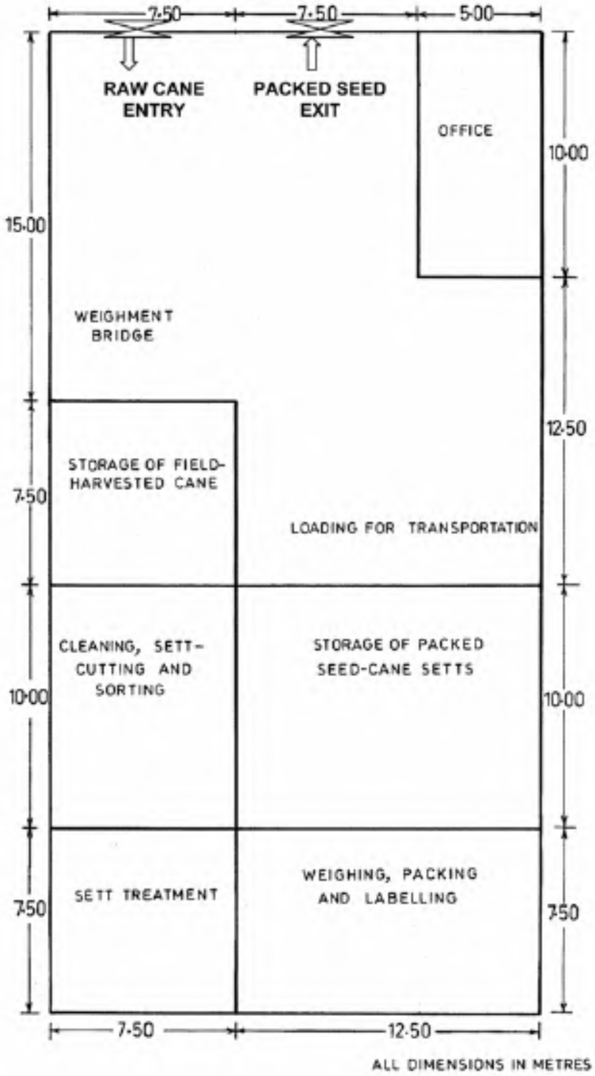

Figure 3. Conceptual layout of cane-seed processing complex (capacity 15 t/d).

seed-cane handling for preparation of processed and packed seed-cane setts will open a new vista of research. There will be need to conduct research to confirm the superiority of this system under diverse situations of seed-cane sett preparation. It will also be needed to assess the maximum life of processed and packed seed setts for specific varieties and agro-climatic conditions. Accordingly, storage life of packed seed-cane setts has to be mentioned on the labels and it may vary with the variety.

The comparative economics of seed-cane handling of the conceptual system and conventional system indicates that the handling of raw seed-cane by processing and packaging under the conceptual system is economically viable. The concept on the one hand makes the seed-cane legally viable and on the other, it adds value and quality to it. The marketing value and demand of such seed-cane need to be worked out through surveys and test-marketing. The potential of the processed seed-cane in providing better germination and checking disease transmission is well-known, but its acceptance among farmers will be established once the technology reaches the farmer's field.

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Nutritional security: a missing link in climate change debates

Manoj-Kumar and A. K. Patra

Climate change is no longer a distant scientific prognosis; it has rather become a reality established beyond doubts. Rise in atmospheric concentration of carbon dioxide (CO_2) and the accompanying increase in air temperature on the earth's surface have been the two most striking manifestations of global climate change in recent decades. Both of these changing climatic variables are closely associated with the growth and productivity of food crops, particularly C_3 crops (e.g. wheat and rice), which constitute about 95% of the agriculturally important crops worldwide. Since atmospheric CO_2 is the sole source of carbon for plants, variations in its concentration have obvious implications for plant growth. The best growth and yield performances of C_3 crops are observed at around 1000–1200 μmol mol^{-1} CO_2 concentration. As the current atmospheric concentration of CO_2 (385 μmol mol^{-1}) is in short supply to saturate the growth and yield responses of the C_3 crops, any further increase in CO_2 concentration is expected to increase the productivity of these crops[1]. Although increased crop yield with rising CO_2 is now a well-established global phenomenon, the effects of increasing temperature may be highly region-specific. The temperature rise in temperate and polar regions, where crop growth is currently limited by unfavourably low-temperature regimes, is expected to reinforce the beneficial effect of elevated CO_2 on crop yield. In contrast, the rising temperature in tropical and subtropical regions, including India, South Asia and Africa, where most of the food crops are already growing at the upper limits of their thermal tolerance, may act in opposite direction to that of rising CO_2.

