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Bright Farming: An Innovative Approach for Sustainable Socio Ecosystem in Climate Change Scenario

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ABSTRACT

Mitigating the effects of global climate change brought about by increasing emissions of greenhouse gases has grown to the worldwide sensed challenges. Possible strategies for lessening the ill impacts of agriculture on climate change and in parallels, optimizing overall yield potential of agricultural crops would certainly consider the initiatives for development of varieties having utmost reflectivity with least/no impact on photosynthetic yield. Crops having traits for maximum reflectivity such as specific plant height, leaf inclination, chlorophyll content, waxy leaf hairs, glossiness and/or canopy structural and morphological traits would be comprised in an ideotype. Genetic manipulation of crop reflectivity and/or selection for specific morphology of canopy might be possible using plant breeding however transgenesis for leaf waxy ness or canopy structure could achieve greater temperature reductions and may offer a viable solution to problem.

Key words: Climate change, Albedo, Crop canopy, Genetic modifications.

INTRODUCTION

Climate signals observed over India in the last 100 years show an increasing trend in surface temperature by 0.3°C, a change in the spatial and temporal pattern of rainfall with respect to normal and occurrence of more intense and frequent extreme temperatures. Climate change has been attributed to alteration in the composition of the global atmosphere due to the growing greenhouse gas emissions on account of the growing human activities and this is in addition to natural climate variability observed over comparable time periods. The rising concentrations of greenhouse gases (GHGs) of anthropogenic origin in the atmosphere such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) have increased, since the late 19th century. The Intergovernmental Panel on Climate Change (IPCC) projects that the global climate may warm by 1.4 to 5.8°C and precipitation may increase up to 7 per cent, and global sea level will rise from 0.09 to 0.88 m by the year 2100[1]. The impact would be particularly severe in the tropical areas, which mainly consist of developing countries, including India.

A certain part of energy, received from the sun, is reflected back to the space by the earth. The reflection coefficient of a natural surface is often termed as albedo and is defined as the ratio of reflected shortwave radiation to the incidence shortwave radiation on a surface and expressed in percentage. The albedo of crop surfaces is ranging between 23 and 30 %. The albedo of earth and atmosphere is 31 %. Growing agricultural crops having desirably higher albedo could bring down the atmospheric temperature as they reflect more sunlight back into the space than natural vegetation. Cultivation of crop varieties having higher albedo traits namely specific plant height, leaf inclination, chlorophyll content, leaf glossiness and/or canopy structural and morphological traits needs to be prioritized and popularized in near future farming practices as “Bright Farming”. Sustainable development has environmental, economic and social dimensions. The likelihood of irreversibility in the consequences of the interactions among climate, ecological and socio-economic systems are major reasons why anticipatory adaptation and mitigation actions are indispensable.

Causes of Concern

India is vulnerable country to climate change. These unprecedented changes in tropical climate are expected to present several adverse implications for agriculture, health, natural ecosystems, freshwater supply and related processes. Agriculture in India contributes 24% of GDP and provides employment to 1.3 million people. At present the occurrence of extreme climate events have caused serious impact in many sectors of agriculture. Crop production is extremely susceptible to climate change. It has been estimated that climate changes are likely to reduce yields and/or damage crops in the 21st century (IPCC, 2007). The climatic changes associated with increasing CO_2 have the potential to affect plant metabolism, growth and yield. Visible leaf injuries including chlrorosis, necrosis and curling of leaves are sometimes observed in connection with CO_2 enrichment[2]. The injurious effects of high CO_2 concentrations may be on account of high leaf temperature and shortened nutrient uptake that is affected by reduced transpiration. Under high light level, excessive accumulation of starch results into chlorophyll break down. The immediate and marked response of plants to elevated CO_2 owes to the biochemical property of Ribulose-1, 5-bisphosphate carboxylase/oxigenase, the primary caboxylase enzyme in C_3 plants. Stomatal conductance and transpiration rates are less in plants exposed to elevated CO_2 and hence affecting leaf metabolism. Under climate change condition, high temperature and water availability are the limiting factors. The inter relationship of elevated CO_2, high temperature, and availability of water Climate change affects the microbial population of the macro-environment (soil, air and water) and the population of pests or other vectors. It is therefore a contributing factor to the occurrence and gravity of biotic stresses attributable to (micro) organisms such as fungi, bacteria, viruses and insects. Abiotic factors such as nutrient deficiencies, air pollutants and temperature/moisture extremes also affect plant health and productivity. While the impact of biotic and abiotic factors on crop production and food security are more obvious, it is important to note that these factors may also have significant impact on the quality attributes of food crops. Of further concern is the impact of climate change on the prevalence of environmental contaminants and chemical residues in the food chain.

Mitigation approaches to climate change: A state of art

The worldwide social and environmental disruptions arising out of climate change necessitate the immediate policy interventions by every country to implement appropriate approaches for mitigation measures. These approaches may be broadly classified as non- agriculture and agriculture.

A number of strategies have been proposed under non- agriculture class to deal with climate change. The most obvious way in which CO_2 emissions can be reduced is by switching from burning fossil fuels to using non-fossil-fuel sources of energy such as nuclear energy, wave and wind power, and geothermal sources. CO_2 could be removed from the atmosphere by carbon sequestration in ocean. The construction of millions of artificial “trees” that extract CO_2 from the ambient air by chemical scrubbing have also been proposed[3,4]. Solar insolation reaching the Earth’s surface might be reduced by the injection of sulfate aerosols into the atmosphere[5,6] or by the construction of a space-based “sunshade”[7, 8]. India, being a developing country, the ethical considerations as well as heavy public investment required for the creation and implementation of infrastructure pose substantial barriers.

