Crops for Future

Khyati Adlakha[1] and Bhupendra Koul[1*]

[1]School of Bioengineering and Biosciences, Department of Biotechnology,

Lovely Professional University, Phagwara-144411, Punjab, India

Abstract

By 2030, it is expected that the uncontrolled population growth rate shall pose a threat to world food-security. Moreover, the over-exploitation of routinely cultivated crops shall worsen the situation. Therefore, these crops are being genetically modified (GM) to enhance the yield and nutrition (biofortification) and to cope with the various abiotic (salinity, drought, temperature, heavy metals, ultraviolet radiation) and biotic stresses (pathogens, insects, weeds). As it is not affordable for every country to opt the GM technology, there is a need to find alternative crops which fulfills the dietary requirements of humans and can serve as feed for animals, without causing any toxicity. This review enlists certain crops with reported vigour (better tolerance to biotic and abiotic stresses), adequate macro and micro nutrients, and several uses. These crops can be used as a substitute to the routine staple food crops.

Keywords: nutrition, food security, alternative-plants, environment

Introduction

Since ancient times, plants have been used a source of food, fodder and medicine. Any plant or plant product produced for profit or subsistence is called a crop. There are a number of crops grown globally, out of which only a few species account for 90% of the calories consumed by people [1]. According to the use, crops have been classified as food crops (fruits, vegetables, and cereals), feed crops (grasses and legumes), oil crops (jatropha, marula), ornamental crops (petunia, daffodils), fiber crops (jute, flax, hemp, cotton) and industrial crops (timber, medicinal plants, bio-energy crops). Fruits, vegetables, cereals, oilseeds and pulses are the major food crops utilized for human consumption. There are around 4, 00,000 vascular plant species all over the world but only a limited number of them are being cultivated widely. To fulfill the requirements of carbohydrates, wheat, maize and rice are the staple food for most of the people of all economic backgrounds [2]. Wheat is the most widely cultivated crop with annual production of about 670 million tons. It has been regarded as the 'miracle crop', as it was helpful in overcoming famines and saved a million lives. Wheat provides 18% of the total caloric needs and 21% of daily dietary protein intake while rice fulfills 19% of calories and 13% of proteins at global level [3]. With the onset of green revolution since 1960s, the demand for wheat has quadrupled. This growth was possible through advancements in semi-dwarf, high yielding varieties and policies favorable to farmers to access seeds, fertilizers and irrigation infrastructure [4],[5],[6],[7]. Maize provides at least 30% calories to people in developing countries. More than 50% of the maize is produced from low or middle income countries, thus it proves to be important in livelihood of poor farmers. As the population will increase, so the need of maize would be doubled. Being a food crop, maize has been used as a key ingredient in animal feed over the past decade. It is also used as a raw-material for industrial bioethanol production [8].

As a response to the increasing demands and constraints for expanding supplies, the price of these crops is expected to increase. For the poor cereal consumers, the outcome will be less affordable food, despite of the measures taken to accelerate growth. The major challenge lies for the future is attaining remarkable growth without compromising on public health and environmental sustainability [9]. The threats that affect the yield are climate change (variability in seasonal temperatures and rainfall) and biotic and abiotic stresses (drought, fertilizer use, adoption of improved varieties). The biotic constraints for maize involve larger grain borer (LGB) (*Prostephanus truncatus*), angoumois grain moth (*Sitotroga cereallela*) and the lesser grain weevil (*Sitophilus oryzae*), which cause an estimated loss of 20-30% of yield and three rusts caused by the *Puccinia triticina* (leaf rust), *P. striiiformis* (yellow rust) and *P. graminis* (stem rust) majorly affect the yield of wheat. The declining soil fertility, water supplies for irrigation, emerging diseases, salinity of soil leading to water scarcity, elevated temperatures and heat stress result in the reduction of wheat production [3], [8]. Although, green revolution provides with good yield of some selected crops, but the production cost is the limitation as it is not affordable for every developing and underdeveloped countries to continue practice this. With changes in environment, key issues and challenges motivate to grow crops that can be used in multiple ways to feed the millions and ensure food security. According to FAO 2009 there should be 70% increase in food production in 2050 to meet the diet requirements of population (10]. Agricultural research acknowledged hidden hunger and malnutrition as the main objectives in food security since 1980s. Therefore, instead of producing genetically modified crops and bio-fortifying them with nutrients, certain crops can be used as an alternative to already exploited crops which can be found locally to meet the immediate nutrient requirements of the human body. This is an interesting and sustainable alternative to fulfill the needs of growing population.

The future crops

There are number of plant species which are used not used to their full potential. These may be overgrown in one part of the world and unknown to the other part. The never-ending debates on climate change (particularly flood prone or drought prone areas) provoke the exploitation of already being used crops. Whereas, these plants are adapted to local climate and biotic stress, they do not require much external input which makes them durable to the climatic stress. Certain non-communicable diseases like cancer, diabetes, cardiovascular diseases or obesity emerge as a result of improper diet, which trigger the growth of underutilized or neglected crops. [11].

