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Breeding For Nutraceuticals in Sub Tropical Fruit Crops - A Review

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ABSTRACT

The value of any crop improvements should be measured by the change in nutritional status and health of the people consuming food products derived. Fruits are nature's wonderful gift to mankind, life-enhancing medicines packed with vitamins, minerals, anti-oxidants and many phyto-nutrients. Fruit breeding to get high nutritional attributes play a rewarding activity for the plant breeders. There is an increasing demand for the nutritionally rich cultivars from the society, for consumption of low volume high value foods as well as to alleviate the malnutrition problem, therefore breeding for nutraceuticals play a major role in fruit breeding programme. As majority of the tropical and subtropical fruits are diversified with many of the important phytochemicals, breeding strategies will definitely help in developing nutritionally rich cultivars.

Key words: *Nutraceuticals, Subtropical fruits, Fruit breeding*

INTRODUCTION

Nutraceuticals are designed to deliver a specific health benefits[17]. There is an increasing realization that nutritious food can play an important role in assuring a healthful lifestyle. People are started to consume more healthful foods that can alleviate problems related to "diseases of over abundance" and diet-related chronic diseases, such as some types of obesity, heart disease and certain types of cancer[49]. There is an increasing attention has been paid by the consumers towards consumption of fruits and vegetables as a source of bioactive compounds.

Several studies have reported the correlation between the dietary intake of fruits and vegetables and a lower risk of chronic diseases/ oxidative stress; such as cancer, cardiovascular and neurodegenerative diseases, obesity and inflammation etc. consumers are increasingly demanding for the fruits and vegetables with bioactive properties that contribute to maintaining a good health and preventing diseases. There is an increasing attention has been paid by the consumers towards consumption of fruits and vegetables as a source of bioactive compounds.

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Several studies have also proved that consumption of fruits and vegetables will lower the risk of chronic diseases/ oxidative stress to the human body.

Importance and scope for nutraceutical breeding in subtropical fruit crops

Fruit breeding refers to purposeful genetic improvement of fruit crops through various techniques including selection, hybridization, mutation and molecular techniques[26,27]. In present days one of the important breeding objectives is to increase quality in order to increase consumption. Improvement of nutritional quality of horticultural crops will be a rewarding activity for plant breeders as we enter the 21st century. In industrialized countries where sufficient food is available to most of the population, there is an increasing realization that nutritious food can play an important role in assuring a healthy life style and eating is not solely for sustenance and body growth[49].

The plant substances are very important to human nutrition must be clearly identified and described if we intend to breed cultivars with improved nutritional attributes. Breeding to improve nutritionally related traits can be approached in a step-wise manner similar to that used for other traits. This might include identification or creation of genetic variability, selection for enhanced levels of important traits using either individual phenotype or family mean values, testing for reliable field performance, and the distribution of new cultivars. In addition to improving amount and availability of desirable nutrients, avoidance of undesirable correlated responses, resulting from genetic or physiological linkages between the trait of interest and other traits deleterious to either plant growth or the consumer, is critically important [18,15].

Majority of tropical and subtropical fruits are rich source of most important bioactive compounds and high antioxidant activity[10]. Mango is a rich source of total carotenoids (Provitamin A), there are various polyphenols in mango, but Mangiferin, is abundant and important bioactive compound. Guava is well known source of ascorbic acid (Vitamin-C), lycopene and high levels of polyphenolic antioxidants[35,48]. Lycopene play a major role in pink pulp guavas. Antioxidant has twice the singlet oxygen quenching activity to reduce the oxidative stress[53]. High antioxidant properties indicate potential nutraceutical use of this fruit. Jamun fruit possess good amount of nutritional value and rich carbohydrates. It is effective in the treatment of diabetes mellitus, inflammation, ulcers and diarrhea and preclinical studies have also shown it to possess chemopreventive, radioprotective and antineoplastic properties. The plant is rich in compounds containing anthocyanins, glucoside, ellagic acid, isoquercetin, kaemferol and myrecetin.

