VEGETABLES: ROOT CROPS

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Contents

Summary

Vegetables are herbs grown in intensive cultivation for human consumption with high nutrition value, containing high amount of water, essential minerals, vitamins and specific food components, flavour and aromatic substances.

Vegetables are mainly eaten for their contribution to the flavour and interest of food and for the supply of vitamins, micronutrients, fibre and other nutrients, including antioxidants essential for the human life. Some vegetables provide volatile, essential oils, which supply aroma and taste to stimulate the appetite, and, have health maintaining effects.

In vegetables vitamins are in a special ratio and in specific chemical environment, therefore the consumption of fresh vegetables is essential for balanced vitamin supply for human organism. Regarding micronutrient supply for the human population vegetables have particularly important role all over the world, especially in the regions where traditionally meat is not consumed.

The decisive elements of quality are that the product would be sound, clean, in particular without residues of agrochemicals, free from pest attack, having good taste and flavour, and, attractive look. In physiological-nutritional sense, some single parameters, such as average nutritive value (ANV) are widely used to characterise the nutritive value of the food plants.

Vegetable production is more or less a topic of horticulture. Cultivation, adequate processing and marketing require a high level of knowledge.

According to their place of origin, vegetables have various requirements for climate. Heat and water demand, as well as day-length, differ for vegetables with tropical, and vegetables with subtropical origin. Some of them are easily adaptable for diverse growing conditions even the sensible species can be modified by new breading and molecular genetic transformation techniques.

Marketable vegetable products may be fruits, seeds, edible pods, leaves, stems or more often metamorphosed stems, tubers and roots, thus, in a practical point of view vegetables can be grouped according to the plant part, for which they are produced. Cultivated plants, which have their edible part underground, are called root and tuber crops.

The thickened taproot and different parts of stem constitute carrots, beets and some radishes and the marketed parts of onions and garlic are modified bud bulbs. The specific taste and odour of their phytochemicals is the key of their importance in all kind of cuisine throughout the world. Leaf vegetables are grown for their tender leaves or shoots. There are salad crops, spinach and spinach-like leafy vegetables. They

contain vitamins, minerals and high in both water content and fibre.

However, there is a possibility of high nitrate contents in leaves, which may be harmful for the consumers mainly if it forms nitrite during storage, processing and after ingestion.

Certain vegetables from the group of Brassicas, including broccoli, Brussels sprouts, cabbages, cauliflower, kale and pak choy, have been recognized to have anticancer properties.

Domesticated Brassica oleracea was bred in different ways to different shoot architectures for the use of leaves, buds, thickened stems or shortened floral parts. Leafy Asian Brassicas have different origin in China and South-East Asia.

The history, role in nutrition, cultivation and constraints of the root crops (carrots, beets, radishes, etc.), bulb alliums (garlic, onions, leeks, etc.), leafy vegetables and cole crops were discussed in this paper.

1. Vegetables as a part of the diet

The group of crops called "vegetables" consists of more than 200 plant species all over the world. Vegetables are mainly produced by horticulture and only for human nutrition. These crops are botanically different annuals, biennials or perennials, however most of them are herbs.

They differ in their chemical composition from other types of crops containing more water, proteins, micronutrients and vitamins than cereals and other staples. Vegetables also contain some phytochemicals, which produce their special flavour and aroma and, may have a beneficial role in health as components of a varied diet.

Their low calorie and relatively high dietary fibre content make desirable to increase vegetable consumption in human diet in the developed countries as well.

More than seventy per cent of the world's vegetable production is grown in the Asian continent, and about the half of it in China (Fig.1.).

Vegetable production is rather labour intensive and cost demanding. Garden production, cold, deep and heated intensive vegetable cultures may need irrigation, careful manure, fertiliser and pesticide use, or heating under foil tents and in glasshouses.

Cutting the tendrils off, pruning, staking, picking leaves or fruits, harvesting bulbs are mostly made by hand, and requires producers' attention to the crop continuously during the vegetation period.

Since harvested vegetables are perishable for their high water content and the high metabolic activity of vitamins, minerals and phytochemicals in their tissues, storage and processing the products, marketing and trade is successful only above a certain level of knowledge and in a well-organised system of the production levels.

