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CLIMATE SMART HORTICULTURE: CONVERTING WASTE TO WEALTH

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Abstract: Horticulture is considered to be "climate smart" when it contribute to increasing food and nutritional security, adaptation (adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts) and mitigation (the effort to reduce loss of life and property by lessening the impact of disasters) in a sustainable (Capable of being continued with minimal long-term effect on the environment) way. With a predicted 9 billion people by 2050, agricultural production will need to increase by 70 per cent to meet new demands for food, feed, fuel and fibre. As agriculture accounts for up to 30 per cent of global greenhouse gas emissions, it's crucial that Climate Smart Agriculture is developed to achieve future food security and climate change goals. The problem is that agricultural systems which perform poorly also require little energy, while the productive ones require more. There is a need to develop an approach to look at agricultural production and energy costs. Ensuring food and nutritional security under a changing climate is one of the major challenges of our era. Climate Smart Horticulture (CSH) has a great role to play at this defining moment because it addresses the food and nutritional security along with climate change problems together, rather than in isolation. CSH is the only sector that offers the triple win of increased productivity, reduced emissions and enhanced resilience to climate change.
Keywords: adaptation, mitigation, sustainable, climate smart horticulture.

Introduction

CSH is Horticulture that is resilient and adapted to climate change; helps reduce emissions and sequester carbon; reduces pressure on forests; maintains ecosystem services and biodiversity; and produces food, fibre and fuel crops that the world needs for maintaining food and nutritional security. With a horticultural crop production of approximately 269 million MT in 2012-13 (NHB Database, 2013), it has surpassed food grain production which approximately 259 million MT in the same year. National Horticulture Mission (NHM) promoted by Department of Agriculture and Cooperation (DAC), Ministry of Agriculture, Govt. of India, which covers 380 districts (60%) in 18 states and 3 union territories out of 640

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in total (Census, 2011) with a mission for improving farm income and livelihood security and enhancing employment generation. Widely cultivated for the high value of their products, horticultural crops include fruits and vegetables which provide essential food, minerals and vitamins that are critical to human nutrition (Kwack, 2007). The production of horticultural crops can be characterized as an open and highly complex system affected by climate, soil, cropping system and interactions between these factors (Lentz, 1998). The production, processing and marketing of horticultural produce are central to food security and economic growth. The overall efficiency, resilience, adaptive capacity and mitigation potential of the production system can be enhanced through improving its various components such as soil and nutrient management, water harvesting, pest and disease control, resilient ecosystem, genetic resources and harvesting, processing and supply chain managements (FAO, 2010). Horticultural crops leaves behind a huge amount of biomass in form of green and dried leaves root and shoot stalk, pseudo stem (banana) in the field itself after harvesting which is potential source of fuel as well as farmyard manure and vermicompost. Post harvest loss in fruits and vegetables amounts to about 20-40% depending upon crops due to lack of proper cold storage and cold chain management. Post harvest processing of many fruits and vegetables which is though very less (only 6-8% in India) generate huge amount of solid waste in form of peel and stone, can be utilized and value added product can be made from it to generate revenue.

Environmental physiology

Environmental physiology is also important to study both the effect of different environmental stresses (shading, heavy metals, drought and salinity, among others) on growth and development and the way plants compensate the detrimental effects of stress through different mechanisms (stress response, acclimation and adaptation) It can be said that knowledge about the interactions between environmental factors and plant physiology facilitates the identification of environmental changes such as lack of light, high temperatures or water deficit (Restrepo-Díaz, 2010). For example, the shading of horticultural crops can reduce photosynthesis rate, transpiration and stomatal density and conductance; and enhance flower abortion. Likewise, high temperatures can affect pollen viability and germination, number of flowers and number of fruits per plant. Finally, ecophysiological information is a tool that can be used in breeding programs to obtain improved cultivars, as well as in strategies of agricultural zoning, thus enhancing productivity.

Vermitechnology and climatic adaptation

Horticultural crop residue generates waste of biodegradable nature. Waste, though considered wastes are not mere waste. They are the misplaced resources which can be efficiently utilized with simple technology such as vermitechnology. The waste management technique consists of three R viz. Reduce, Reuse and Recycle in the order of their desirability. Vermitechnology- is an eco-biological tool for management of waste. It is a method of converting waste into compost by use of earthworms (*Eudrilus eugeniae*). Vermicomposting among other alternatives has been considered as way to transform wastes into useful component for plant and soil diminishing the negative environmental input. Organic manure containing essential amino acids increase the chlorophyll content of leaf which in turn enhances metabolite synthesis resulting in crop productivity (Dash and Senapati, 1985). Horticultural crop residues require minimum of two to three weeks for earthworms to accept them as substrate and feed. Earthworms consume biomass and excrete it in digested form called worm casts. Worm casts are popularly called as Black gold. The casts are rich in nutrients, growth promoting substances, beneficial soil micro flora and having properties of inhibiting pathogenic microbes. Vermicompost is a peat like material with excellent structure, porosity, aeration, drainage and moisture holding capacity. Humic acid is a very important constituent of vermicompost. Many of its important properties are slow release of plant nutrients improvement of soil physical properties enhancement of micronutrient of plants through chelation, reactions etc. Vermicompost is becoming popular as a major component of organic farming system in raising seedlings and for crop production. In the other words, the useless waste should be transformed into a value - added products that can initiate income generating enterprise thus called “Turning filth to Wealth”.

