**Health Fostering Phytochemicals in Horticultural Crops**

**Prananath Barman, Arindam Roy, Nabin Kumar Das and Arup Mandal**

**ICAR-Central Institute for Subtropical Horticulture Regional Research Staion, Malda – 732 103, W.B**

Diet-related chronic non-communicable diseases put a severe burden on health services and are already the leading cause of death and disability in several countries of the South-East Asian Region. With increasing life expectancy, urbanization, and changing lifestyles, this alarming situation is bound to become even more severe in the years to come. These factors underscore the need for us to implement comprehensive and multi-faceted preventive measures, aimed at fostering a culture of nutritious eating for everyone. These preventive activities initiatives to yield results, they must be grounded in scientific evidence, and must be feasible, cost-effective and sustainable.

According to WHO report at press, Geneva, 5 October 2005, faulty dietary practices may promote the onset of several major chronic non-communicable diseases. Health issues such as coronary heart disease, various forms of cancers, diabetes mellitus, gastrointestinal disorders, and various diseases of the bones and the joints are manily occurring because of imbalance diet intake.

Phytochemicals are nonnutritive plant chemicals that contain protective, disease-preventing compounds. More than 900 different phytochemicals have been identified as components of food so far. Phytochemicals refer to the compounds found in plants that were originally classified as vitamins. Phytochemicals are not a necessary for basic body function, nor do they cause any diseases resulting from deficiency.  Thus they cannot be classified as vitamins. Vitamins have diverse biochemical functions, including function as [hormones](http://en.wikipedia.org/wiki/Hormones) (e.g. vitamin D), [antioxidants](http://en.wikipedia.org/wiki/Antioxidants) (e.g. vitamin E), and mediators of cell signalling and regulators of cell and tissue growth and differentiation (e.g. vitamin A). The largest number of vitamins (e.g. B complex vitamins) functions as precursors for enzyme [co-enzymes](http://en.wikipedia.org/wiki/Coenzyme), that generally act as [catalyst](http://en.wikipedia.org/wiki/Catalyst) and [substrates](http://en.wikipedia.org/wiki/Substrate_%28chemistry%29) during [metabolism](http://en.wikipedia.org/wiki/Metabolism). When acting as part of a catalyst, vitamins are bound to [enzymes](http://en.wikipedia.org/wiki/Enzyme) and are called [prosthetic groups](http://en.wikipedia.org/wiki/Prosthetic_group). Phytochemical is not only beneficial in preventing diseases, but also in reversing some disorders. Unlike most vitamins and enzymes, phytochemicals are not destroyed by preparation techniques such as chopping, extracting, cooking or grating.

Accoring to Arshad *et al*. (2005), plant bio active substances could be broadly classified into three categories:

**1. Flavonoids and allied phenolic and polyphenolic compounds:**

About 8000 nos of flavonoids are known to exist in the natural sources. These are mainly concentrated in epidermic cells of leaves and skin of fruits. Low density lipoproteins are the culprits for oxidative damage of cellular DNA, platelet activation and aggregation which increase tendency for blood to clot and thus result in atherosclerosis. Flavonoids are found to inhibit the oxidation of LDL.

**Flavonoids and allied phenolic and polyphenolic compounds group include:**

* Flavonols including catechins, their derivatives and proanthocyanidins are found in tea, apple, apricot, cherry and cocoa.
* Flavonols including quercetin and myricetinare found in onion, apple, broccoli, cherry, grape, berries and tea.
* Flavones are found in parsley, thyme and celery. Anthocyanidins are found in red and purple fruits like grape and cherry. Iso-flavonesare found in leguminous vegetables.
* The principal non-flavonoid compounds are hydroxyl-cinnamates (caffeic acid and ferulic acid), stilbenes (phyto-estrogen) and phenolic compounds (tannins).

