Population growth, food shortages and ways to alleviate hunger

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Improvement of agriculture in developing countries is the only way of alleviating hunger. The available agricultural technology will not be able to meet the challenge of the present population growth of about a billion additional mouths every 12–14 year without detriment to natural resources and the environment and has to be suitably modified. Availability of quality seeds is a major problem in most developing countries. Availability of irrigation water and energy and their use efficiency need to be improved. One of the major drawbacks of modern agriculture has been the overuse or rather abuse of agrochemicals. Their use has to be minimized and alternative ways of controlling pests and diseases in crops using natural products and biopesticides deserve attention. Some breakthroughs in plant types are urgently needed and genetic engineering can certainly help. Fertilizer nitrogen has been the key input in augmenting food (both calorie and protein) production in the past and will continue to do so. It is estimated that in future fertilizer nitrogen need will more than double the present consumption. However, fertilizer nitrogen has been blamed for the pollution of environment and groundwater and surface water due to ammonia volatilization, denitrification and leaching. About one-third of the nitrogen applied to field crops is lost due to the processes mentioned above. There is thus an urgent need for controlled-release nitrogen fertilizers for which leads are already available. What is lacking, however, is a sincere effort and adequate funding so that these are available to the poor farmers in developing countries.

Keywords: Food shortage, hunger alleviation, modern agriculture, population growth.

AFTER humans moved from hunting and gathering food to cultivation of crop plants, the progress was slow in the new Stone and Bronze ages. Domestication of animals and plants moved at a slow speed in the Neolithic (new Stone) and Chalcolithic (Bronze) ages[1]. Modernization of agriculture began in England in the 18th century, when Jethro Tull invented a horse drawn hoe and a seed drill, and Robert Blackwell brought about a revolutionary change in stock breeding[2]. In the 19th century, 'super phosphate' was the first chemical fertilizer produced in England[3]. The tractor with an internal combustion engine was developed in USA in 1901 (ref. 4). Also, the first major jump in cereal yield was ushered in with the development of hybrid corn (maize) in USA in 1917. Large-scale cultivation of hybrid corn increased the demand for chemical fertilizer, specially, nitrogen and three fertilizer plants were put up in USA during 1920s following the discovery of ammonia synthesis by Fritz Haber in Germany in 1910s (ref. 5).

The use of fertilizer nitrogen allowed farmers to grow cereals or other crops on land that would otherwise have been left uncultivated for fertility build-up through a legume (about 25–50% of a farm) in a crop sequence[6]. Other components of modern agriculture are pesticides, which were developed to save the crops from heavy losses due to insect pests, diseases and weeds. Insecticidal property of DDT was discovered in 1939 by Muller in Switzerland and was followed by the discovery of BHC in France and the UK[7]. Nitrophenols were reported as the first group of selective herbicides and were followed by the development of 2,4-D and MCPA in 1940s (ref. 8). Thus by the middle of the 20th century most components of modern agriculture were in use for food production and were of great help in alleviating hunger from the world.

Harmful effects of modern agriculture

The first harmful effect of agricultural development is the fact that land clearing threatens biodiversity[9]. The long-term effects of this have not been fully realized and have not received the attention they deserve.

The second harmful effect of modern agriculture was reported from USA, where too much use of tractors led to erosion of soil by wind known as the famous 'dust bowl' of the Great Plains in 1930s. So damaging was the effect of the dust bowl that the US House of Representatives

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passed the Soil Erosion Act of 1935 and Soil Conservation and Domestic Allotment Act of 1936 (ref. 4). However, this problem was overcome by the development of conservation agriculture, which involved minimum land cultivation and seeding in fields covered with the stubbles left by the previous crop[10–12].

The third harmful effect of modern agriculture was observed with the overuse and abuse of pesticides, specially on vegetables and fruits[13,14].

