

## Health Fostering Phyto-chemicals in Horticultural Crops

**P. Barman, A. Roy, A. Mandal, R. Das, P. Debnath, N.K. Das and D. Nayak**  
ICAR-Central Institute for Subtropical Horticulture Regional Research Station, Malda, W.B.  
Correspondence: prananath.india@gmail.com

Chronic non-communicable diseases associated with nutrition impose a significant burden on health care systems and currently rank as the primary causes of mortality and disability in many countries within the South–East Asian Region. As urbanization increases, this concerning scenario is continuously heading towards an alarming situation for future generation. Comprehensive and multi-faceted preventive measures should be taken immediately to ensure nutritious diet for everyone. These prophylactic activities to yield results must be grounded in scientific evidence, feasible, cost-effective and sustainable for the folks.

A press release published by WHO, Geneva, 5 October 2005, claims that faulty sustenance practices may promote the onset of several major chronic non-transmissible diseases. Health issues such as coronary heart disease, varying of cancers, diabetes, gastro intestinal dysfunction, malady of the bones and joints are mainly occurring because of inadequate nutrition. Phyto-chemicals are non-nutritive plant chemicals that contain shielding compounds for various diseases. Above 900 different phyto-chemicals have been identified as constituents of food so far. Phyto-chemicals are not an imperative element for basic body function, nor do they cause any diseases resulting from deficiency. Phyto-chemicals allude to the compounds found in plants were originally classified as vitamins. Vitamins play a multifaceted role in biochemical processes, like hormones (Vitamin D), antioxidants (Vitamin E) and serving as mediators in cell signaling process. However, Vitamin B complex serves as a precursors for different enzyme co enzymes, generally act as catalyst. These co-enzyme often play the dual role of catalysts and substrates in various metabolic pathways. When vitamins attach to enzymes and become integral to their functioning, they are referred to as prosthetic group. Phyto-chemicals are not only beneficial in preventing diseases, but also in drive back some disorders to its regular form. In contrast to most vitamins and enzymes, phyto-chemicals are not destroyed by devising techniques such as chopping, extracting, cooking or grating.

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

### **1. Flavonoids and allied phenolic/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 rise the tendency for blood to clot and thus result in atherosclerosis. Flavonoids are found to hinder 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 myricetin are 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-flavones are found in leguminous vegetables.
- The principal non-flavonoid compounds are hydroxycinnamates (caffeic acid and ferulic acid), stilbenes (phytoestrogen) and phenolic compounds (tannins).

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

About 25000 terpenoids have been identified from different natural sources. Most commonly prevailing terpenoids are carotenoids, which include  $\beta$ -carotene, lycopene, lutein,  $\beta$ -cryptoxanthin and  $\alpha$ -carotene. The salient dietary sources are carrot, tomato, peas and citrus fruits. Lung cancer has been reported to be significantly reduced with arise intake of carotenoids (Ziegler *et al.*, 1996). Lycopene can curb the chances of prostate cancer. In case of terpenoid groups they are mostly plant sterols, which has received prominence 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 long period of time. Their action articulates on their very low absorption rates and their structural resemblance to cholesterol. Hence their competitiveness in gut with dietary and endogenous cholesterol, reducing assimilation of cholesterol and smooth the path of its removal from the body.

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

Around 12000 alkaloids have been documented 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 live 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-carcinogenic defence apparatus.

### **Phyto-chemicals in the Prevention of Cardiovascular Disease:**

Dietary flavonoids exhibit contrasting associations with mortality related to coronary artery disease, plasma total cholesterol levels, and low – density lipoprotein (LDL). One proposed factor in the development of heart disease is the oxidation of LDL, which directly or indirectly promotes the accumulation of cholesterol esters. As fruits and vegetables, are rich in dietary antioxidants, become incorporated into LDL and undergo oxidation themselves. This process effectively prevents the oxidation of polyunsaturated fatty acids.

### **Anti-inflammatory Effects of Phyto-chemicals:**

Cytokines are peptide hormones secreted by inflammatory cells and stromatal/ 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 tumor growth. Dietary lipids such as omega-6-fatty acids can independently stimulate inflammation by conversion to proinflammatory 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, where COX-1 is act as a housekeeping gene that is expressed constitutively in many tissues. Contrastingly COX-2 is undetectable in most of the normal tissues but it got induced by inflammatory and mitogenic stimuli. Existing reports revealed that COX-2 is important in carcinogenesis. The green world is enrich with many such inhibitors which has the ability to inhibit cyclo-oxygenase. Chemical inhibitor present in Crabapple has an active potentiality to restrict COX enzyme activity. Alpha-viniferin, a trimer of resveratrol, has a restrain 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 several endorsed evidence which connects 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 come up due to genetic alterations with approximately 100 genes identified as encoding oncogenes or tumor suppressor genes. Oncogenes proceeded from normal genes are 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, mutation in the regulatory regions of these genes lead to amplified expression of quite a few copies so that stimulation is an unrelenting and the cell grows in an unregulated manner. 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.

Phyto-chemicals found in fruits and vegetables can affect the above processes by several mechanisms. Free radical distortions induces oxidative stress and able to create DNA damage, which in turn can lead to base mutation, DNA cross-linking, and chromosomal breakage and shuffling. This manifestation can be controlled 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, as a example, has been shown to have several anti-metastatic mechanisms in hepato-cellular carcinoma cells.