Fruits and Vegetable waste utilization- for Bioenergy

Fruits and Vegetable wastes occur throughout the supply chain and vary widely depending on its processing. Globally, more than 30 % of the loss occurs at the retail and consumer levels, of which the post-harvest and processing level wastages account for the major share. The wastes so generated pose an environmental threat and call for the development of a pollution-free model. India, with rich agricultural resources, accounts for 50 million MT of vegetable waste, which is about 30 % of its total production (Verma et al. 2011). Hence, utilization of these wastes generated at different levels of delivery starting from the agricultural farm, post-harvest handling, storage, processing, and from distribution to consumption would be economically highly beneficial. Such wastes can either be used directly as an untreated material for microbial growth or be used by appropriate treatment with enzymes for bioenergy production. Fruits and Vegetable waste is a biodegradable material generated in large quantities, much of which is dumped on land to rot in the open, which not only emits a foul odor, but also creates a big nuisance by attracting birds, rats, and pigs—vectors of various diseases. Apart from post-harvest losses due to lack of storage capacity, processing and packaging of fruits and vegetables according to customers' specifications also plays a major role in waste generation. Fruits and Vegetable wastes include the rotten, peels, shells, and scraped portions of fruits and vegetables or slurries. These wastes can be treated for biofuel production through fermentation under controlled conditions. Characterization of waste can be done physically, chemically, or biologically. Physical characterization of solid wastes include estimation of weight, volume, moisture, ash, total solid, volatile solid (VS), color, odor, temperature, etc., while dissolved and suspended solids and turbidity are estimated for liquid wastes. Chemical studies include the measurement of cellulose, hemicellulose, starch, reducing sugars, protein, total organic carbon, phosphorus, nitrogen, BOD, COD, pH, toxic metals, etc. Besides these biochemical parameters, carbon, phosphorous, potassium, sulphur, calcium, magnesium, etc. can also be tested. All these chemical and biochemical parameters provide an insight on the applicability of waste for employment in specific energy production. Biologic characterization indicates the presence of pathogens and organisms which are indicators of pollution. Joshi *et al*. (1999) reported that wastes from vegetables industries including carrot, peas, and tomatoes have a high BOD and are a rich source of several nutrients like vitamins, minerals, fibers, etc.

Biogas or biomethane:

Biomethane, obtained during anaerobic digestion by the microbial community, is a cheap form of renewable energy that is environmentally friendly. Normally, biogas is composed of 45–70 % methane, 30–45 % carbon dioxide, 0.5–1.0 % hydrogen sulfide, 1–5 % water vapor, and a small amount of other gases (hydrogen, ammonia, nitrogen etc.). Biogas formation in anaerobic digestion involves four different steps, including hydrolysis, acidogenesis, acetogenesis, and methanogenesis which is accomplished by a series of microbial interactions. In hydrolysis, complex carbohydrates, fats, and proteins are first hydrolyzed to their monomeric forms by exoenzymes and bacterial cellulosome. In the second phase (acidogenesis), monomers are further degraded into short-chain acids such as: acetic acid, propionic acid, butyric acid, isobutyric acid, valeric acid, isovaleric acid, caprionic acid alcohols, hydrogen, and carbon dioxide. During acetogenesis, these short-chain acids are converted into acetate, hydrogen, and carbon dioxide. In the last phase, methanogens convert the intermediates produced into methane and carbon dioxide. Almost one-third of methane formation is due to reduction of carbon dioxide by hydrogen. Anaerobic digestion depends on several different parameters for an optimum performance. Different groups of microorganisms are involved in the methane production, and suitable conditions have to be established to keep all the microorganisms in balance. Some of these parameters are: pH (6.7-7.5), temperature, mixing, substrate, C/N ratio, and hydraulic retention time (HRT). Digestion is a slow process and it takes at a minimum of three weeks for the microorganisms to adapt to a new condition when there is a change in substrate or temperature.