The fourth harmful effect of modern agriculture was reported due to overuse of chemical fertilizer, specially nitrogen, resulting in nitrate pollution of surface water and groundwater[15,16] to levels toxic to fish and other marine life[17]. Increased nitrate content in drinking water, green vegetables, milk, etc. led to methaemoglobinaemia (blue baby syndrome) and other human ailments[18]. Further, overuse of fertilizer nitrogen also results in increased liberation of ammonia[19,20] and nitrous oxide[21,22] to the atmosphere. According to the Inter-Governmental Panel on Climate Change[23], fertilizer nitrogen accounts for 18% of the total anthropogenic nitrous oxide emission in the world. While ammonia release contributes to the acid rain, nitrous oxide is reported to be involved in the depletion of the ozone layer[24] and has about 273 times global warming effect compared to carbon dioxide.

The fifth harmful effect of modern agriculture is it being partly responsible for global warming. Burney *et al.*[25] observed that about one-quarter of global greenhouse gas (GHG) emission results from land clearing, crop production and chemical fertilizers. According to latest estimates[26], industry and energy supply, a large share of which is in the developed countries, together contribute about 45.4% towards global warming. Despite this, industrially developed nations blame agriculture, which contributes only 30.9% towards global warming. Agriculture is the major source of livelihood in the developing nations of Asia, Africa and South America, engaging about three-fourth of the world population.

There can be no argument on the fact that the ills of modern agriculture have to be removed. This led to the development of organic agriculture[27,28], which for all its acclaimed advantages is a step backward for increased food production, because yields from organic farms are 20–30% less compared to fields under modern (now generally referred to as conventional) agriculture. Further there is no definite evidence of an improvement in nutritional quality of the produce[29]. Nevertheless, the organic agriculture movement aims at reducing the use of pesticides and chemical fertilizer in modern agriculture.

Sustainable agriculture

The concept of sustainable development, which became well known through the famous Brundtland report, entitled 'Our common future' published in 1987, recognized that the natural resources are not inexhaustible and the development process should be aimed to meet the needs of the present generation without compromising the ability of the future generations to meet their own needs. Agricultural production systems optimize through economic indicators and ignore the fact that human-managed systems degrade the natural resources. They degrade the natural resources and reduce their natural capacity to renew or recycle[30]. Swaminathan[31] observed that the fast-expanding Green Revolution unfortunately leads to unsustainable exploitation of natural resources and to the excessive and unscientific use of pesticides and chemical fertilizers. Hence new tools for measuring sustainability will have to be designed that include economic viability and social intergenerational equity. Thus sustainable agriculture should aim at the desired food production, conservation of natural resources and protection of the environment, while assuring social and gender equity without creating regional imbalances[32,33].

Research on development of sustainable agriculture needs to be given more attention and funds by the Governments all over the world and international organizations.

Population growth

The world population was merely 10 million nearly 10,000 years ago and took almost 8000 years to reach 100 million and another 3804 years to reach the 1 billion mark in 1804 (ref. 34). The next billion was added in 123 years (1927) and another billion in the next 33 years (1964). However, since then an additional billion as been added each 14 to 12 years and seven billionth baby was born on 31 October 2011 near Lucknow in India[35]. According to the UN, global population may level-off at 9 billion by 2050.

Zeigler[36] pointed out that if fertility rate was just 0.5 child per woman less, the global population could be 8.1 billion as against the UN's present estimate of 9 billion by 2050.

Global food production and needs

Global food production, already under the credit crunch, must double by 2050 to level off hunger[37]. Thus in the next 40 years or so, the world will need to produce as much food as in the last 8000 years. According to the UN World Food Programme (WFP), this will be possible only if food security is given top priority[38]. Although Americas and Sub-Saharan Africa offer some hope, the cultivable land availability is declining fast. The world population clock at the International Rice Research Institute (IRRI), Philippines is tickling upward @ 2.4 persons per second, whereas the global productive land availability clock is forever tickling downward @ 1 hectare every 6.67 seconds. The annual cereal productivity rate should