**2. Terpenoids (carotenoids and plant sterols):**

About 25000 terpenoids have been identified from natural sources. Most commonly occurring terpenoids are carotenoids, which include β-carotene, lycopene, lutein, β-cryptoxanthin and α-carotene. The important dietary sources are carrot, tomato, peas and citrus fruits. Lung cancer has been repoted to be significantly reduced with increased intake of carotenoids (Ziegler *et al*., 1996). Lycopene can inhibit the prostrate cancer. Also in terpenoid group are plant sterols, which have gained fame through their proven ability, to reduce plasma cholesterol levels when incorporated into foods. Reduction in LDL-cholesterol of 10-15% have been reported when food containing phytosterols (sitosterol, stigmasterol, campesterol etc.) are consumed periodically over the day, for a period of time. Their action hinges on their very low absorption rates and their structural similarity to cholesterol and hence their competition in gut with dietary and endogenous cholesterol, reducing uptake of cholesterol and facilitating its elimination from the body.

3. **Alkaloids and sulphur containing compounds:**

About 12000 alkaloids have been identified so far. Glucosinolates found in sprouts, broccoli and other member of *Brassica* family and derivatives of sulphur amino acid cysteine, found in the onion family. Biologically active breakdown products of glucosinolates are isothiocyanates due to metabolism in the colon by the gut bacteria, which then interact with colonial epithelial cells, enter the circulation via the colonic mucosa, and thereafter induce anti-carcenogenic defence mechanisms.

**Phytochemicals in the Prevention of Cardiovascular Disease:**

Dietary flavonoids have been inversely correlated with mortality from coronary artery disease, plasma total cholesterol and low-density lipoprotein (LDL). Oxidized LDL has been proposed as an atherogenic factor in heart disease, promoting cholesterol ester accumulation and foam cell formation. Dietary antioxidants from fruits and vegetables get incorporated into LDL, and become oxidized themselves, thus preventing oxidation of polyunsaturated fatty acids. Phytochemicals also reduce platelet aggregation, modulate cholesterol synthesis, absorption and reduce blood pressure. Systemic inflammation may also be a critical factor in cardiovascular disease. C-reactive protein, an inflammatory marker, may be a stronger predictor of cardiovascular disease that LDL cholesterol, and the anti-inflammatory activity of phytochemicals may play an important role in the health of the heart.

**Anti-inflammatory Effects of Phytochemicals:**

Cytokines are peptide hormones secreted by inflammatory cells and stromal/adipocyte cells that mediate the inflammatory response, and these cytokines (e.g. IL-1, IL-6 and Tumour Necrosis Factor-alpha) are signals that stimulate tumour growth. Dietary lipids such as omega-6 fatty acids can independently stimulate inflammation by conversion to pro-inflammatory prostaglandins. The omega-3 and omega-6 fatty acids compete for the active sites on cyclo-oxygenase (COX) enzymes. There are two isoforms of COX, designated COX-1 and COX-2. COX-1 is a housekeeping gene that is expressed constitutively in many tissues. On the other hand, COX-2 is undetectable in most of the normal tissues but is induced by inflammatory and mitogenic stimuli. There is accumulating evidence that COX-2 is important in carcinogenesis. The plant world is rich in inhibitors of cyclo-oxygenase. Compounds extracted from crabapple fruits have demonstrated activity in COX enzyme inhibitory and antioxidant bioassays and alpha-viniferin, a trimer of reseveratrol, has an inhibitory effect of COX-2 and inducible nitric oxide synthase. Animal studies have also demonstrated the inhibition of colon cancer from curcumin in turmeric and inhibition of skin and breast cancer from carnisol in rosemary.

**Anti-cancer Effects of Phytochemicals:**

There is established evidence which relates the protective benefit of fruit and vegetable intake against cancers of the lung, colon, breast, cervix, oesophagus, oral cavity, stomach, bladder, pancreas and ovary. Cancer emerges due to genetic alterations with approximately 100 genes identified as encoding oncogenes or tumor suppressor genes. Oncogenes originated from normal genes responsible for producing growth factors (such as IGFs) or growth factor receptors (like HER-2-neu). These genes normally turn on and off as a part of the complex set of events underlying normal cell functions. However, in cancer cells, mutations in the regulatory regions of these genes lead to amplified expression of multiple copies so that stimulation is an unrelenting and the cell grows in an unregulated. Contrastingly, a tumor suppressor gene encodes a protein halts cell growth and triggered apoptosis by binding to the specific elements within the nucleus. For example, recent conducted studies on animal has demonstrated the inhibition of intestinal tumour development by tart cherry anthocyanins. Phytochemicals found in fruits and vegetables can affect the above processes by several mechanisms. Free radical damage which induces oxidative stress can cause DNA damage, which in turn can lead to base mutation, DNA cross-linking, and chromosomal breakage and rearrangements. This damage can be minimize by dietary antioxidants in fruits and vegetables through modulation of detoxifying enzymes, scavenging of oxidative agents, stimulation of the immune system, hormone metabolism, and regulation of gene expression in cell proliferation and apoptosis. Whole plant extracts may have more than one mechanisms. Curcumin, for example, has been shown to have several anti-metastatic mechanims in hepato-cellular carcinoma cells.