Some these crops are listed as:

1. Millets

Millets belong to the family of cereals which are cultivated in Nigeria, Sudan, India and Niger covering over 32.2 million hectares of land. They include foxtail millet (*Setaria italica*), Barnyard millet (*Echinochloa crus-galli*), kodo millet (*Paspalum scrobiculatum*), finger millet (*Eleusine coracana*), little millet (*Panicum sumatrense*), pearl millet (*Pennisetum glaucum*), prosomillet (*Panicum miliaceum*), fonio (*Digitaria sp*.) and tef (*Eragrostis tef*). Due the ability to tolerate moisture deficiency, pearl millet (Fig. 1) is cultivated mostly [12]. In comparison to rice, maize and sorghum it contains higher concentration of protein (11.6%) and minerals (2-3%), low fiber content (1-2%) and higher oil content (4-9%). They can be easily stored in low moisture but the flour turns rancid with time, hence, cannot be stored for long. The flour is helpful in preparation of porridges and breads. The unprocessed flour can be directly used in fermentation and brewing. It can also be used as feed for poultry, pigs, sheep and cattle but may accumulate nitrogen which can be potentially toxic, if not maintained properly [13]. The disadvantages in post-production, consumption and conservation are the matter of scientific research [14]. The adaptation of finger millets to unfavorable climatic and soil conditions makes it suitable to grow in arid and semi-arid regions which are low with water availability. Additionally, the low glycemic index and delayed release of glucose (because of slower digestion) of finger millet proves to be beneficial for diabetic patients. Tef has come into limelight due to lack of gluten [15].

Fig.1: pearl millet (*Pennisetum glaucum*)

2. Bambara groundnut (*Vigna subterranean* L.)

Bambara groundnut is a member of family Fabaceae which is grown primarily due to significant quantities of carbohydrates, protein and fat. It is a herbaceous annual legume with compact tap root system and numerous geotropic lateral roots. The trifoliate leaves bear a stiff and thickened petiole at the base. The peduncle bears two papilionaceous yellow flowers. Peduncle elongates during pollination and fertilization to bring the ovaries to ground level. It forms pods on or just below the ground surface as in Fig. 2. Tropical regions of Sahara has cultivated Bambara groundnut since centuries. It is also grown in Eastern Africa, Madagascar and parts of South and Central America. The seeds have generally been utilized for human consumption and to feed chicks. The knowledge and cultivation of Bambara groundnut is limited and only small-scale farmers grow it in rural areas of Savannah. The flour from seeds can be used to make cakes. Farmers are encouraged to grow this crop because it is an exception of complete nutrients which lays a strong foundation of good human health. The seeds contain amino acids other than methionine which may not be found in any other bean. The above mentioned bean has been helpful in providing complete nutrition as cereals alone do not fulfill all the nutritional requirements of the human body. Kwashiokar, a protein deficiency disease in children has proven to overcome by including bambara groundnut in traditional diets in the rural areas of sub-Saharan Africa. The medicinal benefit of the plant has been exhibited by use in traditional medicine therapies. The ethno-botanical survey showcases the medicinal advantages of this plant, for example, it has been helpful as remedy for internal bruising, cataracts and diarrhea. Till date, no toxicity and potential health hazards have been published from bambara groundnut [16].

Fig. 2: Bambara groundnut (*Vigna subterranean* L.)

3. Winged bean (*Psophocarpus tetragonolobus*)

Asparagus pea, winged bean or Goa bean belongs to family fabaceae with longitudinal winged pods, tuberous roots and both growth forms (annual and perennial) (Fig. 3). It grows in hot and humid countries where growing soybean is difficult. It gives both economic and ecological benefits. Mentioning the fact, that all the parts of the plant can be utilized, it has earned the titles 'supermarket on a stalk' and 'one species supermarket'. It also improves the soil by nodulating more than the other legumes. The seed contains comparatively more protein (33.8%) than lima beans (23.3%), cowpea (22.5%) and pigeon pea (22.4%) and almost similar to soybeans. The carbohydrate content is higher (23-40%) in winged beans whereas sulfur containing amino acids are limiting as compared to other legumes [17], [18]. To fulfill human diet, vitamins (Vitamin A, B1, B2, B3, B6, B9, C and E) and minerals (K, Ca, P, Mg, Na, B, Zn) are present in adequate quantity. Some of the anti-nutritional factors present in winged bean like phytate (interferes with dietary minerals), trypsin inhibitors, hemagglutinins and chymotrypsin inhibitors are found in extensive quantities. Autoclaving winged bean's flour can inhibit the activity of trypsin (30-40%), chymotrypsin (15%) and hemagglutinin (75-96%). Commercially, winged bean tofu, snack foods, coffee substitute, curd, etc. have been tested in Thailand and Ghana. The oil extracted from seeds, has been used as a substitute for oil, especially in fried foods. Thus, attempts should be made to extend commercialization of winged bean so that new opportunities to use the plant can be explored [19].