be higher than annual population growth. Unless productivity growth rate is higher than the population growth rate, all such countries will have to depend on imports from countries where food production is higher than the demand. In contrast, the rate of growth in production of major cereal crops in the world dropped from 3.2% per annum(pa) in 1960s to 1.5% in 2000. Somewhat similar data are reported from India, where the crop output declined from 2.8% pa during 1966–67 to 1991–92, to 1.1% pa during 1998–99 to 2006–07 (ref. 39). In the later half of 1960s, Noble laureate Norman E. Borlaug introduced dwarf Mexican wheat in India, ushering in India's Green Revolution. Similarly, introduction of semi-dwarf varieties of rice from IRRI and the development of high-yielding rice varieties by rice breeders in India considerably increased rice production in the country. However, the green revolution that brought self-sufficiency in food in India is showing signs of technology fatigue and has caused ecological damage[40] and needs to be suitably modified.

Food shortages, famines and food wars

Food has always been and will probably continue to be in short supply in one or the other part of the world. The extent of food shortage in the world can be gauged from the fact that since biennial 1990–92, the number of undernourished people has always been above 800 million and in 2008–09 it crossed the one billion mark, which was about 15% of the world population. The global hunger index (GHI), a new concept and tool developed by the International Food Policy Research Institute (IFPRI) in 2006, consists of three interlinked, hunger-related indicators, namely the proportion of undernourished in the population, the prevalence of underweight in children, and mortality rate of children. In 2011, the GHI was 22.9 in South Asia, 21.7 in Sub-Saharan Africa, 8.6 in Southeast Asia and 4.9 in Latin America[41]. The GHI for India was 23.7.

Food shortages and famines occur more frequently in Asia and Africa. In the 18th and 19th centuries, droughts and famines occurred frequently in India. In the famine of 1876–78, about 60 million people were affected and mortality exceeded 5.25 million. The then British Government was really touched by this colossal loss of life and property and constituted a Famine Commission in 1880, which recommended an improvement of Indian agriculture. Again, the famine of 1899–1900 affected 55 million people and resulted in a serious loss of human lives, crops and cattle. J. E. Scott, an American missionary commented 'The misery is terrible. But still worse is the fearful emaciation: living skeletons are on every side'[42].

Since agriculture in India depends on monsoon rains, their failure is the main cause of droughts and famines. Considering this Lord George Nathaniel Curzon, the then Viceroy of India (1898–1905) appointed an Irrigation Commission to study irrigation in India. This was followed by the establishment of provincial departments of agriculture and establishment of the Imperial (now Indian) Agricultural Research Institute (IARI) at Pusa (Bihar) in 1905. IARI shifted to New Delhi in 1935. These developments helped in improving Indian agriculture and severe droughts in 1918, 1978 and 1987 did not cause human deaths due to shortage of food.

Famines are of common occurrence in Africa also. In mid-2002, famine conditions were centred mainly in South Africa, but by the end of the year it spread to the horn of Africa (Ethiopia, Eritrea)[43]. According to WFP, as many as 38 million people lived under the threat of starvation. Other than bad weather, political strife and armed conflicts between several countries were also responsible for food shortage and came in the way of food distribution by UN agencies.

The major causes for global shortages other than bad weather include poor development of agriculture, demand for better quality of food by the expanding middle-income class and reduction in agricultural land due to urbanization and industrialization. Another major cause of global food shortage is the diversion of corn and sugarcane to biofuel production in USA, Brazil and some other countries. Increased speculation in agricultural commodities is also partly responsible for global food shortages.

Ways to alleviate hunger and malnutrition

The only way to alleviate hunger and malnutrition is to increase food production and improve food quality. To discuss this at a global level is difficult. A brief description of the Indian experience follows, to highlight the major problems and likely solutions.

A brain-storming session was recently organized by the National Academy of Agricultural Sciences at New Delhi on the carrying capacity of Indian agriculture[44]. It emerged that agricultural production in India cannot increase without increased and efficient use of water, energy, plant nutrients and agrochemicals. Also important is the prevention of post-harvest losses and value-addition of agricultural products. Some of these aspects are briefly discussed.