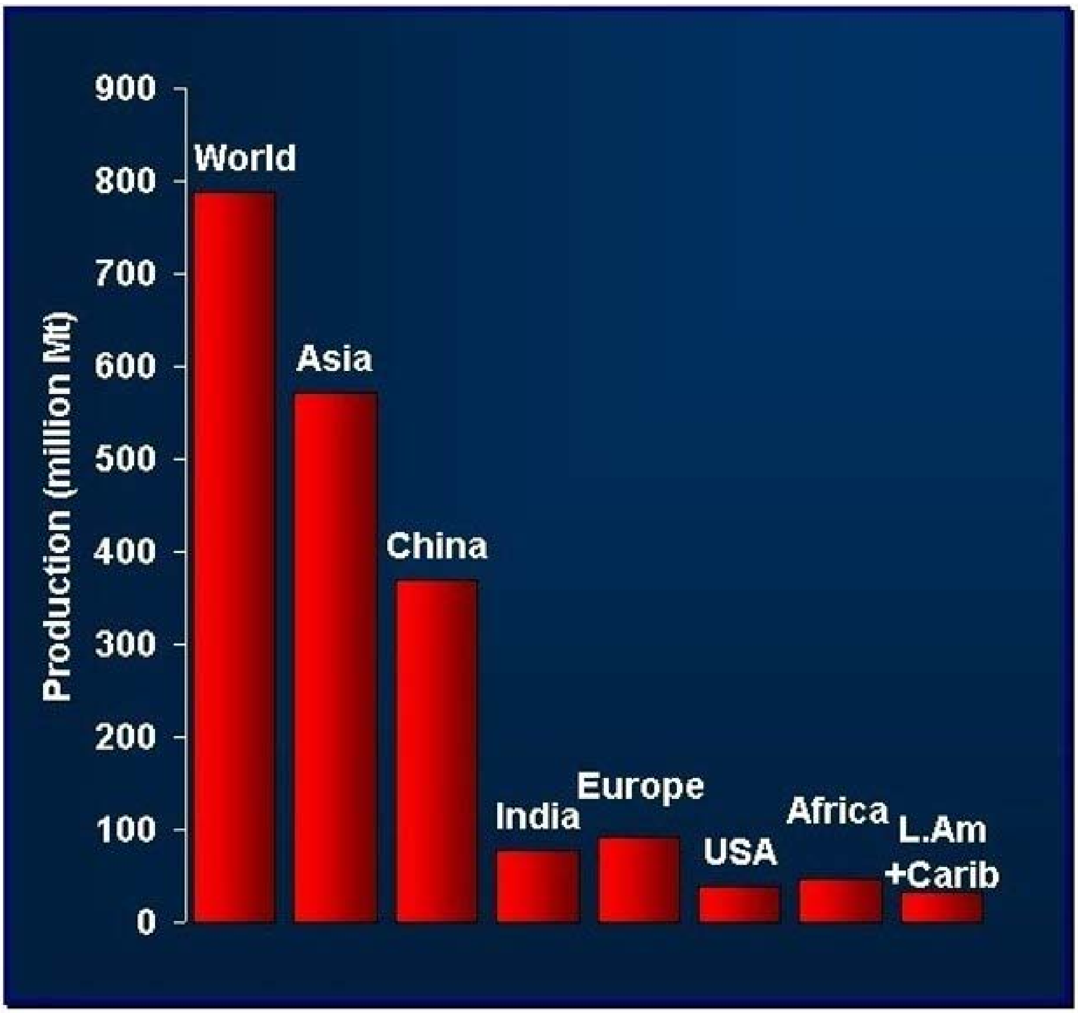

Figure 1: Production of vegetables including melons in the world 2002. (Source: FAOSTAT)

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Some of them are easily adaptable for diverse growing conditions even the sensible species can be modified by new breading and molecular genetic transformation techniques.

