additional benefit from sugar and by-products was estimated to be ₹ 7199 crores per year. During this period, Co 0238 has fetched an additional return of ₹ 14,381 crores to the farmers (from sugarcane and fodder) in Uttar Pradesh, Punjab, Haryana, Bihar and Uttarakhand. As a result, the profit of farmers increased by about ₹ 45,405/ha. The economic surplus model was fitted to estimate the total gain to society/economy due to adoption of Co 0238, and its distribution among consumers and producers. Accordingly, the total annual economic gain (surplus) was Rs 10,064.3 crores, distributed in the share of 40 : 60, between the consumers and producers respectively.

In the context of the Government of India's priority of doubling the income of farmers, Co 0238 has made a significant contribution. Mere cultivation of Co 0238 brings ₹ 45,405/ha additional income and with the adoption of more crop husbandry packages, including intercropping and wide row spacing, Co 0238 has the potential of multifold increase in the income of farmers, as has already been demonstrated by 12 farmers associated with ICAR-SBI.

Co 0238 has greatly contributed towards achieving the 32.1 mt sugar production (about 7 mt in excess than the consumption) in the country during 2017–18, which in turn led to a policy decision by the Government on permitting direct conversion of sugarcane juice into ethanol. Recent reports are more encouraging. A record sugar production of 33.2 mt was reported during 2018–19 season.

Aforesaid analysis illustrates how a single technology could bring about tremendous impact at the national level. Co 0238 thus has brought in a 'sweet revolution' benefitting lakhs of farmers, and for the sugar industry which has been in the doldrums, this variety is bringing fresh cheer and hope. Crossing the zonal boundaries, this wonder variety continues to elevate the living conditions of lakhs of Indian sugarcane farmers. Co 0238 thus stands as a quotable example of the power of plant breeding to bring about drastic surge in agricultural production and farmers' economic condition, thereby improving the national economy. A technology easily acceptable, and cheaply adoptable, varieties like Co 0238 reinforces the need for investments in plant breeding research to reap multifold benefits to agrarian countries like India.

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Imported superfood quinoa versus Indian nutricereal millets

Annvi Dhaka and Manoj Prasad

Millets are highly nutritious cereal crops that have been the traditional crops of our ancestors for ages. However, with the popularization of other cereal crops, we started to lose interest in these nutritious traditional crops irrespective of their numerous health benefits. Further, the absence of adequate processing technologies and government policies have added to this negligence. In addition to this, globalization has introduced foreign cereals to Indian markets. There is a need to emphasize the development and proliferation of millets since these crops are capable of fulfilling nutrient requirements of every section of society and are well suited to the geographical conditions of our country.

Superfoods are those food items that are either nutritionally rich or contain bioactive phytochemicals and provide added health benefits[1]. This definition allows including grains like millets, quinoa, oats, amaranth, chia seeds, banana, avocado, spinach, berries, lentils and many others into the category of superfoods[2]. Increasing research and awareness have inspired people around the world to include superfoods in their daily diets. Globalization has allowed people the option to choose among various types of superfoods outside their geographical boundaries (https://agritrop.cirad.fr/575493/). This has flooded the food markets with all kinds of superfood varieties of the world. Big brands such as Quakers and Kellogs have been successful in making oats, quinoa, and similar products accessible to the Indian consumers. On the other hand, native varieties of superfoods like millets and amaranth are still struggling to make it to the shelves of shops and homes. Among various grains of foreign origin, quinoa and oats have captured a significant portion of the Indian food market.