Seed

Quality seed is the driver of agricultural production, yet seed replacement rates for most grain crops are very low in India – 25% in rice, 18% in wheat, 19% in sorghum and 11–16% in pulses[45]. National and state agencies cater to the systematic seed production and distribution in the public sector. In addition, there has been a good growth in the private sector, including some multinationals. This has increased the availability of quality seeds to a large

number of farmers at an appropriate price. GM crops can make a great change in increasing the production potential of crops and *Bt* cotton is an excellent example of such a change[46].

Water

Water is becoming scarce globally. In India the water requirement is projected to increase from 708 BCM (billion cubic metre) in 2010 to 1178 BCM in 2050 (ref. 47). The groundwater recharge is estimated at 433 BCM (ref. 48). A major cause of concern is the over-exploitation of the groundwater through indiscriminate drilling of tube wells in several parts of the country[48]. Suggested measures include:

- Creating more storage in existing reservoirs by controlling siltation in catchments.
- Harvesting more rain water.
- Reducing seepage losses in canals.
- Devising efficient water distribution system.

Most irrigation water is surface-applied in India. Water use efficiency can be greatly increased by developing micro-irrigation (drip and sprinkler)[49]. Quality of groundwater is also a concern, specially the high levels of iron and arsenic in the eastern states of the country.

Agrochemicals

The installed capacity of pesticides in India is nearly 145,400 tonnes annually[45]. Cotton, rice, vegetables and fruits account for nearly 80% of total consumption. With the introduction of *Bt* cotton, the consumption of pesticides in cotton has been considerably reduced. Due to large-scale rural to urban migration, the wages of farm labour have considerably increased and the demand for herbicides is increasing. More and more farmers are shifting to chemical weed control. However, development of resistant bio-types of weeds, such as *Phalaris minor* is creating problems. Similarly, insecticide-resistant biotypes are also seen to be developing and solutions to these have to be found. Plant-derived insecticides such as those from neem (*Azadirachta indica*) are finding favour[50] and a country programme entitled 'Development of products of neem as environmental friendly pesticides' is being undertaken by the Department of Chemicals and Petrochemicals with financial assistance from the United Nations Development Programme (UNDP). It may be mentioned that overuse of pesticides in vegetables and fruits has become a major problem in India.

Energy

Indian agriculture is increasingly becoming dependent on commercial energy. Increasing mechanization in agriculture and irrigation using groundwater requires electricity or diesel. Production of fertilizers and agrochemical is also energy-intensive. Current per capita consumption of electricity is 704 kWh in India as compared to 2328 kWh in China and 13,611 kWh in USA[45]. Availability of 2 kW/ha needs to be assured for intensive agriculture, agro-processing and rural living[45].

Fertilizers

About 40% of the increase in cereals and thereby a similar increase in plant protein production has been due to fertilizer nitrogen along with adequate supply of other plant nutrients. High-yielding varieties and hybrids of cereals need much more nitrogen[51,52]. Further increase in the production of cereals and plant proteins will also not be possible without application of additional fertilizer nitrogen[53]. Kawashima *et al.*[54] predicted a global nitrogen consumption of 220 Tg/yr by the middle of the 21st century. Recently Tilman *et al.*[55] have also advised increased application of nitrogen in developing countries as the possible way of meeting the projected global crop production by 2050. It is widely accepted[56] that about one-third to half of applied nitrogen is lost to the atmosphere or groundwater and pollutes them. There is thus an urgent need for developing more efficient nitrogen fertilizers, such as controlled release nitrogen fertilizers[57] or nitrogen fertilizers blended with nitrification inhibitors[58,59]. From the viewpoint of India, neem-coated urea is important. Use of nitrification inhibitor blended nitrogen fertilizers are reported to reduce the emission of nitrous oxide[60,61] as well as methane[62].

Conclusion

Efficient use of the tools of modern agriculture (seed, water, fertilizer, agrochemicals, energy) and preventing their overuse or abuse is the only way to assure adequate food production and alleviate hunger without being detrimental to the environment.

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