Mitigation Technologies to Lower Greenhouse Gases

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Abstract - Increasing concentration of green house gases in the atmosphere has already resulted in chaotic weather systems that will have major effects on the coastal ecosystem, and drought and salinity will escalate. Of all the green house gases, the major culprits being CO_2 and methane. To bring down the CO_2 levels in the atmosphere, spreading of green cover seems to be one of the biological remedies to mitigate the threatening effects of global warming. Photosynthetically four kinds of plants can be recognized such as C3, C4, CAM and C3-C4 intermediates plants, of which C4 is an efficient fixer of atmospheric CO_2. In addition, attempts are being made to introduce C4 genes into C3 plants (C3 plants harboring photosynthetic genes such as Phospho-enolpyruvate carboxylase (PEPCase) and pyruvate orthophosphate dikinase (PPdK)) to make them more adoptable to drought, salinity and high temperature the major environmental effects of global warming. Exploitation of the coastal regions for cultivation of many types of seaweeds as vegetables for human consumption, Phytoplankton enrichment both in saline waters of oceanic environment and fresh water will lead to further CO_2 depletion in the atmosphere. CAM plants in particular to some extent can take care of respired out CO_2 at night.

Keywords - Light dependent CO_2 absorption, C4 photosynthetic genes, green cover escalation, transgenic plants, drought and salinity, high temperature tolerance.

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1 Introduction:

Global warming is the most sensitive and alarming issue in the present day environment causing acrimonious debate among the countries. The global warming is defined as an increase in the average temperature of the near-surface air and oceans. The raising of earth's temperature is governed by various components such as CO_2, O_3, CH_4, N_2O, CFCs and water vapour that absorb radiative gases and thus increase atmospheric temperatures. The increase in atmospheric green-house gases are due to anthropogenic activities. The large scale emission of methane in the atmosphere is from natural wetlands, rice practice and livestock Biomass burning, natural gas production, termite landfills and coal mining also release methane. Rice-waste cropping system is considered as the major green house gas emitter [1],[2],[3]. Because of over exploitation of fossil fuel and the natural resources, it has become more difficult than ever before to maintain global energy balances between the atmosphere and the earth's surface. For hundreds of thousands of years, the level of CO_2 in the earth's atmosphere generally ranged from 200-300 ppm by volume. Fluctuations observed have been the result of ice age cycles. The industrial revolution, which was energized by carbon waste fuels, has caused and continues to cause a dramatic raise in atmospheric CO_2. The largest natural areas that remain on earth

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are oceans and forests, both of which act as carbon sinks. But these sinks are over-loaded. Deforestation has diminished the ability of land-based plants to reduce CO_2. The oceans have become more acidic due to absorption of CO_2 emitted by fossil fuels for more than a century.

The concentration of CO_2 in the atmosphere is constantly increasing due to anthropogenic emissions by about 1ppm per year [4]. Presently, the CO2 is around more than 30% higher than before the industrial revolution [5]. The need for a proactive approach to sustaining our environment through better framework is more felt than ever.

2 INFLUENCES OF GLOBAL WARMING ON THE ENVIRONMENT AND BEHAVIOR OF FLORA AND FAUNA

It is opined by environmentalists that as a result of global warming there is a continual increase in temperature, sea level, decreased availability of water from precipitation and run-off, wind patterns and storms. The effects of many of the environmental factors are still being studied. However, temperature influences biology of organisms (morphology, reproduction, growth and behaviour), affect dissolved oxygen in water (pO_2) and plays a direct role in sea-level raise. These changes are bound to affect flora and fauna. Storms and their associated winds can have major negative effects on coastal eco-systems and shoreline structures. For instance, the best known effect of global warming is on reefs in coral bleaching which is a breakdown in the symbiotic relationship between the coral animal and the unicellular alga that lives within coral tissues. The alga called Zooxanthallae produces carbohydrates and other photosynthetic products that the coral can use, and the alga is sustained by the coral's waste products that serve as nutrients- a recycling of this symbiotic process enhances the productivity of both the organisms. This relationship is weakened by the increase in global warming [6], [7].