Fig. 3: Winged bean (*Psophocarpus tetragonolobus*)

4. Taro (*Colocasia esculenta*)

A tropical tuber (Fig. 4) belonging to family Aracea, it is mostly grown for its underground corms. Taro is a wonderful source of carbohydrate, with starch content of 28.3% in pink colored and 27% in white colored taro. The starch granules are easily digestible thus, various food products can be obtained. The two beneficial components are extracted: starch and mucilage. The starch is resistant in nature, i.e. it is slowly digested in lower gastrointestinal tract of human which delays the absorption and liberation of glucose in blood thus, reduces the risk of diseases [20]. The mucilage contains angiotensin which has antioxidative activities. Being a carbohydrate source, roots and tubers do not contain gluten which reduces the chances of celiac disease (CD) [21]. The content of protein and fat are low but it is a rich source of Vitamin B1, B2, B3, C, phosphorus, calcium, iron which are essential for the human diet. The acridity factor in taro causes itchiness and inflammation to consumers. It may even give sharp irritation and burning sensation in throat or mouth. It is assumed to reduce by peeling, soaking, grating, fermentation or baking with ethanol [22], [23]. The anti-nutritional factors, trypsin inhibitor activity and oxalate contents of corm interfere with the bioavailability of other important biological compounds [24], [25]. The oxalate is responsible for the acridity in Taro. Various food products are extracted from taro, such as flour (which helps in preparation of cookies, noodles and pastes) and ice cream products. The taro promises high economic benefits, if the production is increased by technology and consumer acceptance [26].

Fig. 4: Taro (*Colocasia esculenta*)

5. Moringa (*Moringa oleifera*)

Moringa tree (Fig. 5) has been recently studied for its medicinal properties. Belonging to family moringaceae, it is native to foothills of Himalaya and north-west India. Since ancient times, leaves of moringa have been included in diet to keep up with the mental health. All the plant parts of moringa are valuable in food and medicine for humans as well as animals. The seed oil contains high amount of oleic acid, which is highly preferable to use in medicines. The nutrient content of the plant is high, such as proteins, carbohydrates, fiber, vitamins, fat and essential amino acids [27], [28]. The plant is used to overcome deficiencies of vitamins and minerals in different parts of the world. Various dishes can be prepared from the immature pods like dal, corma and cutlet. The powder of leaf, flower and seed can be used in various food applications like breads, cake, cheese, yoghurt, biscuits and soups. The study of moringa shows numerous therapeutic activities like antibacterial activity (against gram-positive and gram-negative bacteria), anti fungal activity (against *Penicillium* sp., *Rhizoctonia solani*, *Aspergillus flavus*, etc.), anti-viral activity, anti-diabetic, anti-oxidant, anti-inflammatory, anti-parasitic, anti-cancer and anti-tumour activities. Moringa acts as a great substitute against alfalfa and oil seed cakes for the fodder of grazing animals due to its high protein and low antinutritional content. The unsaturated methyl esters of seed oil prove to be beneficial in biodiesel production [29].

Fig. 5: Moringa (*Moringa oleifera* Lam.)

6. Jatropha (*Jatropha curcas*)

Belonging to Euphorbiaceae family, jatropha is a large shrub with about 5-7 meters in height. It is native to Mexico, Brazil, Peru, Bolivia, Paraguay and Argentina in distribution but now it has pantropical distribution.

It has deep taproots and shallow lateral roots which prevent soil erosion and landslides and smooth surfaced leaves. It is a monoecious plant with terminal inflorescence that forms ellipsoidal fruits after pollination (Fig. 6). Seeds contain certain toxins like curcin, lectin, phytates, trypsin inhibitors and phorbol esters, which should be detoxified before consumption of seed cakes. It can grow in wide range of soils where sandy or gravelly soils are preferred with well drainage and good aeration. It has low nutritional requirements with maximum pH of 9. It requires Ca and Mg fertilizers in case of low pH. The use of Jatropha has been promoted for the production of biodiesel alternative to sugarcane and maize [30]. The seeds are harvested when mature for the best oil yields. The seeds turn yellow brown from green in maturity. The seeds (whole seeds or kernels) are oven dried or sun dried before being exposed to mechanical expellers.

Fig. 6: Jatropha (*Jatropha curcas*)

The chemical extraction (n-hexane method, use of alkaline protease or solvent extraction) uses only kernels as feed. The oil-quality is dependent on more of environmental factors (seed-size, seed-weight, oil content) than genetic factors. The oil extracted is further processed into bio-diesel through transesterification. The oil is transesterified to methyl esters and glycerol. The caloric value of Jatropha bio-diesel is lower than conventional diesel and causes less NO_X emissions [31].

Conclusion

Plants have been inevitable part of human civilization serving as food and feed to animals as well. The dominance of certain plants on the land has led to their exploitation. To ensure food security, there is need to find the substitute which provide with nutrition and act as medicine too. Modern agricultural demands to tackle the challenges imposed by already-known staple crops, plants need to be grown which are recently cultivated by small-scale farmers to provide with economic and sustainable future. These plants might be under-used in some part of the world, but their local adaptation to climate fetches the optimal yield without any external efforts. Genetic conservation and improvement of such crops will provide a better alternative for staple crops of future. The crops can be utilized as food, feed, medicine and bio-energy crops.

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