Also vegetables can grow under artificial conditions, in controlled environment such as in glasshouses, foil tents, or growth chambers. However, many consumers state that the quality of the crop is much higher in its natural environment…

1.1 Role in nutrition

The majority of vitamins and micronutrients essential for the human life can be supplied by vegetable consumption. Some vegetables provide volatile, essential oils, which have health maintaining effects: in the representatives of Cruciferous crops (cabbages, turnips and rutabagas, radishes) there are essential oils, which contain sulphur, and are partly nitrogenous (mustard oil compounds). These are important as natural therapeutics, since they display anti-microbial, cholagogic, thyreostatic effects and reduce blood pressure. Essential oils containing sulphur (di- and polysulphides) and not containing nitrogen are present in garlic and onions, leeks and chives, are strongly anti-microbial. Carrots, parsnips, celery and parsley provide oils mainly of the terpene series, which contain neither sulphur, nor nitrogen.

Vegetables have been found to help prevent a host of diseases if their consumption meets the requirement of the organism for vitamins, minerals, fibre and other nutrients, including antioxidants.

1.2 Vitamins in vegetables

Consumption of fresh vegetables is essential for balanced vitamin supply for human organism. In vegetables vitamins are in a special ratio and in specific chemical environment. Vegetables are rich in vitamins C, E and K and carotenes (among them beta-carotene is the precursor of vitamin A, retinol) synthesized in the plant tissues. Red, orange, yellow vegetables and dark green leafy ones, such as tomato, carrot, winter squash and broccoli, kale and spinach are high in carotenes. From the group of carotenoids beta-carotene, lycopene and lutein are well-known compounds, which appear to protect against many diseases via reducing the damage from free radicals.

Higher lycopene content in blood may reduce the risk of various cancers, while lutein may decrease the risk of macular degradation in elderly people's eyes.

Vitamin C (ascorbic acid) is a well-known antioxidant. It occurs quite generally in vegetable plants, though certainly in different quantities - some species surpass the others considerably. High amount of ascorbic acid is available in green vegetable pepper, tomato, cabbage, broccoli, kale, Brussels sprout, which can be eaten as fresh salads, slightly steamed vegetables or pickles. Exhausting heating, boiling or long-time storage, freezing or drying may result in the gradual reduction of vitamin C content by 20 per cent (during freezing) to 80 per cent (during drying) of the original value.

Vitamin E (alpha-tokoferol) is abundant in nuts, vegetable oils but it is found in green vegetables too, such as Brussels sprouts, broccoli, spinach, parsley's green, celery, asparagus and green peas. Its main role is that as an antioxidant it helps to protect the cells from damage, and that way affects ageing, infertility, heart disease, cataracts and cancer.

Vitamin K_1 (fillokinon) is found in the majority of green leafy vegetables, in lettuce, spinach, broccoli and cabbages.

In tomato, parsley green, green peas vitamin B1, in spinach, pulses and parsley green vitamin B6, in lettuce biotin, and in a host of other vegetables niacin are found. (Niacin is known to be effective in lowering blood cholesterol.) High folic acid content is characteristic for spinach, red beet, kale, Brussels sprouts, asparagus and melon.

1.3 Minerals and their bioavailability

The mineral content of vegetables varies with species, ripeness, climatic, soil and cultivation conditions. High potassium content and favourable potassium:sodium ratio promote utilisation in the human body, particularly for potassium rich vegetables such as green peas, kohlrabi, and spinach. Magnesium is abundant also in green peas and spinach as well as red beet.

Regarding micronutrient supply for the human population vegetables have particularly important role all over the world, especially in the regions where traditionally meat is not consumed. In balanced diet vegetables provide iron, copper, chrome, molybdenum, iodine and selenium in an advantageous ratio and sufficient amount. Bioavailability of iron to humans is only 3-8 per cent from plant foods, however some promoter substances normally found among plant metabolites can enhance it. Many types of vegetables are rich in some organic acids such as ascorbic acid (vitamin C), and other factors, e.g. phytoferritin, or beta-carotene, which improve iron bioavailability. In copper deficiency when iron utilisation also decreases, consumption of pulses, nuts and some mushrooms can help. Flavonoids in spinach, onion and root crops also promote the availability of iron and zinc to human. Additionally, flavonoids are considered to protect against the damaging effects caused by free radicals. Intake of chrome and molybdenum with pulses, iodine and selenium with spinach, garden sorrel, lettuce, cucumber, garlic and mushroom can be done.