In addition, global warming also seriously affects arable land by way of increasing salinity by sea water inundation, and also escalates the area of desertification. Therefore, there is an impending necessity than ever before to generate transgenic plants to cope–up with the fast deteriorating environmental conditions for agricultural cropping or screen the germplasm resistant to abiotic stresses.

2.1 Major impacts of Global warming on agriculture and food security

Most importantly the effect of global warming will seriously hamper crop productivity in general and rice cultivation in particular [8]. Salinity on arable land will increase by seawater inundation and thus causing the spread of salinity. Irregular monsoonic periods and raise in temperature will lead to further escalation of drought-prone lands. Therefore, there is a need to genetically engineer plants or screen the germplasm of elite staple food crops for drought as well as salinity. Hence there is a priority of research to acclimatize the food crops to the swiftly changing environmental conditions and also to step up productivity to satiate the hunger of the burgeoning populations.

3 STRATEGIES TO LOWER THE GREEN HOUSE GASES

Although there are several ways of mitigating green house gases, the biological tool appears to be more economical and viable and very simple to administer in the natural environmental conditions.

Photosynthetically there are four kinds of plants and they are as follows: 1.C3, 2. C4, 3.C3-C4 (intermediates) and 4. CAM (Crassulacean acid metabolism) plants. Majority of crop plants belong to the C3 type wherein the atmospheric light dependent CO_2 absorption is by the universal carbon fixing enzyme RuBISCO (Ribulose 1,5-bisphosphate Carboxylase /oxygenase- E.C.4.1.1.39). This enzyme is considered to be less efficient as it can bifunctionally couple with either CO_2 or O_2 under increasing concentrations of O_2 in the atmosphere. On the other hand, the C4 plants which are mostly Monocots such as sugarcane, maize, sorghum and millets that are efficient fixers of atmosphere CO_2.

These C4 plants harvest CO_2 from the atmosphere by the enzyme PEP Carboxylase which is devoid of O_2 sensitivity and therefore, there is no loss of fixed carbon photosynthetically, a process called photorespiration (light dependent efflux of CO_2) which is predominant present in C3 plants. The list of C4 genes is given in Table 1. Therefore, currently the environmental and agricultural scientists are seriously involved in moving the C4 genes into the C3 plants through genetic engineering.

Table 1. List of C4 genes

C4 genes	**Location**	**Functions**
PEPC	Leaves	Carbon fixation- high affinity for CO2- no oxygenase activity
NADP-ME	Stomatal guard cells	Formation of malic acid during stomatal opening
	Seeds	Provision of reducing equivalents and carbon skeletons for fatty acid biosynthesis
	leaves	Provision of reducing equivalents, stress responses.
NAD-ME	Leaves	Together with PEPC involved in anaplerotic provision of carbon skeletons for amino acid biosynthesis.
NADP-MDH	Leaves	Reduction of OAA in the chloroplast, shuttling excessive redox to malate.
PEPCK	Non green tissues	Gluconeogenetic PEP reduction from OAA
	Stomatal guard cells	PEP regeneration from pyruvate

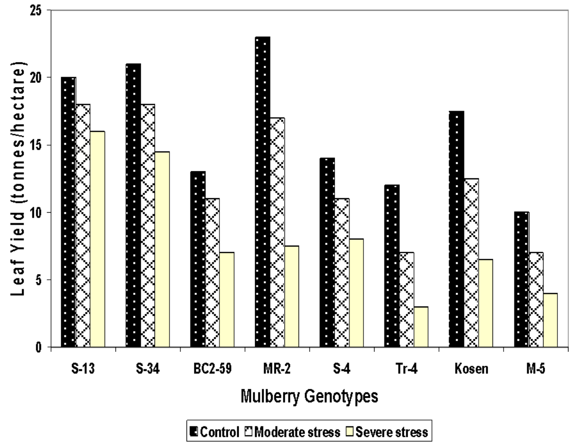
Such a C3 transgenic plant will be a predominant absorber of atmospheric CO_2. In support of this Vivekanandan and Saralabai (1997) [9] pointed out the importance of transgenic plants in improvement of crop productivity by way of increased atmospheric CO_2 fixation and assimilation of nitrogen. Reddy at al., (2004) [10] stressed the need to improve carbon assimilation in plants through increased anti-oxidative systems (ROS Scavenging). Therefore, it is evident that under stress conditions if CO_2 is to be absorbed photosynthetically the anti-oxidative system (SOD, catalase, reductase) should be enhanced in vivo which will pave way for plants to adopt to drought stress through synthesis of LEA and dehydrins stress proteins.