Quinoa (*Chenopodium quinoa*) is native to Latin America and has been grown for the last 5000 years. It was still a local crop until the 1990s when research into its potential led quinoa to spread to other countries. Quinoa is a member of the Goosefoot family (Chenopodiaceae) and is considered a superfood because of its high protein value. NASA's CELSS Programme included quinoa feed for long-duration human space flights (https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19940015664.pdf). Due to its excellent nutritional content, the primary use of quinoa seed is consumption. The protein content in quinoa seeds varies from 13.8% to 16.5% (ref. 3). All of the 10 essential amino acids are present in significant amounts in quinoa seed. The carbohydrate source is starch and falls in the range of 58.1–64.2%, with 11% amylose constituent[4]. With high mineral contents like calcium, magnesium, iron, copper and zinc, quinoa can be a constituent of a balanced human diet[5]. When compared to other crops like wheat, rice and barley, quinoa has a high amount of riboflavin (B2), α-tocopherol (vitamin E), and carotene. Oil

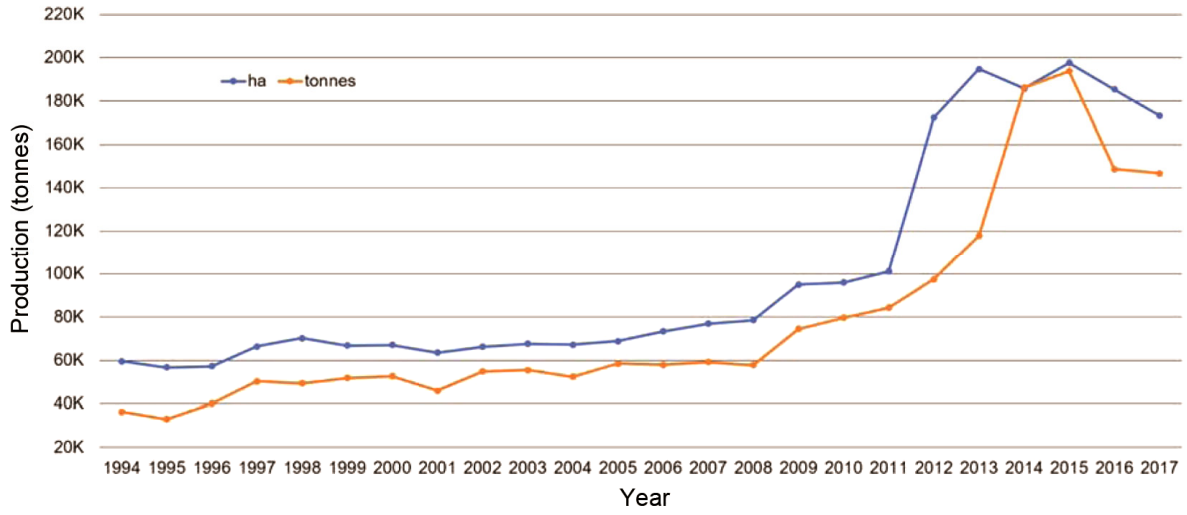

Figure 1. Production (tonnes) and area harvested (hectare, ha) of quinoa from the year 1994 to 2017. (Source: FAOSTAT).

content present is between 1.8% and 9.5%, and an adequate amount of essential fatty acids like linoleic acid and linolenic acid adds more to its nutritional value[6].

With advanced studies and interest shown by people the popularity of quinoa started to grow. Hence the number of countries in which quinoa is cultivated increased from eight in the year 1980 to 75 in 2014. Till 2016 more than 100 countries have started growing quinoa[7]. India has also recently joined in, with states like Andhra Pradesh and Uttarakhand emerging as the main cultivators of quinoa in the country. The declaration by the United Nations General Assembly to celebrate the year 2013 as the International Year of Quinoa (IYQ) gave a significant boost to quinoa cultivation. From Figure 1, the worldwide increase in quinoa production is clearly evident after 2013. FAO has also begun to promote quinoa in several countries outside the Andean region.

Quinoa can adapt to a variety of geographical conditions, and it can grow from sea level to 4000 m above sea level[8]. The cold climate to the subtropical environment has been found suitable for its growth. Quinoa requires 150 days of developmental time for harvesting. It is because of this reason that parts of Northern Europe and Canada are unsuited for its growth[9]. Bolivia and Peru are the largest producers of quinoa in the world, accounting for 80% of the total production. Other leading producer countries are USA, Ecuador, China, Argentina, Chile, France and Canada, which contribute to the rest of the world production.