In view of the possible impacts of these changing climatic variables on crop yields, the subsequent impact on global as well as regional food security has been the focus of intensive research and debate among the scientific intelligentsia across the globe. However, an equally important or perhaps a more important issue of nutritional security is largely missing in all these debates. This is particularly surprising in today's context when almost half of humanity is suffering from different kinds of malnutrition, with the degree of nutritional deficiency being more acute in poor and developing countries located in the tropical and subtropical regions. Given the strong dependence of the people in India, South Asia and Africa on plant-based diets for their nutritional security with virtually no access to nutritionally fortified food products, the nutritional well-being of people in these regions depends broadly on three factors: (1) sufficient availability of food; (2) sufficient concentration of nutritionally important food constituents/mineral elements in food, and (3) adequate bioavailability of these nutrients in consumed food. A majority of the research efforts to date have gone into predicting the impacts of climate change on the availability (yield) of food (first factor) which relates to food security, whereas the impacts on the latter two factors, i.e. concentration and bioavailability of nutrient elements in available food which determines the food quality and hence the future of nutritional security, are largely unknown.

Why expect changes in nutritional qualities of food?

Crop plants synthesize food by taking carbon from the atmosphere and other essential nutrients from the soil as raw materials. However, as the CO_2 content in the atmosphere is increasing, availability of other essential nutrients (N, P, Zn and Fe) in the soil is practically constant or decreasing, i.e. never increasing in unison with the rising atmospheric CO_2, suggesting a possibility of altered chemical composition of the food synthesized by the plants[2]. As plants absorb more atmospheric carbon, they produce higher-than-normal levels of carbohydrates, but are unable to boost their relative intake of soil nutrients. This dilution effect can result into increased yields of carbohydrate-rich food grains with lower levels of macro- and micronutrients. Such a possible alteration in chemical composition of the food grains with respect to nitrogen (protein), iron and zinc besides many other vital nutrients, can exert significant influence on the nutritional qualities of food produced under elevated atmospheric CO_2.

Normally, plants absorb soil nutrients through their roots in two ways. Nutrients can be sucked in along with the water absorbed by the plant, or they can just diffuse down into the root along a concentration gradient. Increased CO_2 disrupts both the mechanisms. Higher concentration of atmospheric CO_2 reduces the rate of transpiration and thus weakens the transpirational pull, which in turn slows down the flow of water from the roots upward. With less water flowing through their system, plants suck in less of the soil nutrients. Also, reduced water flow makes the soil wetter, which dilutes its nutrient content and hence a drop in the diffusion rates. Overall, the effect drastically reduces the availability of nutrients in the root zone, which can subsequently reduce the concentration of macro- and micronutrients in edible plant parts. In general, the effects of increasing temperature on these mechanisms are opposite to those of increasing CO_2. Therefore, rising temperature can also theoretically alter the contents of nitrogen, phosphorus, iron, zinc and other essential nutrients in the plants by regulating the uptake of these nutrients through influencing the nutrient transport by altered mass flow and diffusion rate in the soil. Climate change-induced alteration in soil-water content can also potentially influence the availability and uptake dynamics of essential nutrients by the plants. The possible interactions of the atmospheric CO_2 and temperature along with some other associated climatic variables are, therefore, expected to decide the nutritional qualities of food in the future world of changing climate.

Knowledge gaps on nutritional qualities of food

In recent years, several studies on the potential effects of elevated atmospheric CO_2 and temperature on crop growth and productivity have resulted into a fairly good understanding of the climate-change impacts on food security in different regions of the world. However, the impacts of changing climate on nutritional qualities of major food crops still remain an under-researched and largely an overlooked issue, despite the fact that malnutrition continues to be the most important health problem the world is facing today. Malnutrition generally results from a lack of either protein or micronutrients such as iron, zinc, iodine, vitamin-A and many other secondary compounds of nutritional value in food. For the poor populations in the developing world, meat is scarce, and plants provide the primary source of both protein and micronutrients. However, the logically possible alteration in the concentration and bioavailability of these vital nutrients under rising atmospheric CO_2 and temperature with altered soil water and soil nutrient availability is least understood.