On the other hand, if transfer of genes becomes difficult, in plants like Mulberry which are not easily amenable to tissue culture as well, the vast repertory of germplasm can be screened for drought and salinity tolerance [11][Table 2].

Table 2. Leaf yield in terms of biomass production in Mulberry genotypes in coastal saline soils (EC=3.65mS/cm) of Vedaranyam, Tamilnadu,India.

S.No.	Mulberry Genotypes	Leaf Yield (tonnes/acre)
1	M-5	1.28
2	MR-2	1.37
3	C-1	4.67
4	BC2-59	7.25
5	Tr-8	3.93
6	Tr-10	1.94
7	S-13	2.19
8	S-30	5.02
9	S-36	4.17
10	S-41	4.28
11	G-5	1.28
12	ACC-235	1.91

Dorcus and Vivekanandan (1994) [11] (Fig.1) identified S13 as a major germplasm to withstand drought by maintaining higher leaf yield through unperturbed atmospheric photosynthetic CO_2 fixation as measured by IRGA. Similarly, Augustian Dorcus and Vivekanandan (1995)[12] pointed out from their field studies in coastal saline soil that a mulberry genotype called BC2-59 as the most saline tolerant plant under high salinity conditions. They



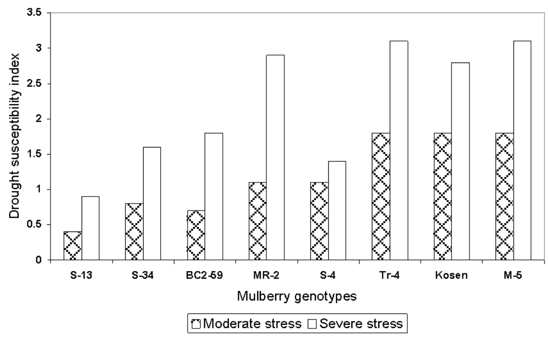


Fig. 1.a) Leaf yield per hectare and b) Drought susceptibility index in 2-year old mulberry genotypes under irrigated, moderate and severe water stress conditions during dry season.

also made a mention that among the 12 mulberry genotypes tested BC2-59and S-36 possessed higher rate of CO2 fixation[Fig.2]. Hence in cash crops such as mulberry, genotype with high photosynthetic CO_2 fixation may be planted in a large scale to diminish the atmospheric CO_2 under tropical climatic conditions. Bamboo is an important and integral part of many natural and agricultural eco-systems. It provides food and raw materials (provisioning services) for consumers in developing and developed countries. It regulates water flows and reduces water erosion on slopes and along riverbanks, and can also be used to treat wastewater besides acting as windbreak in shelterbelts, offering protection against storms (regulating services). As poor people will be

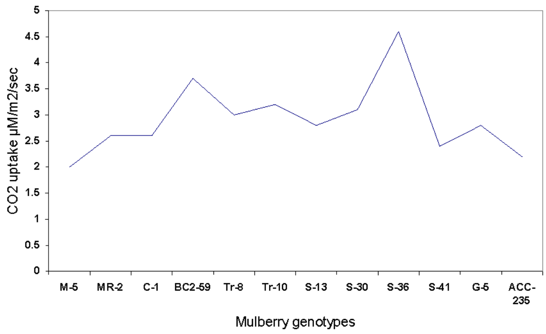


Fig. 2. Photosynthetic potential of two-year old mulberry genotypes (Light = 9.99 watts/sec; Mean temperature = 39.3°)