Quinoa cultivation started in a few Indian states with the initial support from state governments, including Andhra Pradesh, Rajasthan and Uttarakhand[10]. In 2013, the Project Anantha experiment was started in the districts of Hyderabad and Anantapur by the state government of the then Andhra Pradesh[11]. The quinoa cultivated in these areas belonged to the Bolivian variety, which can grow in various environmental conditions. During the *rabi* season of the year 2015–16, quinoa was grown in Bhilwara and Chittorgarh districts of Rajasthan in an area of 50 ha. This yielded 18 quintals of quinoa per hectare. Quinoa seeds mini kits were distributed to farmers of 13 districts of Rajasthan in the financial year 2017–18, to promote this crop among farmers to boost their income.

Moreover, even after 71 years of independence, India has not achieved the goal of grain self-sufficiency. One-fourth of the world's hunger population resides in India, which is home to around 190 million poorly nourished people. Further, the problem of malnutrition impacts healthy human development drastically. Children are the primary sufferers of severe malnutrition and under nutrition. As per the Global Hunger Index (GHI, https://www.globalhungerindex.org/results/) which is calculated on the basis of four GHI measures – undernourishment pervasiveness, child stunting, child wasting and child mortality, out of the 119 countries (GHI was not counted for developed countries with low hunger prevalence and countries where data could not be collected due to unrest/violent atmosphere or any other reasons) considered for evaluation, India ranked 102. With a disquieting score of 30.3, India is suffering from a hunger level that is counted in the severe category. According to the Global Nutrition Report 2018, the mortality of children under 5 years was 39.4%, under-5 wasting was 14.5%, and under-5 stunting was 30.2% in India. For the year 2015, 26.6% male population faced high blood pressure issues, while 24.7% of females had problems related to high blood pressure. Around 9.1% males and 8.3% of the female population suffered from diabetes in the year 2011 (https://globalnutritionreport.org/nutrition-profiles/asia/southern-asia/india/#profile). With a change in daily habits and deficient nutrient diets, chronic lifestyle diseases like cardiovascular disease, diabetes, hypertension, obesity are reaching a soaring high. Hence, there is an urgent requirement to search for alternatives that are indigenous to our country and available at affordable prices for every section of society. The best answer to the above problems is our ancient miracle nutri-cereals called millets.

Millet is a common name attributed to a group of small-seeded coarse grains. Earlier, often designated as orphan crops, millets are mostly used in Asian and African countries for food and fodder whereas in American and European

Table 1. Nutritional values of quinoa and other superfoods compared with millets

Food	Carbohydrates	Fibre	Protein	Fats	Ash	Vitamins (mg/100 g)				Minerals (mg/100 g)	
						A	B1	B2	B3	Ca	Fe
Quinoa	64.6	7.0	14.12	6.1	2.8	0	0.36	0.32	1.5	47	4.57
Buckwheat	71.5	10.0	13.25	3.4	2.1	0	0.1	0.43	7.02	18	2.2
Flaxseed	28.9	27.3	18.29	42.2	–	0	1.64	0.16	3.1	255	5.73
Chia seeds	42.12	34.4	16.54	30.74	–	–	0.62	0.17	8.83	631	7.73
Amaranth	65.25	6.7	13.51	7.02	2.9	0	0.12	0.2	0.92	159	7.61
Goji berry	77.06	13.0	14.26	0.39	–	15.2	–	–	–	190	6.8
Wild rice	74.9	6.2	14.7	1.1	–	0	0.12	6.73	6.73	21	1.96
Oats	66.27	10.6	16.89	6.9	–	0	0.76	0.96	0.96	54	4.72
Finger millet	82.2	3.4	8.7	1.8	2.8	6	0.3	0.1	1.4	350	5.0–9.9
Proso millet (dehulled)	80.1	0.7	12.5	4.9	0.8	–	0.41	0.28	4.54	8	2.9
Pearl millet	75.6	2.3	11.6	4.8	2.2	22	0.3	0.15	2.0	25	3.0–9.8
Foxtail millet	66.9	4.1	11.8	4.1	3.3	–	0.6	0.1	0.99	20	4.9
Barnyard millet	74.0	2.0	15	5.2	1.3	–	0.3	0.09	–	210	7.6
Little millet	66.3	7.0	10.7	6.0	5.9	–	0.41	0.28	–	17	–
Kodo millet	73.5	8.4	10.2	3.9	3.6	–	0.2	0.10	–	35	1.7

All values calculated for 100 g grain weight[2].

