter wheat and summer rice.

Potato production also involves some distinct disadvantages and problems.

Bulking (in marketing, transport, storage, etc.). The bulkiness of this crop is evident to anyone who has harvested potatoes, weighed yields of research plots, or driven a truck load of potatoes. When we plant, harvest, market, or consume potatoes, we deal with about five times the equivalent amount of grain.

Perishability and postharvest losses. A major barrier to increased consumption of the potato in developing countries is its semiperishable nature and postharvest losses. In many developing countries, nearly one-third of the harvested crop often would pay far greater rewards than would a similar investment in increased consumption of the potato. Thus, the potato is host to many pathogens and pests—fungi, bacteria, viruses, nematodes, aphids, beetles, leafhoppers, etc.—which have plagued potato growers around the world. The sharp rise in potato productivity—first in developed countries and more recently in developing countries of the Third World—is due in part to the successful control and management of these pathogens and pests. This campaign must be intensified if the current potato cultivars are to continue to rise in importance, particularly in developing countries.

This list of advantages and disadvantages is not complete and will change as our experience with growing the potato expands into new regions of the world. I do not doubt that more vegetable crops will have an important role in food production in these countries and in the nutrition of their people. How can we accomplish this? We first need to study each of the criteria listed above. How can we maximize the productivity of these horticultural crops and judge them by the criteria listed above. How can we maximize the advantages of a potentially important vegetable crop? If disadvantages exist, how can we minimize them? Such information and decisions will help to determine the future role of horticultural crops in the subsistence agriculture of small-farm owners in the developing world.

Strategies for international cooperation in agricultural research and development

International cooperation is as old as horticultural crops are important from the point of view of food production, but we must not lose sight of the fact that they have a very important role to play in improving the quality of life of the people of the world. The potato crop is a good example of how international cooperation can be helpful.
tical science itself. Beginning with visits and collaboration among individual scientists, it slowly expanded during the first half of this century. Before World War II, many fruitful international collaborations began. Vavilov took place between scientists in Europe and North America. For example, Vavilov’s and Bukasov’s classic plant explorations in the Americas in the 1920s and 1930s generated worldwide interest not only in plant taxonomy, but also in genetic resources and the potential value of new food plants.

During the past 50 years, as means of communication have become more sophisticated and travel to distant regions has become more common, the interchanges of technology and plant material have increased dramatically and travel to distant regions has become more common. For example, Vavilov’s and colleagues from other countries.

We have seen how potato production has significantly increased in Third World countries during the past 40 years. However, it is now important to note that the rate of increase in potato production in these countries has been greater than that of many other food crops. Why? And will this trend continue?

The establishment in the 1960s of Sabritas, a Mexican enterprise of Frito Lay, the U.S. distribution giant, with more than 5000 trucks serving 350,000 outlets and annual sales of more than $1 billion. The guiding force behind the remarkable growth of funds and resources, the Regional Cooperative-
success of this food enterprise was the dedi-
cated and intelligent leadership of John Warner,
the founder of Sabritas and its president until
his recent retirement. Warner had not only the
e xecutive talent and technical knowledge to
create and lead this successful commercial
operation, but also the wisdom and personality
to merge Sabritas into the national scene, gain-
ing the respect and admiration of the agricul-
tural sector.

As the company grew and prospered, Warner shared his success with local farmers and
national institutions involved in food produ-
duction. Production contracts with growers,
collaboration with the national certified seed
program, and support of national research pro-
grams in areas of mutual interest created a firm
national base on which the company could
grow and a stronger national food production
program in accordance with national priorities.

Sabritas is an excellent example of a highly
profitable international agribusiness venture that
builds strength and continuity in the national
program. This case shows the great international
opportunities awaiting the food industry, when
the encouragement and support of national in-
stitutions and programs are given priority
alongside the commercial goals of the business.

It is my hope and recommendation that
members of the private sector, as they pursue
their commercial goals internationally, will
not neglect the mutual benefits to be gained
from sharing food production and processing
technology with the Third World. With its
combined resources of excellent personnel,
advanced technology, and a vision of expand-
ing international cooperation, the private sec-
tor could be at the beginning of a most exciting
and fruitful period.