worse hit by the effects of climate change, action plans for adaptation need to be tailored to the environmental conditions (UNFCCC, 2007). The light-weight and versatility of harvested bamboo also lends itself to innovations to cope with increased floods, such as raised housing in Ecuador and Peru and floating gardens in Bangladesh [13]. Therefore, bamboo forests are important in social forestry and are not at risk from deforestation to the same extent as the tropical forests are. Bamboo has higher rate of CO2 absorption from the atmosphere compared with other fast growing trees in sub-tropical and tropical regions. Similarly, mangrove afforestation as a forte against tsunami coupled with reduced deforestation may be considered as a tool for mitigating global climate change. Increasing the level of carbon sequestration- the process in which plant communities capture carbon dioxide through photosynthesis and transform the gas into solid biomass- is one of the viable options for reducing the total amount of carbon dioxide in the atmosphere and thus mitigating future dangerous climate change-related scenarios.

In consonance with this, the microscopic marine organisms called Coccolithophores are one of nature's most prolific consumers of atmospheric carbon dioxide. Coccolithophores are phytoplanktons that live in the upper layers of the world's ocean. Many phytoplanktons absorb more CO_2 than they produce and therefore, they act as efficient carbon sink. The microalgae such as Chlorella and several other diatoms are being used in recent times for biodiesel production [14]. Hence they have been cultivated on a large scale in the oceanic environment along the shores and incidentally such luxuriant growth of microalgae (phytoplanktons) will lead to more absorption of CO_2 from the atmosphere through photosynthesis. In fact, phytoplanktons are responsible for about half of the photosynthesis on earth.

It is more pertinent to mention at this juncture that photosynthetically there are peculiar plants which have the special mechanism of CO_2 sequestration by an unique pathway called CAM (Crassulacean acid metabolism), by which these plants fix atmospheric carbondioxide only at night leading to extreme acidity of the cell sap in the morning. Further, the plants have unique adoptability mechanism to grow and complete its life cycle in water-stressed regimen coupled with high temperature.

Already the uniqueness of the plants has drawn attention of millions of people all over the world and it is no wonder that they are cultivated as ornamentals, although desertified area is their natural aboard. If propagated on a large scale, these plants will take charge of huge quantum of nocturnal CO_2 efflux by the land and marine plants to some extent

India is a large developing country with diverse forest ecosystems and therefore, India is called megabiodiversity country. India has formulated and implemented a number of policies and programs aimed at escalation of forest cover and biodiversity conservation. Both afforestation and reforestation is implemented side by side [15]. India

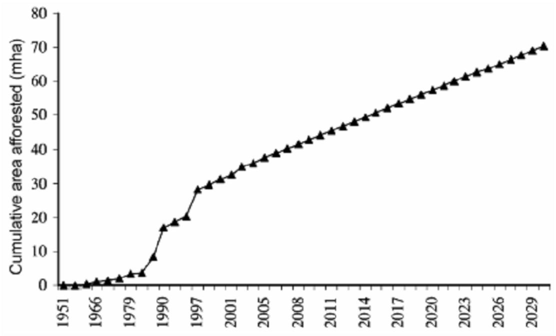


Fig. 3. Project afforestation scenario over the years

has a goal to bring one third of the geographic area under the forest and tree cover. All the forest policies and programs have tremendous implications for carbon sink and forest management**.** The national communication of the Government of India to the UNFCCC already reported that the forest sector is only a marginal source of CO_2 emission. The prime minister of India announced in 2008, of 6 Mha greening program. The atmospheric CO_2 levels will be brought down assuming that there is no further deforestation but only afforestation and reforestation programs to continue. In a similar way, the river bank of Cauvery and the adjoining lands have already been greened up by the forest department of Tamilnadu, India by planting fast growing tree species such as Eucalyptus, Casuarina and Teak. Such newly created forest covers in various parts of Tamilnadu, India will lead to more fixation of CO2 from the atmosphere.