As per the study conducted by Basu and Rhone (2008) on different phyto-chemicals in fruits and vegetables such as:

**Carotenoids:**

Carotenoids a diverse group of phytochemicals are responsible for the vibrant colors found in numerous vegetables., including shades of yellow, green and orange. This extensive family of compounds encompasses alpha-carotene, beta-carotene, lutein, lycopene, cryptoxanthin, canthaxanthin, zeaxanthin, and others. Carotenoids plays avital role in safeguarding the body, contributing to a reduced risk of conditions such as heart disease, stroke etc. Additionally they may have anti aging properties, mitigate complications associated with diabetes and enhance lung function. These beneficial compounds are predominantly found in fruits and vegetables displaying rich hues of dark green, yellow, orange or red. The following information describes four different types of the carotenoids:

**Beta-Carotene:**

Beta-Carotene offers potential benefits in terms of retarding the aging process, lowering the likelihood of specific cancer types, enhancing lung function, and mitigating diabetes related complication. This essential compound is abundantly present yellow orange produce like mangoes, cantaloupe, apricots, papaya, kiwifruit, carrots, winter squash and green vegetables such as broccoli, spinach and kale.

**Lutein:**

Lutein plays a crucial role in preserving our eyes visual health demonstrating its ability to lower the risk of cataracts and muscular degradation, the primary causes of blindness in the elderly people. Additionally, it holds promise in reducing the risk of specific cancers. Kale, spinach and collard greens stand out as rich source of lutein. Other notable lutein providers include kiwifruit, broccoli, Brussels sprouts, Swiss chard etc.

**Lycopene:**

Lycopene rich diets reduces prostate cancer and heart disease. Red fruits, vegetables such as tomatoes and cooked tomato products, red peppers, pink grapefruitand watermelon etc are the richest sources of Lycopene.

**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 represent another extensive group of beneficial phytochemicals commonly encountered in fruits and vegetables. Also referred as bioflavonoid. They serve as potent antioxidants in our bodies. These antioxidants play a pivotal role in neutralizing or deactivating highly unstable and reactive molecules known as free radicals. Its widely believe that free radical damage contributes to a range of health issues like cancer, heart diseases etc. Flavonoids encompass a diverse array of compounds, each demosnstrating distinct protective

health benefits. Among the well known flavonoids are 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 lessen the risk of heart disease, cancer, blood clots and stroke. Red grapes, red grape juice, and red wine contain resveratrol.
- **Anthocyanins:** Anthocyanins, found abundantly in blueberries, have demonstrated remarkable potential in countering the effect of aging. In study, elderly rats that consumed the equivalent of half a cup of blueberries daily for eight weeks experienced improvements in balance, coordination, and short term memory. Researchers speculate that similar benefits may extend to humans as well. Moreover anthocyanins present in blueberries and canberries have exhibited preventive properties against urinary tract infection.
- **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. Tangeritin is 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.

#### **Ellagic acid:**

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 phyto-chemicals 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 belongs to the group of phytochemicals known monoterpenes. It is prominently

present in the rinds and the edible white membrane of citrus fruits, including oranges, grape fruit, tangerines, lemons and limes. Limonene is believed to play a role in safeguarding lung health and potentially lowering the risk of specific cancer type.

### **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 phyto-chemical content in plants in response to exogenous factors:**

#### **Effect of plant growth regulators on phyto-chemical 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<sup>-1</sup> paclobutrazol and 2.5, 5, 7.5 and 10 µM L<sup>-1</sup> ABA were used for the treatments to determine the optimum concentration of paclobutrazol and ABA. Among the treatments, the 15 mg L<sup>-1</sup> paclobutrazol and 7.5 µM L<sup>-1</sup> 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 no change in the dry weight and growth of the plants were observed. Hence, 15 mg L<sup>-1</sup> paclobutrazol and 7.5 µM L<sup>-1</sup> 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<sup>-1</sup> paclobutrazol and 7.5 µM L<sup>-1</sup> ABA were given to each plant by soil drenching. The treatment was given on 50, 70 and 90 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-CuSO<sub>4</sub> 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% H<sub>2</sub>SO<sub>4</sub> 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 ascorbic acid content was determined using a standard curve prepared with ascorbic acid and the results were expressed in milligrams per gram fresh weight (Table 01).

Growth stages (DAS)	control	paclobutrazol	ABA
Ascorbic acid :	Root		
60	0.66±0.023	0.68±0.024	0.39±0.014
80	1.47±0.051	1.78±0.062	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

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 defense mechanisms, which include the accumulation of specialized metabolites or phyto-chemicals (Thakur et al., 2019). An elicitation of defense 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 an eustressor, and found positive physical properties, flavor 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 favours 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 methylerythritol 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, upregulates 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 phyto-chemicals like grapes, blueberries, Broccoli, garlic, onion, ginger, green tea, fenugreek, noni (*Morindaci trifolia*) and *Thymus vulgaris* etc.
- Phyto-chemicals are not source of energy but act as protectant against chronic diseases.
- Phyto-chemicals concentration is effected by pre-harvest and post-harvest factor.
- Changes in phyto-chemical content with genotypes, irrigation, salinity and PGRs need to be studied.
- Modification of the phyto-chemical 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 phyto-chemical is actually "new"-it's only our understanding of them that's new. Research in this area is expanding rapidly

because it appears that phyto-nutrients offer the best protection we know of against the diseases that plague us today.