[Basu and](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=Search&Term=%22Basu%20A%22%5BAuthor%5D&itool=EntrezSystem2.PEntrez.Pubmed.Pubmed_ResultsPanel.Pubmed_RVAbstract) [Rhone (2008)](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=Search&Term=%22Rhone%20M%22%5BAuthor%5D&itool=EntrezSystem2.PEntrez.Pubmed.Pubmed_ResultsPanel.Pubmed_RVAbstract) studied on different phytochemicals in fruits and vegetables such as:

**Carotenoids:**
Carotenoids are the pigments responsible for the colors of many red, green, yellow and orange fruits and vegetables. Carotenoids are a large family of phytochemicals which include alpha-carotene, beta-carotene, lutein, lycopene, cryptoxanthin, canthaxanthin, zeaxanthin, and others. Carotenoids protect the body by decreasing risk of heart disease, stroke, blindness, and certain types of cancer. They may also help to slow down the aging process, reduce complications associated with diabetes, and improve lung function. Fruits and vegetables that are dark green, yellow, orange or red contain carotenoids. The following information describes four different types of the carotenoids:

**Beta-Carotene:**
Beta-Carotene may help to slow the aging process, reduce the risk of certain types of cancer, improve lung function, and reduce complications associated with diabetes. Beta-carotene is found in yellow-orange fruits and vegetables such as mangoes, cantaloupe, apricots, papaya, kiwifruit, carrots, pumpkins, sweet potatoes, winter squash, green vegetables such as broccoli, spinach and kale.

**Lutein:**
Lutein is essential for maintaining proper vision of our eyes It has been shown to reduce the risk of cataracts and macular degeneration, the leading causes of blindness in older people and may help to reduce the risk of certain types of cancer. Kale, spinach and collard greens contain maximum lutein. Other sources of lutein include kiwifruit, broccoli, collard greens, brussels sprouts, swiss chard, and romaine lettuce.

**Lycopene:**
Diets rich in lycopene have been shown to reduce the risk of prostate cancer and heart disease. Lycopene is found in red fruits and vegetables such as tomatoes and cooked tomato products, red peppers, pink grape fruit and watermelon etc.

**Zeaxanthin:**

Zeaxanthin may help to prevent macular degeneration, which is the leading cause of visual impairment in people over 50 age. It may also help to prevent certain types of cancer. Corn, spinach, winter squash, and egg yolks contain zeaxanthin.

**Flavonoids:**

Flavonoids are another large family of protective phytochemicals found in fruits and vegetables. Flavonoids, also called bio-flavonoids, act as antioxidants. Antioxidants neutralize or inactivate highly unstable and extremely reactive molecules, called free radicals that attack the cells of our body everyday. Free radical damage is believed to contribute to a variety of health problems, including cancer, heart disease and aging. There are many different types of flavonoids and each appears to have protective health effects. Some of the better known flavonoids include resveratrol, anthocyanins, quercetin, hesperidin, tangeritin, kaempferol, myricetin, and apigenin. Flavonoids are found in a variety of foods, such as oranges, kiwifruit, grapefruit, tangerines, berries, apples, red grapes, red wine, broccoli, onions, and green tea. The five primary flavonoids found in fruits and vegetables are:

**Resveratrol:**

Resveratrol may reduce the risk of heart disease, cancer, blood clots and stroke. Red grapes, red grape juice, and red wine contain resveratrol.