The consumption of these fruits will helps to overcome the oxidative stress to human body. Truly the fruit market has become a segment of organized retail. These fruits are marketed all over the world and consumers are used to a huge variety of products too. Associated to fruit sensorial trait it is important to link fruit nutritional quality in a way to place on the market fruit that attracts consumers. Therefore in addition to sensorial quality fruit should possess increased nutritional quality, which is strictly associated with fruits biochemical compounds such as vitamins, minerals, polyphenols, anthocyanins and flavonoids[33,34,54,20]. The quantity and quality of bioactive compounds possessed by fruit is strictly related to fruit genotype[46,16].

Breeding for Nutraceuticals

High quality breeding stocks in the form of segregating families are the assurance of a breeding program for the future. Understanding the variation and inheritance within and between families for specific traits will position the breeder to more quickly and accurately change towards new consumer needs. The overall goal in product development in the form of new fruit cultivars is not merely the crossing of two parents and identification of new potential cultivars, but also to obtain information and develop new techniques to maximize genetic improvement of the breeding stock involved. For a breeding program to be successful, the maintenance of records on variation will greatly reduce costs and increase breeding efficiency.

The breeding of more nutritious, better-tasting cultivars can be successful if the variability and heritability of the bioactive compounds, which is defined as the total antioxidant capacity, indicate the possibility of achieving breeding progress. It is well known that the availability of genetic diversity within compatible species of any given crop will enhance the extent of any improvement[5]. The biotechnological approach is also an option to supplement this improvement, through modifications of specific biosynthetic pathways[14]. However, the success of both breeding and biotech approaches is dependent on deep knowledge of the sources of the most useful wild and cultivated genetic diversity to be used in genetic and genomic studies

Total Antioxidant Activity

Antioxidants play an important role in protecting the cells and organ systems of the body against reactive oxygen species, Vitamin C, vitamin E, and beta carotene are among the most widely studied dietary antioxidants. Vitamin C is considered the most important water-soluble antioxidant in extracellular fluids. It is capable of neutralizing reactive oxygen species in the aqueous phase before lipid peroxidation is initiated. In addition to an antioxidant effect, flavonoids may exert protection against heart disease[36]. Majority of subtropical fruits are the source of total antioxidants.

Breeding for higher levels of a trait requires that there should be substantial variation in the plant breeding population and heritability that is sufficiently high to make ample improvement in the trait, warranting the expenditure for testing selections from successive generations. The variation in AA (Antioxidant activity) and TPH (Total phenols) exists among red raspberry cultivars. Gonzalez *et al.,*[21] reported high positive correlation between total phenolics and antioxidants, and Liu *et al.*,[32] proved the correlation between TPH and AA was r=0.99. Many fruits particularly berry and cane fruit are rich sources of phenolic antioxidants[28,51]. The option is to increase the levels of antioxidants in plant food through breeding. This can be succeeded if the variability and heritability of Antioxidants trait is indicative that progress through breeding is feasible[3]. Connor *et al.,*[9] demonstrated a moderate heritability of the AA, total phenolic content and anthocyanins content in blueberry (*Vaccinium* L. *species*) from breeding programme. He also confirmed a high level of variability in these traits among genotypes from same breeding programme and high phenotypic correlation among the traits while Howard *et al.,*[25] showed significant variability among blue berry selections and cultivars in another North American breeding programme.Thus breeding for higher antioxidants appears realistic in case of blueberry.

The New Zealand blackcurrant (*Ribes nigrum* L.) breeding programme aims to improve the antioxidant content of blackcurrants by using anthocyanin content as a selection criterion. Phenotypic and genetic correlations were moderately high (rp > 0.53, rg > 0.46) between all traits apart from correlations with relative antioxidant activity and bioavailability ratios and the correlation between delphinidinrutinoside and cyanidin-glucoside.Narrow-sense heritability estimates were moderate to high (0.46-0.80) except for the relative antioxidant activity and bioavailability ratios (0.28), indicating that phenotypic selection of parents may be successful. Implications are discussed for breeding blackcurrants with increased antioxidant levels. Although the ACY was approximately half of the TPH and values ranged widely, ACY and TPH were closely correlated. This suggests that the expression of non-anthocyanin phenolics was linked to expression of anthocyanins[11].