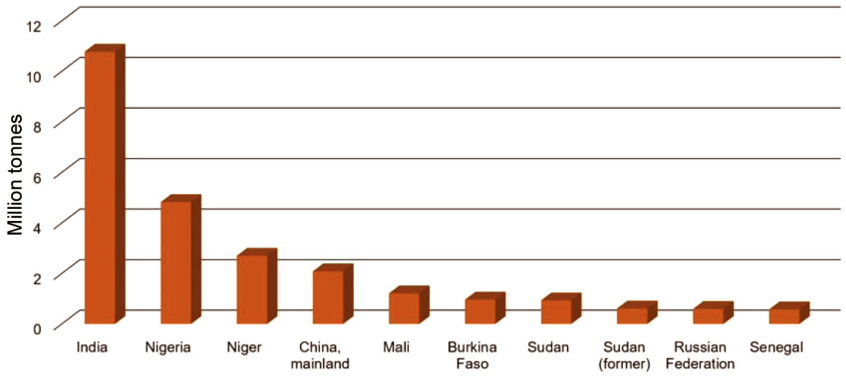

Figure 2. Bar chart showing the top 10 millet producing countries of the world. The average production in tonnes from the year 1994 to 2017 is shown on the *y*-axis (Source: FAOSTAT).

continents, these have been used for poultry. Taxonomically belonging to the Poaceae family, millets include different species which differ from each other at various hierarchies of species, genus or subfamily. Commonly grown millets are pearl millet (*Pennisetum glaucum*), foxtail millet (*Setaria italica*), finger millet (*Eleusine coracana*), proso millet (*Panicum miliaceum*), barnyard millet (*Echinochloa* sp.), kodo millet (*Paspalum scrobiculatum*), tef (*Eragrotis tef*), fonio (*Digitaria* sp.). Millets are C4 crops possessing Kranz leaf anatomy for efficient CO_2 fixation and reduced photorespiration. Due to this reason, millets perform better compared to C3 crops under unfavourable conditions like drought and high temperature, nitrogen, and carbon dioxide limitation and less fertile soil[12]. Further, millets have shorter life cycles, require less input, and show remarkable response to fertilization systems[13]. Millets generally take a short span of 65–90 days from sowing to seed harvesting stage. Therefore, millets can be of significant utility to the farmers dwelling in dry, desolate and infertile lands.

India is the largest producer of millets amongst all the 89 millet producing countries (Figure 2). For the year 2017, India accounted for a 31.96% share of the whole millet produced worldwide (http://www.fao.org/faostat/). The production of millet in India has increased by 12.24% in the year 2017 (11.56 million tonnes) compared to 10.29 million tonnes in 1994. However, the area under millet cultivation in India for the aforementioned time period has dropped by 34% from 13.77 million hectares (m ha) in 1994 to 9.09 m ha in 2017. This has been due to 70% increased productivity in 2017 from the year 1994 (http://www.fao.org/faostat/). However, before the 1970s, millets were consumed as a staple food, but over the years, due to accessibility to other commercial staple crops like wheat and rice, its consumption decreased[14].