**Anthocyanins:**
Anthocyanins, which are particularly high in blueberries, have been shown to protect against the signs of aging. In one study, elderly rats that ate the equivalent of a half-cup of blueberries daily for eight weeks improved balance, coordination, and short-term memory. Scientists think these results may apply to humans as well. Anthocyanins in blueberries and cranberries have also been shown to prevent urinary tract infections. Blueberries, cherries, strawberries, kiwifruit, and plums contain anthocyanins.

**Quercetins:**
Quercetins may reduce inflammation associated with allergies, inhibit the growth of head and neck cancers, and protect the lungs from the harmful effects of pollutants and cigarette smoke. Apples, pears, cherries, grapes, onions, kale, broccoli, leaf lettuce, garlic, green tea, and red wine contain quercetins.

**Hesperidin:**

Hesperidin is a flavonoid that may protect against heart disease. Hesperidin is found in citrus fruits and fruit juices, such as oranges and orange juice, grapefruit and grapefruit juice, tangerines, lemons, limes, mandarins, and tangelos.

**Tangeritin:**
Tangeritin may help to prevent cancers of the head and neck. Tangeritinis found in citrus fruits and their juices.

**Phenolic compounds:**
Phenolic compounds may reduce the risk of heart disease and certain types of cancer. Phenolic compounds may be found in berries, prunes, red grapes and red grape juice, kiwifruit, currants, apples and apple juice, and tomatoes.

**Ellagicacid:**
Ellagic acid is a phenolic compound that may reduce the risk of certain types of cancer and decrease cholesterol levels. Ellagic acid is found in red grapes, kiwifruit, blueberries, raspberries, strawberries, blackberries, and currants.

**Sulphoraphane:**
Sulphoraphane is in a class of phytochemicals called isothiocyanates. Sulphoraphane may reduce the risk of colon cancer. Cruciferous vegetables such as broccoli sprouts, broccoli, cauliflower, kale, Brussels sprouts, cabbage, bok choy, collard greens, turnips and turnip greens contain sulphoraphane.

**Limonene:**
Limonene is in a class of phytochemicals called mono-terpenes. It is found in the rinds and the edible white membranes of citrus fruits, such as oranges, grapefruit, tangerines, lemons and limes. Limonene may help to protect the lungs and reduce the risk of certain types of cancer.

**Indoles:**
This family of phytochemicals may reduce the risk of certain types of cancer, including breast cancer. Indoles are found in cruciferous vegetables, such as broccoli, cauliflower, kale, brussels sprouts, cabbage, bok choy, collard greens, watercress, and turnips and turnip greens.

**Allium compounds:**

Allium compounds may reduce the risk of certain types of cancer and lower cholesterol and blood pressure. Garlic, onions, chives, leeks, and scallions are the source of allium compounds.

**Alteration in phytochemical content in plants in response to exogenous factors:**

**Effect of plant growth regulators on phytochemical content:**

Nair *et al.* (2009) studied on antioxidant potential of *Ocimum sanctum* under growth regulator treatments. In the preliminary experiments, 2, 5, 10, 15 and 20 mg L-1 paclobutrazol (PBZ) and 2.5, 5, 7.5 and 10 μM L-1 abscisic acid (ABA) were used for the treatments to determine the optimum concentration of paclobutrazol and ABA. Among the treatments, the 15 mg L-1 PBZ and 7.5 μM L-1 ABA concentration increased at 50 percent of dry weight significantly and higher concentration slightly decreased the growth and dry weight. In the lower concentrations, there was nochange in the dry weight and growth of the plants were obseved. Hence, 15 mg L-1 PBZ and 7.5 μM L-1 ABA concentrations was used to study the effect on *O. santum* plants. Three vials each were used for the treatments with PBZ and ABA respectively and 3 vials were kept untreated and served as the control. 15 mg L-1 PBZ and 7.5 μM L-1 ABA were given to each plant by soil drenching. The treatment was given on 50, 70 and 90 days after planting (DAP). The plants were uprooted randomly on 60, 80 and 100 DAP and used for determining, antioxidant potential. One gram of fresh material was ground in a pestle and mortar with 5 mL of 10% TCA, the extract was centrifuged at 3500 rpm for 20 minutes. The pellet was re-extracted twice with 10% TCA and supernatant was increased 10 mL and used for estimation. To 0.5 mL of the extract, 1 mL of DTC reagent (2,4-Dinitrophenyl hydrazine-Thiourea-CuSO4 reagent) was added and mixed thoroughly. The tubes were incubated at 37°C for 3 hours and to this a solution of 0.75 mL of ice cold 65% H2SO4 was added. The tubes were then allowed to stand at 30°C for 30 min. The resulting colour was read at 520 nm in a spectrophotometer (U-2001-Hitachi). The ABA content was determined using a standard curve prepared with ascorbic acid and the results were expressed in milligrams per gram fresh weight (Table 05).