Rubus L. species are also reported to demonstrate high levels of AA with variation among species[13,39]. Ann Marrie Connar[3] studied the variance component and narrow sense heritabilities were estimated for antioxidant activity, total phenolic content and fruit weight of red raspberry fruit from offspring of factorial mating design. Female X male parent interaction was not significant in case of AA and TPH. Antioxidant activity and TPH were highly phenotypically correlated (r=0.93); their genetic correlation (r=0.59) implies that substantial additive gene factors underlie the phenotypic correlations. High heritability for different traits and closeness of their genotypic and respective phenotypic variation indicated that reliable selection could be made for these traits on the basis of phenotypic expression being less influenced by environmental effects. For more reliable and maximum genetic information heritability estimates coupled with genetic advance should be considered[6]. Genetic advance is the improvement over the base population that can potentially make from the selection character. Kumar *et al*,[29] observed additive gene action for 100-seed weight in grape genotypes. Panse[41] also pointed out that high heritability coupled with greater genetic advance is mainly attributed to the additive gene action. Higher heritability coupled with high GA was observed for total phenols, which may be due to additive gene action, and thus selection would be effective for this component for further improvement. Similar results were reported for number of flowers and number of fruits in each year with high heritability and high GA indicated these characters were controlled by additive genes and effective selection could be made[4]. The nutritional and health promoting properties of *P. guajava* together with the increased interest in its antioxidant properties, indicate the potential nutraceutical use of this fruit. Therefore there is a need for the proper selection of cultivars with appropriate polyphenol composition for the intended use of the fruit.

Total soluble solids and acidity

The fruit soluble solids and titratable acidity contents are strictly controlled by the genotype[19]. High sugars and relatively high acid content are generally required for good flavour[47] and in general to their balanced ratio is highly related the fruit sweetness perception, an important factor in determining consumer preference. A huge variability of fruit antioxidant capacity and antioxidant compounds is existing among cultivars of some species and clearly among types of fruit from different species. Of peculiar interest is also the difference found among cultivated and wild species. Wild species have higher level of nutritional attributes when compared with their respective cultivated varieties, but at the same time they have a loss of other important fruit quality traits, such as for example fruit size and firmness. Thus, wild germplasm has an important role as a source of genes to improve fruit nutritional and nutraceutical quality[50].

Colour pigments (Anthocyanin, Carotenoids and Lycopene)

Anthocyanins are members of the flavanoid group of phytochemicals; predominant in fruits consists of cyaniding, pelargonidin, petunidin, the flavonols (quercitin, kaempferol), flavones and flavanones etc. Anthocyanins are important polyphenolic components of fruits, especially berries. They are potent antioxidants in vitro and may be protective against many degenerative diseases[31]. The free radical scavenging and antioxidant capacities of anthocyanin pigments are the most highly publicized[37].

Connor *et al.*,[9] studied the variation and heritability estimates for antioxidant activity, total phenolic content and anthocyanin content in blue berry. Here we can see the narrow sense heritability and among family, within family variance components were estimated for antioxidant activity, total phenolic content and anthocyanin in blue berry fruit. Narrow sense heritability estimates allow breeder to predict the likelihood of success in changing population traits through cycles of breeding and selection by indicating the degree to which individuals phenotypes reflect breeding values. The heritability estimates in this study have several limitations including possible upward bias due to environmental covariance, as the parents and the offspring were grown at the same location.

Inheritance of fruit color in lowbush blueberry has qualitative and quantitative components. In crosses between the black-fruited *V. angustifolium* var. *nigrum* (Wood) Dole and the typical blue-fruited *var, angustifolium,* the “nigrum” phenotype is inherited as a single semi dominant gene influenced by modifying genetic and environmental factors[1,2]. In a diallel cross of blue-fruited low bush blueberry parents, Aalders and Hall[2] concluded that the environmental component of variation for fruit color was large and also that genetic variation was large and mainly additive.