In a meta-analysis of the available literature, Taub *et al.*[3] found considerably lower protein concentration in five major food crops of the world (wheat, rice, barley, soybean and potato), when grown under elevated atmospheric CO_2 compared with ambient CO_2. Similarly, Loladze[2] reported a substantial decline in the mean concentration of almost all the essential nutrients, including N, P, Ca, S, Mg, Fe, Zn, Mn and Cu in plant tissues. However, Idso and Idso[4], based on CO_2 enrichment studies, suggested that the ongoing rise in CO_2 content in the atmosphere will continue to increase food production around the world while maintaining the nutritive quality of the food as well, provided enough nutrients are available in the soil for plant uptake, which is unlikely in most of the tropical soils, particularly in India. Information on the effects of elevated CO_2 on some other nutritionally important elements such as iodine, chromium, selenium, etc. is still missing.

Although quite a few reports exist on the impact of singly elevated CO_2 on the protein and micronutrient contents of food crops, the interactive effects of elevated atmospheric CO_2 and temperature under a more realistic future scenario of concurrent elevation of these two climate-change components are hardly understood. The obvious reason behind the dearth of information regarding impact of rising temperature and interactive effects of elevated CO_2 and temperature on food quality is that, the majority of the work in this line has been done by researchers in the temperate countries where rising temperature is not considered as a stress on crop yield and quality, and hence their works are mainly confined to the effects of elevated CO_2 alone[5]. Paradoxically, the tropical and subtropical regions, including India, entire South Asia and Africa, where the impact of climate change is projected to be the most devastating, and nutritional deficiency is the most prevalent, have not given adequate attention towards this issue of utmost contextual importance.

A recent study[6] has revealed some discomforting facts regarding yield and nutritional qualities of wheat under the simulated future levels of atmospheric CO_2 and temperature expected to prevail in the Indo-Gangetic Plains of India by the early second half of this century. Besides a significant reduction in wheat yield (17%), a marked decline of 9–24% in protein, Zn and Fe concentrations was also observed in the study. To make matters worse, the quality of protein and bioavailability of Fe and Zn in wheat grains were drastically reduced under the combined elevation of atmospheric CO_2 (650 μmol mol^{-1}) and temperature (ambient + 3°C)[6]. The observed decline in micronutrients content and their bioavailability in food grains can potentially intensify the already existing acute problem of micronutrient malnutrition in India. Although the study was conducted in controlled-environment growth cabinets with only wheat as a single test crop, the results provide enough imperatives to examine the nutritional qualities of all the major food crops across the agro-climatic zones of India under the projected scenario of climate change in future.

Task at hand and action for the future

Understanding of the possible impacts on both food and nutritional security is required for evolving an integrated adaptation/mitigation strategy to sustain and improve the quality of human life in the face of multitude of challenges posed by climate change. However, despite the growing recognition of human malnutrition as the world's top problem (Copenhagen Consensus Conference, 2008), nothing substantial has yet been done to understand the impact of changing climate on nutritional qualities of food, which is a major determinant of the nutritional well-being of humans. Lopsided focus of the crop improvement programmes on yield attributes with continuous negligence of quality parameters has already resulted into lower concentrations of protein and micronutrients (such as Fe and Zn) in currently grown crop varieties. With the further depletion of these nutrients in major food crops under rising atmospheric CO_2 as hinted by some of the recent studies, although not comprehensive enough to offer a convincing conclusion, many impoverished areas of the world already threatened by shortages in food supply may face an additional burden of 'hidden hunger'. However, the effects of other climate-change components such as soaring temperature, increasing atmospheric concentration of ozone (O_3), reduced soil-water availability and altered availability of soil nutrients in combination with the increasing CO_2 need to be evaluated with respect to food quality in order to get a more comprehensive picture of the climate-change impacts on nutritional security on a global and regional scale. If the elevated CO_2-induced quantitative and qualitative decline in protein and micronutrient contents of food grains still continues, there would be a greater need of developing nutritionally improved crop varieties with increased protein and micronutrients levels through agronomic and molecular techniques of bio-fortification. An adequate and balanced fertilization with proper inclusion of micronutrients would be required in future crop-production practices. In view of the strong dependence on cereal-based diets, the task would be particularly challenging for India, where nutrient status (especially micronutrients) of agricultural soils is declining rapidly, whereas the country has an onus of feeding one-sixth of humanity with sufficient and nutritionally adequate food in the face of impending global climate change.

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