Bioethanol

The wastes from fruit and vegetable processing industries being rich in polysaccharides (cellulose, hemi-cellulose and lignin) can be subjected to solid state fermentation for the production of ethanol and butanol, which has several uses (Laufenberg et al., 2003) such as a solvent in many industries and also as a liquid fuel supplement. Vegetable waste to biofuel production consists of biomass pretreatment, saccharification, and fermentation. The general process for bioethanol production from fruits and vegetable wastes has been given in Fig. 1. The potential microorganisms for ethanol fermentation is *Saccharomyces cerevisiae*. Fruits and Vegetables wastes represent one of the important biomass sources that have a potential to be converted into ethanol. Examples of these wastes for biofuel production include potato peel wastes, apple pomace, orangepeel, carrot residues, etc. Conversion of these wastes into biofuel not only produces value-added products, but also reduces the disposal costs of these wastes.

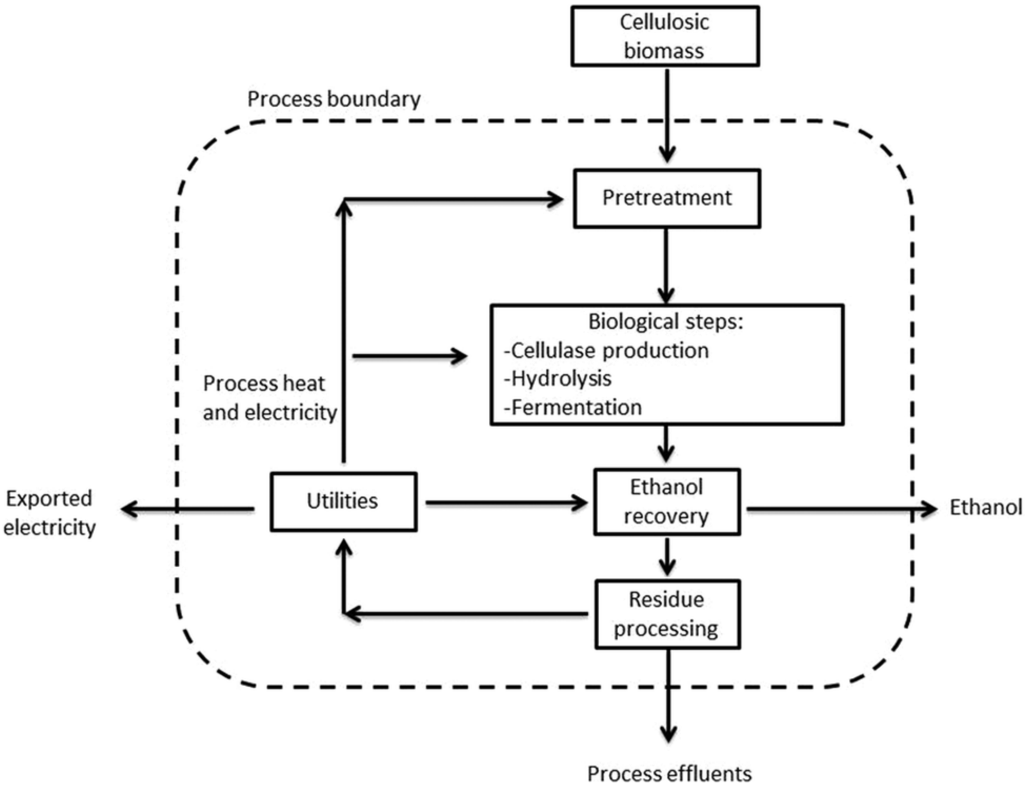

Fig. 1. Flow diagram for bioethanol production from fruits and vegetable wastes

Table 1. Bioethanol production from several types of food wastes

Substrates	Micro-organisms	Incubation time (h)	Ethanol yield (g/L)
Potato peel	S. cerevisiae	24–48	7–20
Apple pomace, waste apples	S. cerevisiae	72–96	8.44–77.32
Banana peel, banana waste	S. cerevisiae	96–120	16.96–56.02
Beet waste, beet pomace	S. cerevisiae	96	14.99–116
Kitchen garbage, kitchen waste	S. cerevisiae	24–67.6	30–33.05
Pineapple waste	S. cerevisiae	72	2.54–68.64
Soybean litter, soybean molasses	S. cerevisiae	24–40	1.16–63.5

(**Source:** Singh et al. 2012)

Conclusion

An integrated approach is fundamental for achieving the multiple objective of climate smart horticulture namely adaptation and mitigation goal along with improvement in horticultural crop productivity, economic development and livelihood through converting waste to wealth. Nutrition and biodiversity converge to a common path leading to food security and sustainable development. An old Chinese proverb says Waste is “something we have not yet learnt to use. Thus efficient use of horticultural waste at each stage of crop production, harvesting, Post harvest handling including storage, transportation along with processing and thus “Turning Filth to Wealth” would be a true approach to climate smart horticulture.

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