Among the agriculture approaches, four biological approaches encompass (i) reducing atmospheric CO_2 concentrations through soil carbon sequestration, (ii) afforestation, (iii) fertilizing the oceans to increase primary productivity and (iv) reducing increases in surface temperatures through increasing the albedo of crop plants. The arable crops are primarily grown for food, feed and fodder and the annual replanting of varieties with specifically desired modifications is needed in order to retain continued climatic benefits. Bright farming has the advantage in that the infrastructure required to create and propagate specific physiological leaf and canopy traits is already in place. India is a mega-biodiversity country with forests account for about 20% (64 million ha) of the geographical area and agricultural lands (lands used for agricultural production, consisting of cropland, managed grassland and permanent crops including agro-forestry and bio-energy crops) occupy about 40-50% of land surface. Recent studies imply that changes in land usage are reflected in the spatial distribution of the surface albedo pattern, obviously resulting in changes in the surface radiation balance[9]. In India, land use pattern has affected the per capita availability of land for agriculture. It has drastically reduced from 0.22 hectare in 1950 to 0.10 hectare in 2000 and projected to be 0.06 hectare in 2050.The total forest cover record was 131 million hectare in 1851, which has further declined from 71.8 million hectare in 1951, and 63.9 million hectares in 1991, to around 67.6 million hectares in 2001, which depicts a consistently declining trend in India's forest cover till now. Overall the forest cover has been decimated from nearly 40% of India's geographical area a century ago to 22% in 1951 and to 21% in 2001.

Historical land-use change, involving a change from natural vegetation with a relatively low albedo to crop vegetation with generally higher albedo[10], has suppressed surface temperatures[11,12], partially offsetting the warming due to present-day elevated atmospheric CO_2 concentrations.

Characterization of albedo variety

Higher albedo traits comprise of specific plant height, leaf inclination, chlorophyll content, the presence or absence of leaf hairs, leaf glossiness and/or canopy structural and morphological traits. For crop growing to height of 50 to 100cm albedo is usually between 0.18 and 0.25 when ground cover is complete but values as small as 0.10 have been recorded for forests. In general, maximum values of albedo (0.25) are recorded over relatively smooth surface. The fraction of radiation transmitted and reflected by a leaf depends on the angle of incidence. Chlorophyll exceeds about 4mg/cm^2 of leaf surface for greater absorption of radiation. Waxy versus non-waxy varieties of barley can exhibit albedo differences of up to 0.16 (with respect to photosynthetically active radiation wavelengths). Canopy albedo depends on morphology of canopy (leaf albedo, orientation, structure etc). Because significant variability already exists, both among different varieties of the same crop plant[13–15] and between species[11], Different varieties of maize have been observed to differ by up to 0.08.

Approaches - biotechnology, breeding

Future selective breeding and genetic modification, in their complementarities, would offer the potential for a degree of climatic mitigation through bright farming. It will of course be important to establish that new crop strains with increased albedo will at least maintain and ideally improve on yields of existing varieties. Accordingly, it will be essential to ensure that increased albedo does not impact negatively on yield, water relations or the ability to resist pathogen attack. The manipulation of crop albedo might be possible using conventional plant breeding. Albedo can vary significantly between varieties of the same crop species, for instance because of differences in canopy morphology[16] and leaf-surface properties[13, 14]. Careful selection of the plant variety grown can, by itself, thus provide a degree of mitigation of future warming. As solar elevation is important in determining the net albedo of the canopy, the specific crop variety could be deliberately selected according to the latitude in which it is grown. For optimizing plant albedo, selection for specific canopy properties is one possible avenue.

In Arabidopsis, 24 loci are known to affect 'glossiness'[16,17] and many of these have been cloned. There are also 'glossy' mutants available in maize and barley; for example, there are 1,560 eceriferum (cer) mutants in barley representing some 85 complementation groups[18]. These resources raise the prospect of using genetic modification (GM) procedures to increase leaf surface albedo. With the growing understanding of cuticular wax biosynthesis pathway[19,20], there are opportunities for using GM approaches to increase canopy albedo. Such genetic modifications could be designed to be wavelength specific and weighted toward wavelengths lying outside of the photosynthetically active radiation region (i.e., <400 nm and >700 nm). Reported results reveal that glaucous varieties of wheat and barley are grown under water-limited conditions exhibit increased grain yields as compared to their non-glaucous counterparts[21]**.** Temperature reductions could be achieved by genetic modification of plants for high albedo. Choosing the more reflective crop varieties would not disrupt global food production. Thus use of GE plants and selected conventional breeding methods can play important roles in future agricultural sustainability[22].

Importance for society:
A sustainable eco-system

The potential inequity of climate impacts has important implications for social justice and geopolitics. Indian farmers in general and farmers of semi arid region in particular are vulnerable to climate change and need affordable solutions. Since farming is one of the contributors to the problem of climate change, it must play a remedial role. Properly designed climate change responses in crop varieties can be part and parcel of sustainable development and prevent or avoid damages to human systems and, thereby, contribute to the healthy socio-ecological balance.

The above observations imply that a concept of bright farming, based on increasing crop albedo, has some potential to help mitigate climate change on a regional basis. This concept rests purely on modeling[23] study and requires to gather data at field level to assess the real potential of the concept, prior to large scale implementation and adoption of bright farming.

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