Progenies from a partial diallel mating scheme using 17 high bush *(Vaccinium corymbosum* L.), lowbush *(V. angustifolium* Ait.), and half-high *(V. corymbosum/V. angustfoliu)* hybrid parents were subjectively evaluated for fruit color, picking scar, and firmness in two seasons. The correlation coefficients between the GCA effects and the parental phenotype scores were low; indicating that selection of parents within this material based on their phenotype may not be indicative of progeny performance. GCA effects depended to some extent on the species ancestry. *Vaccinium angustifolium* parents produced progeny with relatively dark, soft fruit with large scars. When the high bush and half-high parents were crossed with one another, segregation patterns were typical of predominately additive gene action.

Both Moyer *et al.*[39] and Connor *et al.* [9] reported that ACY had lower correlations than TPH with antioxidant activity. In this study ACY and TPH had similar correlations to ORAC because of the close relationship between the expression of ACY and TPH. The high genetic correlations between ACY, TPH and ORAC suggests that any one of these measures will co-select for the other traits in the population and that only one of these measures need be taken. High positive correlations between ACY and the four main individual anthocyanins mean that selection based on ACY should also increase the amounts of each of the four main individual anthocyanins.

Anegative correlation between the fruit colour (both L* and Chroma Index) with the phytochemicals traits and in a pale shiny strawberry fruit such as ‘Idea’ resulted with lower antioxidant capacity, while the dark dull fruit (e.g. fruit of AN94.414.52 and ‘Sveva’) with the highest antioxidant values[7,8].

Lycopene is regarded as one of the most efficient singlet oxygen quencher and peroxyl radical scavenger of all the carotenoids and may represent an important defense mechanism in the human body. Lycopene is a natural pigment that imparts red color to tomato, guava, rosehip, watermelon, and pink grapefruit[24]. Tomatoes (especially deep-red fresh tomato fruits) and tomato products are considered the most important source of Lycopene in the Western diet[42,44]. Among fruits pink pulp guavas are good source of lycopene.

As an antioxidant, lycopene has twice the singlet-oxygen-quenching activity of β-carotene and ten times the activity of α-tocopherol (vitamin E)[53]. According to Rao and Shen[43] the consumption of 5–20 mg of lycopene produces a significant reduction in lipid and protein oxidation in the human body. Most of the carotenoids are efficient antioxidants; Lycopene has been shown to be one of the most efficient singlet oxygen quencher and peroxyl radical scavenger among all the carotenoids.

Role of Biotechnology for improving phytochemicals

In recent years the application of molecular technologies has steadily increased[23]. New high-throughput sequencing techniques, Bioinformatics data mining, Quantitative gene expression analysis and novel phenotyping platforms are now becoming a reality and will have much larger application. Some genetic maps are developed for strawberry and raspberry[30,45]. Several quantitative trait loci (QTLs) controlling traits involved in nutritional quality such as vitamin C have been mapped in strawberry[38]. This approach can further benefit from the current development of tools for large analysis of fruit metabolites and rapid development of genetic maps between different plant species will allow the localization of candidate genes Transgenic approaches can provide an alternative although there is currently public concern about their use in agriculture where the genes from other organisms were used. Till now several crops such as rice[40] and tomato[12] used successfully to increase the nutritional value.

The integration of breeding knowledge with availability of complete genome and the genetic transformation tool either for gene validation or for transferring useful safe genes will represent next future in improvement.

CONCLUSION

In order to achieve higher bio-availability, three approaches are possible: i) increase the concentration of the nutrient; ii) increase the percentage of bio-availability and iii) a combination of these two strategies[22]. The most feasible strategy currently available is to breed a variety with increased nutrient content. The breeding of more nutritious, better-tasting cultivars can be successful if the variability and heritability of the bioactive compounds indicate the possibility of achieving breeding progress. Therefore breeding of fruit crops mainly for nutrition point is the need of the day, as it will help to feed the hungry planet.

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