To overcome the increase in temperature, salinity and water stress as a consequence of global warming, work has already been initiated to raise saline tolerant plants. These plants with newer set of genes have already been created and are in open field trials. Wherever there is vast germplasm, investigators have started screening the plants for temperature tolerance under continues CO_2 enrichment [16], [17] and salinity [18].

4 CONCLUSION

The ongoing global deforestation coupled with unmitigated efflux of CO_2 from the industries, leading to high intensity of global warming resulting in catastrophic events such as unpredictable climatic changes, increasing temperature, fast escalation of salinity and drought over arable lands and have drawn the attention of scientists all over the world.

Our own work coupled with the work of others [1],[3],[9-13] point out to the fact that the efflux of CO_2 into the atmosphere can be checked by plantation program creating more social forests coupling with reduced deforestation as well as by increasing the intensity of microalgae called phytoplanktons that are efficient absorbers of atmospheric CO_2. Incidentally they also form a good source of biodiesel production.

Therefore, priority is given for mass cultivation of these algae. The major sinks for CO_2 sequestering are the land plants and the phytoplanktons which are efficient absorbers of atmospheric CO_2. To take care of the efflux of CO_2 at night as a boon from the nature, we have a special category of plants studded with an unique metabolism called CAM that has the ability of absorbing CO_2 only at night [Carbon cycle in Fig.4].

Therefore, to surmise, it is more appropriate that the ever increasing of CO_2 in the atmosphere can be taken care of through phytoremediation by way of escalation of the green cover over the wastelands, denuded forest soil and deserted areas. It is pertinent to mention at this juncture that already research is afoot in moving photosynthetically efficient genes (C4 enzymes) into C3 plants (recipients) through transgenic technology in transforming C3 plants as efficient fixers of atmospheric CO_2.

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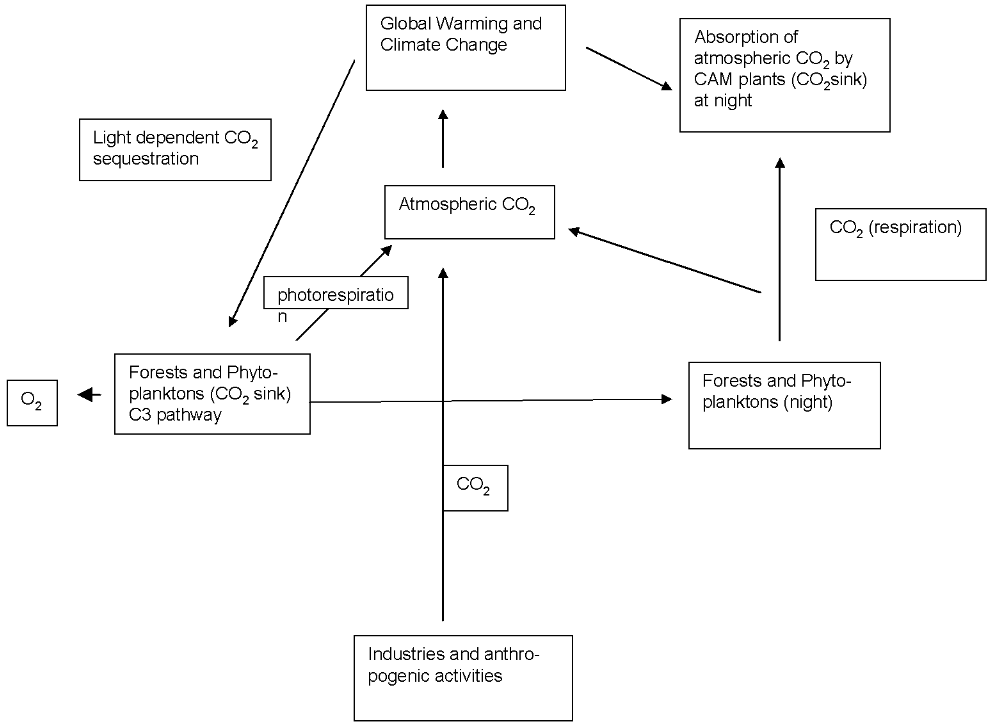

Fig. 4. Carbon cycle in C3 plants in the present day global warming.