Vegetables also contain various substances that can inhibit the bioavailability of essential micronutrients to humans. Iron, zinc, magnesium and calcium are affected by phytates additionally iron and zinc absorption and utilisation can be interfered by fibres, tannins and other polyphenols, and hemagglutinins. These substances are called "antinutrients" and can find in legume seeds and cereal grains. Lectines are hemagglutinines that are plant proteins primarily in pulses. In beans, lentil, peas, soybean and groundnut hundreds of lectines have been found with various toxicity on the gut. Oxalic acid as an antinutrient affects calcium bioavailability and is abundant in the leaves of spinach and garden sorrel and the stems of rhubarb. Brassicas and Alliums (e.g. kale, broccoli, garlic, onion) contain goitrogens, which inhibit iodin utilisation. Some alkaloids contained by Solanum species may have a poisonous effect as solanin in greened potato tubers.

1.4 Dietary fibre

Vegetables are adequate source of dietary fibre. Dietary fibre is found only in plants, - grains, fruits and vegetables - contains cellulose, hemicellulose, lignin and pectin the building materials of plant cell wall. Fibre has high capacity for water absorption and retention and to fix fat and other organic substances. Due to these properties dietary fibre intake is important in the diet as influencing on human metabolism.

Dietary fibre is made up two main groups of substances. These are (1) the soluble fibre that consists of mainly pectin, and is broken down to simpler compounds by the microflora in the colon, and (2) the insoluble fibre that passes through the digestive tract largely intact. The part of it that is broken down supplies short chain fatty acids important for the human metabolism. Both types of fibre reduce the risk of the diseases of digestive system, particularly of the colon, and, soluble fibre has some other benefits on heart health as is considered to prevent high blood cholesterol. Intake of dietary fibre is highly recommended for diabetics as it may help reducing insulin demand, the concentration of serum lipids and regulates blood sugar level.

1.5 Taste of vegetables

Vegetables are mainly eaten for their contribution to the flavour and interest of food and for the supply of vitamins and micronutrients. Some vegetables provide volatile, essential oils, which supplies aroma and taste to stimulate the appetite. Flavour factors include sweet, sour, salty and bitter tastes perceived by tongue and aromas perceived by the nose. Flavour is a combination of taste and smell. Taste is one of the most important characters from the consumers' point of view. In its complexity many components have a role; the ratio between acid and sugar contents, the nature of the acids, the proportions of the individual acids to another, to the sugar, to the ester, aldehyde, keto compounds, the nature of the possible volatile oil - not merely its quantity - which determine the intensity of the taste. Some amino acids producing sweet taste and bitter, astringent substances contribute to the special harmonic taste of the vegetables. Also other taste-related sensations, like pungency are important for flavour.

It is widely concerned that growing conditions highly affect the flavour of vegetables. Climate, soil properties, plant nutrient supply affect the nature and proportions of taste compounds. With physiologically balanced complete nutrition the taste of the product is generally improved. Whereas over-fertilization with nitrogen leads losses of flavour and aroma in celery, tomatoes, cucumber and bell peppers, and an undesirable flavour and odour in cabbages.

1.6 Quality concerns

Good quality is important for the consumers to enjoy the meal and for better health, and, for growers, shippers and marketers to achieve more cash income.

The decisive elements of quality are that the product would be sound, clean, in particular without residues of fertiliser and pesticide chemicals, free from pest attack, having good taste and flavour, and, attractive look.

Culture at suitable location is a prerequisite of high quality production. In the areas where certain vegetables are traditionally grown, both the advantageous climate and soil conditions, the low risk of pests and diseases, and the high level of the knowledge of producers lead to produce an excellent product met the consumers' highest demand. When cultivation is extending to areas with less favourable ecological conditions - mainly for economic reasons - new, advanced cultural methods should be involved in production as high level fertilisation, greenhouse production and plant protection. It leads altered nutrient composition of the marketed product - and sometimes contamination with some poisonous residues of pest control substances - unwanted taste, peculiar shape and colour, etc. if they are applied inappropriately. In many case treatments with plant protective chemicals alter the characteristic taste or cause the disappearance of the aroma. In order to the avoidance of these disadvantages, for the protection of the consumer, there are strict limit values for pesticide-residue, heavy metal and nitrate contents in various vegetables strictly controlled by the food control bodies in markets.