**Table- 01: Antioxidant potential of Ocimum sanctum under
growth regulator treatments**

|  |  |  |  |
| --- | --- | --- | --- |
| Days after planting (DAP) | control | PBZ | ABA |
| Ascorbic acid :  | Root |
| 60 | 0.66±0.023 | 0.68±0.024 | 0.39±0.014 |
| 80 | 1.47±0.051 | 1.78±o.062 | 0.66±0.025 |
| 100 | 3.96±0.134 | 5.63±0.180 | 0.94±0.038 |
| Stem |
| 60 | 0.54±0.019 | 0.59±0.020 | 0.05±0.002 |
| 80 | 1.63±0.054 | 2.29±0.085 | 0.70±0.030 |
| 100 | 3.25±0.122 | 3.86±0.155 | 0.59±0.023 |
| Leaf |
| 60 | 1.59±0.055 | 1.82±0.063 | 0.13±0.006 |
| 80 | 0.13±0.006 | 2.04±0.068 | 0.63±0.023 |
| 100 | 4.00±0.134 | 6.34±0.244 | 6.34±0.244 |

The PBZ treatments increased the ascorbic acid content in the root tissue of *O. sanctum* to 142.18% over the control on 100 DAP and the ABA treatment recorded a decline in ascorbic acid content than that of the control and it was 23.74% over control on the 100 DAP (Table 05). PBZ treatments increased the ascorbic acid content in the stem tissue of *O. sanctum* to 119.02% over the control on 100 DAP. The ABA treated recorded a lower ascorbic acid content than that of control plants (18.15% over the control) on 100 DAP. The ascorbic acid content of the leaf tissue increased with age in the treated and control plants. Treatment with PBZ significantly increased the ascorbic acid content of leaves when compared to the control; it was 158.18% over the control with PBZ treatment and 16.97% over control reduction with the ABA treatment on 100 DAP.

**Effect of environmental stress on phytochemical content:**

In general, during unfavourable environmental conditions that may be caused by biotic (pathogen attacks) or abiotic (drought, salinity, temperature, exposure to UV radiation) stressors, plants activate defence mechanisms, which include the accumulation of specialized metabolites or phytochemicals (Thakur et al., 2019). An elicitation of defence mechanisms in plants, in order to enrich synthesis of specialized metabolites without negative effects on crop growth and productivity, has been recently considered as an economic and sustainable technique for increasing the content of specialized metabolites in plants grown for better human nutrition (Hassini et al., 2019). Various biological, physical, or chemical stressful factors that trigger the signaling pathways leading to a higher bioactive compound content and quality attributes of plant products are also known as eustressors (Rouphael et al., 2018).

**Salinity stress:**

Although salt stress is considered an abiotic factor associated with crop productivity reduction, salinity eliciting is able to improve the quality of the final product (Rouphael et al., 2018). Several studies have explored salinity as aneustressor, and found positive physical properties, flavour compounds, bioactive compounds, and anti-nutrients as a result of salt application (Sarker et al., 2018).

Šamec et al. (2021) investigated the potential role of NaCl (50–200 mM) as an eustressor for the accumulation of health promoting phytochemicals and maintaining the homeostasis of macro- and micro-elements in three, hydroponically grown Brassica leafy vegetables (Chinese cabbage, white cabbage, and kale). In Brassica leafy vegetables, three groups of specialized metabolites are associated with their health benefits: polyphenols, glucosinolates, and carotenoids (Šamec and Salopek-Sondi, 2019), all of which were increased under salinity treatments (0–200 mM NaCl). The increase in these compounds is related to their function as a non-enzyme antioxidant to counteract the increase of reactive oxygen species and hence contribute to the plant’s health under salt stress.