3) National foundations. Recently, interna-
tional donors have been searching for innova-
tive ways to strengthen national agricultural
production systems. One of the more promising
new strategies is the National Foundation for
Agricultural Research and Development, spon-
sored by the private sector and financed
by private and public funds. This nonprofit
foundation is independent in its operations
and management but closely related to govern-
ment agricultural priorities and strategies.

The oldest such foundation is the Hondu-
ran Agricultural Research Foundation (FHIA),
which conducts research on traditional and
nontraditional food crops in Honduras. FHIA
emphasizes research in certain priority areas,
including vegetable crops, mango, pineapple,
pepper, and palm hearts.

In 1987 the Ecuadorian Agricultural Devel-
opment Foundation (Fundagro) was established.
It serves as a catalyst to link the public and
private sectors in supporting national research,
extension, and education opportunities.

Positive results to date indicate: 1) better
coordination between national institutions in
shared priority programs, 2) more cost-effi-
cient use of scarce national resources, and 3) a
stronger link with international sources of
technology.

New strategies for international coopera-
tion. The International Science Corps and re-
gional production and training centers are two
initiatives that could add new dimensions to
international cooperation in agricultural re-
search and development.

The establishment of an International Sci-
ence Corps, which is proposed here for your
comments, would provide opportunities pri-
marily for students and young professionals to
obtain international experience. The related
fields of food production, processing, and
marketing would be included. This program
would be organized, administered, and financed
as a collaborative venture involving the private
sector, appropriate government agencies (such
as the U.S. Agency for International Devel-
opment and the Peace Corps), and scientific
and educational institutions.

The exciting opportunities for international
involvement in the food production sciences
make a coordinated national endeavor that
would provide professional experience in other
regions of the world an urgent necessity.

We shall need new generations of young
professionals who have the vision and experi-
ence to undertake the new worldwide coopera-
tive ventures in food production, processing,
and marketing.

In 1985 the Univ. of Arizona established
the Maricopa Agricultural Center (MAC) on
851 ha of flat, irrigated land between Tucson
and Phoenix. Governed through the Univ. of
Arizona Foundation, MAC devotes 162 ha to
the university’s agricultural research programs,
with the remaining 689 ha operated as a com-
mercial farm for profit. The most modern
production technologies are used to produce
high yields of such local crops as cotton,
alfalfa, wheat, and grapes. Profits are used to
defray all costs of operation and encourage the
development of new crops and technologies.

Unique production training opportunities are
available for graduate students, both national
and international.

Looking to the future, other regional pro-
duction and training centers are being planned
for Africa (Morocco), the Middle East (Ku-
wait), Asia (Pakistan), and Latin America
(Mexico). Preference is being given to regions
with arid climates, similar to that in Arizona,
and regions where the pressure on efficient,
sustainable agricultural production is so criti-
cal.

The regional production and training cen-
ters would 1) develop the newest production
technologies at the farm level and test their
eco-friendly viability; 2) provide an international
base for field-oriented production training for
scientists from countries with similar climate
stresses; 3) coordinate and develop research
on new production technologies in arid agri-
cultural zones; and 4) be financially self-sup-
porting.

CONCLUSION

ASHS has a fine history of international
cooperation, both as a Society and as indi-
vidual scientists. Your International Affairs
Division is designed to promote productive,
cost-efficient international collaboration on
projects of mutual interest.

I believe that some of the strategies and
experiences discussed here might encourage
the Society to continue its role in these interna-
tional agricultural research and development
activities.

The horticultural crops of the world are
invaluable agricultural resources that have re-
alyzed only a fraction of their potential in
providing food and high-quality nutrition to
the people of the world, particularly in devel-
oping countries. Let us make these valuable
food plants available to everyone, through an
intensive, small-scale, subsistence agriculture
that is also sustainable.

We are living in one of the most exciting
and critical periods in the history of mankind.
As we approach the biological limits for what
this planet can support, we must realize that we
are living in one world. And as citizens of one
world, we must collaborate with dedication
toward a single goal—a world without hunger
that conserves the quality of our environment
and our natural resources.

I ask again: Are we equal to the challenge?