In standardization of quality grades in the point of view of the practical marketing of vegetables, generally visual attributes, size (or weight), shape and colour and, "freshness" are the main basis of commercial criteria. Category limits for the various products are more or less tailored to the nutritional values, rejecting both the too small and the oversized products. Vegetables must be attractive for the eye of the consumers. Nice shape, firmness, beautiful colour and healthy skin, free from scares, spots, rust, cracks and other skin faults, no frost damaged, etc. are wanted when choosing our food.

Figure 2: Vegetables in a market in Budapest, Hungary

Although, the commercial grades have proved to be helpful in many cases, their effect is not complete in the physiological-nutritional sense. We have not known all of the functional substances "phytochemicals" which play a role in health-support effect of the vegetables. These substances are active and efficient in fresh and well-processed vegetables. That's why there is an effort to render a single parameter to the product for the characterisation of its biological value: contents, which determine nutritional value, wholesomeness and health-giving factors.

Average nutritive value (ANV) is a widely used parameter of the nutritive value of the food plants. The amounts of protein, fibre, calcium, iron and carotene are involved regarding also the oxalic acid content and freshness of the product.

$$\text{ANV/100 g edible part} = \frac{\text{protein, g}}{5} + \text{fibre} + \frac{\text{Ca, mg}}{100} + \frac{\text{Fe, mg}}{2} + \frac{\text{vitamin C, mg}}{40}$$

In the case of fresh consumption vitamin C content is divided by 20; for high oxalic acid content Ca content should be divided by 200.