**Drought stress:**

Drought stress favors rapid damage and leakage of plant cell membrane, however, the intensity of damage caused by reactive oxygen species (ROS) mainly depends on its balance between production and elimination by the antioxidant scavenging system (Azooz et al., 2009).

Sarker and Oba (2018) subjected *Amaranthus tricolor* leafy vegetable to the different irrigation treatments as FC (100% field capacity, control), mild stress (90% FC), moderate stress (60% FC), and severe stress (30% FC).As per their reports, all the nutritional and bioactive compounds, phenolics, flavonoids and antioxidant capacity of A. tricolor leaves was very high under mild drought stress as well as severe drought stress condition, in comparison to control condition, that could be contributed as valuable food sources for human diets and health benefit. Thus they opined that nutritional and bioactive compounds, phenolics, flavonoids play a vital role in scavenging ROS and thus would be beneficial for human nutrition by serving as good antioxidants and anti-aging sources in human health benefit.

**Biotic stress:**

Biotic factors, such as microorganisms, herbivores, and other species of plants could affect plant growth, as well as secondary metabolites production (Vivanco et al., 2005). Biotic factors include a more sophisticated interaction of plant biochemistry and physiology (Briskin, 2000). It can be assumed that biotic factor effects are related to either plant interactions with microorganisms or plant physiological aspects, such as phenology and ontogeny (Pavarini et al., 2012).

In plant roots, arbuscular mycorrhizal fungi (AMF) and plant growth promoting rhizobacteria (PGPR) are the most studied microbial groups (Alfonso and Galán, 2006). In general, the increased concentration of secondary metabolites in plant roots, leaves, and fruits has been related to the defense response of plants to microorganism colonization (Suzuki et al., 2014; Toussaint, 2007). However, some reports indicate that some microorganisms promote the absorption of phosphorous by plants, which activates the methyl-erythritol phosphate pathway that signiﬁcantly affects secondary metabolite production, such as chlorophylls and carotenoids (Carretero-Paulet et al., 2006). Moreover, pathogen microorganisms from manure, urban sludge, and livestock waste are being currently studied as fertilizers in vegetable production (Ingham et al., 2004). Plants detect the presence of an herbivore through the oral secretion it leaves within a wound; this damage induces the production of toxic secondary metabolites, repellents, and volatile compounds, such as aldehydes, alcohols, esters, and terpenoids (Vivanco et al., 2005).

Ibanez et al. (2019) reported that wounding stress applied on leaves days before harvesting the strawberry fruit, up-regulates systemic gene expressions associated to carbon partition, MJ biosynthesis and polyphenol biosynthesis in the fruit. Based on their findings, they supported the idea that higher levels of healthy phytochemicals reported in organic fruits and vegetables could be due to the wounding component of the biotic stress attributed to insects to which the plant are exposed to.

**Conclusion:**

Phytochemical is a more recent evolution of the term that emphasizes the plant source of most of these protective, disease-preventing compounds. A true nutritional role for phytochemicals is becoming more probable every day as research uncovers more of their remarkable benefits.

Based on the above studies we can conclude that:

* Horticultural crops contain rich sources of phytochemicals like grapes, blueberries, Broccoli , garlic, onion, ginger, green tea, fenugreek, noni (*Morindacitrifolia*) and *Thymus vulgaris etc.*
* Phytochemicals are not source of energy but act as protectant against chronic diseases.
* Phytochemicals concentration is effected by pre-harvest & post harvest factor.
* Changes in phytochemical content with genotypes, irrigation , salinity and PGRs need to be studied.
* Modification of the phytochemical composition through molecular methods needs to be studied.

One finger pointing in this direction is a body of research that strongly links the importance of diet to health--studies are showing that as we move away from the diet of our ancestors we succumb to "modern" diseases. Of course, no phytochemical is actually "new"--it's only our understanding of them that's new. Research in this area is expanding rapidly because it appears that phytonutrients offer the best protection we know of against the diseases that plague us today.

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