Millets are a source of high nutritional value diets (Table 1). Most of the millets have gluten-free grains, although proso millet and foxtail millet contain both gluten as well as non-glutenous types of grains[15]. Millets are proteinous grains with high crude fibre content, optimal fat content and are rich in minerals and vitamins. Millet proteins are a rich source of essential amino acids except for threonine and lysine, although rich in sulphur-containing amino acid methionine and cysteine[16]. Millets are rich in dietary fibres, and it has been reported that little millet and kodo millet have significantly high dietary fibre of 38% and 37%, along with higher amount of polyunsaturated fatty acids[17]. The attribute of high dietary fibre and low glycaemic index adds to the nutraceutical value of these grains. The admirable nutritive values of these crops are also strengthened by high mineral levels of zinc, calcium and iron, and high levels of phytochemicals[18]. Millets are a good source of phytochemicals like phenolics (ferulic acid, protocatechuic acid), lignans, phytates and sterols[19]. Pearl millet has been reported to be significantly rich in dietary fibres, resistant starch, antioxidants and minerals[20]. It has been reported that

higher calcium levels, soluble dietary fibres, and lower glycaemic index of finger millet helped reduce blood glucose levels in diabetic patients[21]. In another report, it was identified that the addition of millet protein to diabetic patients' diets reduced blood glucose level, showed higher insulin sensitivity and increased their high-density cholesterol[22]. Further, it has been reported that when type 2 diabetes patients were supplemented with foxtail millet, they showed better glycaemic control after 90 days of supplementation[23]. Finger millet has been reported to lower high blood pressure and the risk of heart attack[24] and has shown a considerable effect on blood plasma and has helped in the reduction of LDL cholesterol by 9% and triglycerides by 15% (ref. 25). Also, finger millet possesses other health attributes, like anticancerous properties, anti-inflammatory and platelet aggregation inhibitory activity[26]. There are reports which support the benefits of millets in preventing the occurrence of many diseases like cardiovascular diseases and cancer. They also help in reducing high blood pressure and risks of heart diseases, lowering cholesterol levels, improving gut health[15].

The government of India launched a project in 2011–12 under Rashtriya Krishi Vikas Yojana (RKVY) called the initiative for nutritional security through intensive millets promotion (INSIMP). The main objective of this scheme is to achieve increased millet production through improved productivity and better post-harvesting technologies. One of the reasons that restrain millet consumption is its poor processing. The project also includes the supply of better processing techniques/equipment to Krishi Vigyan Kendras (KVK), entrepreneurs, and NGOs. (http://nfsm.gov.in/Guidelines/DRAFTguidelines%20of%20Initiative%20for%20Nutritional%20Security%20through%20Intensive%20Millets%20Promotion.doc-1.pdf). Furthermore, schemes like the International Development Research Centre (IDRC) and CIDA (Canadian funds) have also been introduced to scale millet production and consumption. These schemes also assist through funding the Revalorizing Small Millets in the Rainfed regions of South Asia (RESMISA) initiative. Indian Institute of Millet Research (IIMR) has been working to commercialize and promote millet for end users. Other schemes like the National Agriculture Innovation Projects led by ICAR, All India Coordinated Project in Home Science, and other policy initiatives are working to include millets in mid-day meals, promote nutri-farms, and procure support to millets (http://millets.res.in/vision/vision2050.pdf). To promote millets, the year 2018 was observed as the National Year of Millets in India. India has proposed to celebrate the year 2023 as International Year of Millets to the Food and Agriculture Organization (FAO) Council at their 160th session organized in (http://www.fao.org/fileadmin/user_upload/bodies/CL_160/MY336_13/MY336_CL_160_13_Rev1_en.pdf). Further, there is a need for increasing demand in the consumers and subsequently expanding the supply to meet the requirements. Apart from the consumption aspect, other areas can also be explored like animal/poultry feed, industrial ethanol production, alcohol production and biofuel production.

The nutritional qualities of millets are comparable to quinoa. Although quinoa outweighs millets in many nutritional attributes, its prices make it unaffordable to everyone, especially when the main category of people suffering from malnutrition is the low-income population. Therefore, Indians need to favour millets that are more affordable, have shorter life cycles, indigenous to the country, and support the local farmers. There is a need for more scientific data and studies for millet improvement along with enhanced technology, and engineering in millet post-harvesting and grain processing. Collaborative efforts are required from food technologists, policy-makers, governing bodies, media, and people to revive the ancient nutricereal millets.

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