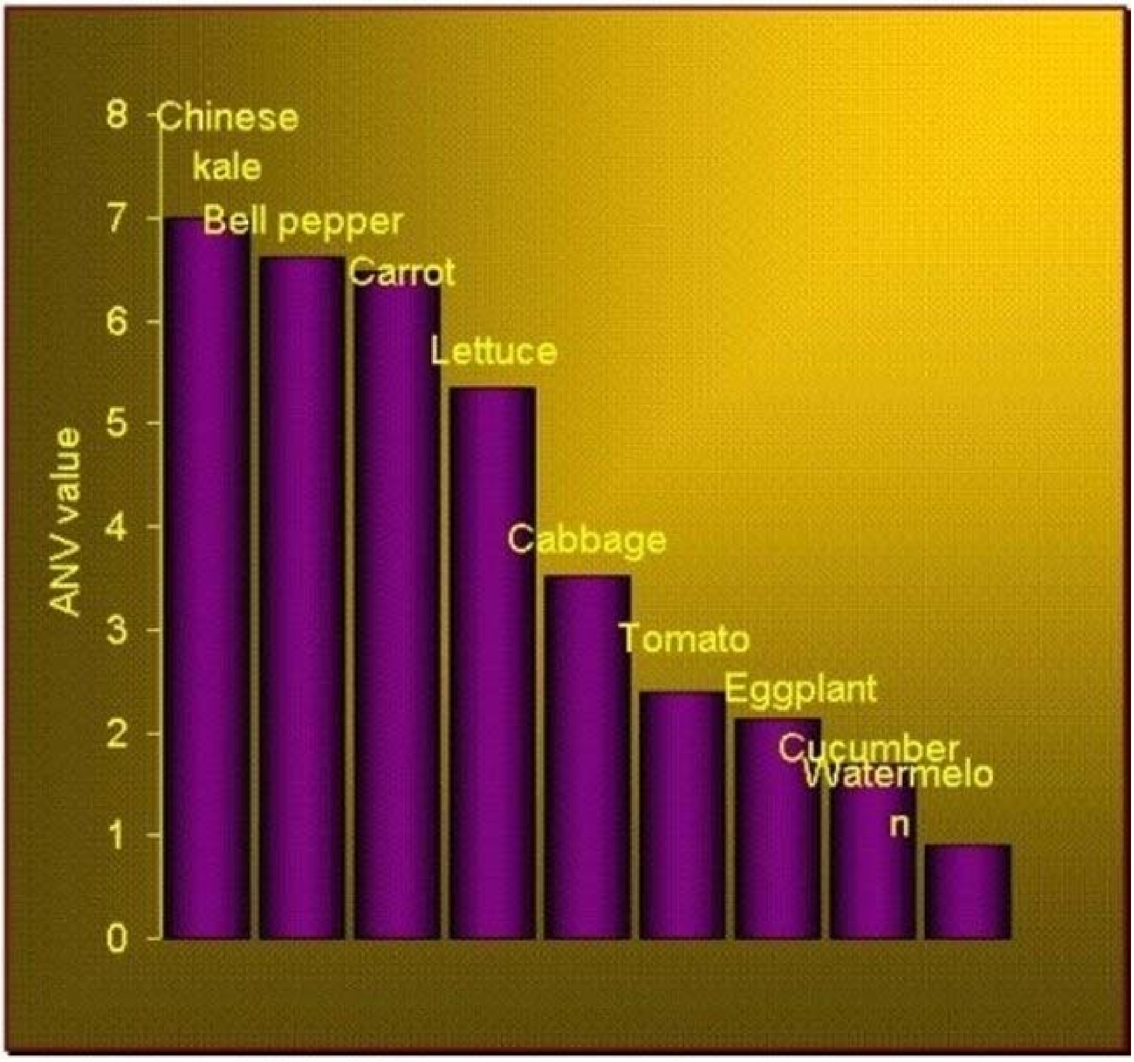

Figure 3: ANV values of some vegetables. (Source: Győri, 1999)

Unfortunately, there may be some harmful substances also, which we cannot see when choose a crop in the market.

To secure and maximize rural incomes and to supply health-giving vegetable products to the consumers in the cities a high level organization of production, storage and transport, and, marketing is essential. Production of a high-quality crop, its post-harvest handling along the way to the final market is most successful if involved in a single system. While store and transport the perishable fresh vegetables the maintenance of a low temperature (down to 0^{o} C), high (85-95 %) relative air humidity and a satisfactory air circulation is necessary to reduce respiration and transpiration rate on account of the reserve substances and water content of the marketable crop. Also the use of proper (not too deep) containers, gentle loading and unloading operations are very important steps of a well-organized marketing chain. Timing, the duration and costs of the transport, the number of different marketing levels involved, all affect both on the quality of crops and the growers' income.

2. Root vegetables

Man domesticated the similar parts of various plant species for similar use in different parts of the world and on different elevations, such as yams in Africa and Asia, taro in Asia, cassava, sweet potato, potato in America in low, medium and high altitudes. Additionally, different parts of the same plant species are used in different regions, leaves and petioles here, and roots there. Cultivated plants, which have their edible part underground, are called root and tuber crops. The thickened taproot, hypocotyl and the epicotyl constitute carrots, beets and some radishes, while early spring radish has its thickened hypocotyl belowground; potatoes have modified stem tubers, and the marketed parts of onions and garlic are modified bud bulbs.

There are a host of crops or vegetables cropped for their underground part all over the world. Some of them are consumed for their high starch content, some for high water content and taste. The main starchy root and tuber crops are discussed in 5.2.3.3. Chapter of this Volume entitled "Starch bearing plants". Only those Root crops which are concerned as vegetables for their chemical composition are to be discussed here.

2.1 Carrots

Carrots belong to the family of Apiaceae, and have two cultivated varieties: Daucus carota ssp. sativus convar. sativus (long type carrots), and Daucus carota ssp. sativus convar. curtus (short type carrots). Carrot has been produced for 3-4 thousand years. It was endemic in Europe and presumably domesticated in the Mediterranean Basin, then dispersed around the world. It is mainly a field crop, but also forced in Europe and USA. World annual production is around fourteen million tons, more than third part in the developing countries (Fig. 4.). The thick red, orange or yellow roots are consumed as fresh vegetables, row or cooked, processed by the canning industry, or for dry products such as powder soups or stored for later consumption.

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Biographical Sketch

Krisztina R. Végh is a research worker in the Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences (RISSAC) Budapest, Hungary. She completed her MSc in Biology in Budapest Science University (ELTE) Hungary. Her PhD thesis analysed the nutrient dynamics in the rhizosphere, by using measurements and modelling. Her interests also include system modelling in sensitive environments, in drought-prone areas, and, in nutrient deficient conditions. She has conducted several research projects on plant nutrition, water use and drought tolerance, and cooperated in both Hungarian and international research. She has worked in Uppsala, Sweden, in Tokyo, Japan, and now she works in joint projects on sustainable plant nutrition, together with Indian universities and research institutes.