



Rice bean: A healthy and cost-effective alternative for crop and food diversity

Piverjeet Kaur Dhillon¹ · Beenu Tanwar²

Received: 8 April 2017 / Accepted: 23 April 2018

© Springer Science+Business Media B.V., part of Springer Nature and International Society for Plant Pathology 2018

Abstract

Rice bean (*Vigna umbellata*), an underutilized grain legume or pulse, is often considered a minor crop in Nepal and Northern India. Rice bean is attracting attention worldwide owing to its high yielding ability, resistance to viral, fungal and bacterial diseases, adaptability to grow in less-fertile lands, simple domestic processing and good nutritional potential, which help to make it an affordable substitute for conventional pulses. However, the presence of some anti-nutritional factors such as phenols, saponins, phytic acid, and enzyme inhibitors limit its usage, but simple domestic processing methods such as sprouting, pressure cooking and fermentation can alleviate these problems and enhance its nutritional adequacy. Rice bean can be cultivated in a range of soils to produce high quality grain as well as highly nutritious fodder for livestock, and thus a synergistic effect can be achieved for both human and animal nutrition. Although a multipurpose crop, little has been done to assess its field diversity, to develop high yielding varieties, or to tap its potential in terms of commercial importance and market value. Further research and promotion of rice bean could play a significant role in a diversified sustainable approach to alleviate the global problem of protein and energy malnutrition.

Keywords Rice bean · *Vigna umbellata* · Domestic processing · Nutritive value · Food security · Nutritional security

1 Introduction

Pulses and grain legumes are important constituents in the diets of people residing in developing countries (Katoch 2013). Apart from adding variety to the diet, grain legumes are a low cost source of dietary protein and other nutrients and hence, are often termed ‘poor man’s meat’ (Modgil et al. 2012; Thongram et al. 2016). Dry beans such as mung bean and black gram hold a prominent place in India (Goyal et al. 2014; Goyal and Siddiqui 2014) whereas chickpea, pigeon pea and lentil are the other most consumed pulse crops around the world. However, due to their cultivation on poor soils and susceptibility to biotic and abiotic stresses their productivity is usually low, and thus, it is difficult to meet the increasing demands of an expanding human population, both in

developed and developing countries (Sultana et al. 2014). Present over-reliance on these few major staple legume crops has unsustainable agronomic, ecological, nutritional and economic risks which can only be addressed by utilizing improved cultivars, modern production technologies and expanded cultivation of underutilized minor crops (Schmidt et al. 2010). Crop diversification provides opportunities to introduce temporal and spatial heterogeneity into uniform cropping systems and will help develop resilience to biotic and abiotic stresses. Additionally, underutilized legume crops are a source of essential vitamins, micronutrients and protein and, thus, a valuable component for helping to attain nutritional diversity and security. One such underutilized legume, rice bean (*Vigna umbellata*) (Fig. 1), has great potential for complementing traditional pulses in terms of both its nutritional and economic potential.

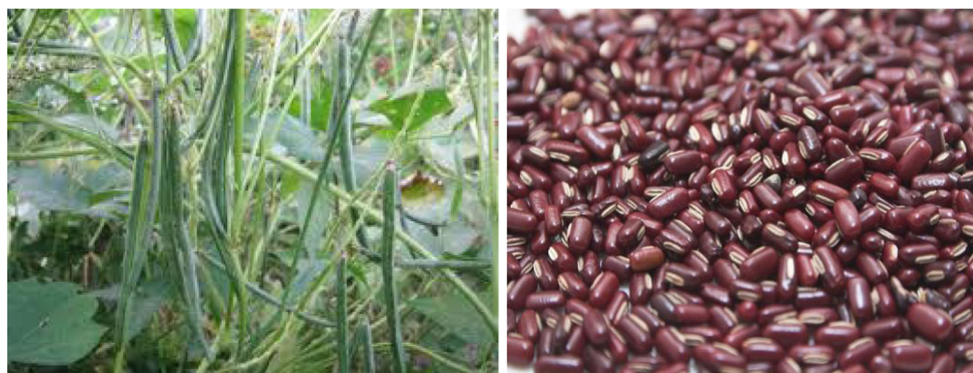
Rice bean is a warm-season annual legume crop with yellow flowers, which is mainly used as a dried pulse and can also be used for fodder and green manure. Traditionally, it is grown as an intercrop with cowpea, maize and sorghum in India, Nepal, China and Bangladesh. Rice bean is thought to be the outcome of cross-fertility of a wild species, *Vigna umbellata* var. *gracilis*, which is naturally found in southern China, northern Vietnam, Laos, Thailand, Burma and India (Tomooka et al. 1991). Recently, owing to its nutritional

✉ Beenu Tanwar
beenutanwar@gmail.com

¹ Department of Food Technology and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab 144411, India

² Department of Dairy Technology, Mansinhbhai Institute of Dairy and Food Technology, Dudhsagar Dairy Campus, Mahesana, Gujarat 384002, India

Fig. 1 Rice bean (*Vigna umbellata*) plants and seeds



properties it has been further domesticated in south-east Asia and north-east Asia. Rice bean has several other names, including red bean, climbing mountain bean, mambi bean, oriental bean, ohwi, ohashi, *Dolichos umbellatus* Thunb., and *Vigna calcarata* (Roxb.) and Kurz.

Rice bean has been classified as a crop well adapted to sub-humid regions with 1000–1500 mm precipitation, along with other adaptations to such factors as rainfall pattern, moisture distribution, temperature, cloud cover and relative humidity, soil characteristics, pests and diseases (Rachie and Roberts 1974). Appreciable levels of crude protein with 59–93% protein digestibility and all essential amino acids (especially methionine, tryptophan, lysine, tyrosine and valine), minerals, vitamins, and a relatively high proportion of healthy, unsaturated fatty acids make it a nutritious health package (Kaur and Kapoor 1990; Mohan and Janardhanan 1994; Katoch 2013).

Despite possessing enormous potential to mitigate economic and nutritional deficiencies, lack of scientific research and consumer awareness has limited consumption to some local communities of a few developing countries such as India and Nepal and has prevented its global commercialization (Buergelt et al. 2009). Hence, there is need for a review of recent scientific knowledge related to rice bean as a source of food and nutraceutical compounds to aid nutritional security and extension and crop improvement programs.

The taxonomic description of rice bean is:

Kingdom	: Plantae
Sub kingdom	: Tracheobionta
Super division	: Spermatophyta- Seed plants
Division	: Magnoliophyta- Flowering plants
Class	: Magnoliopsida- Dicotyledons
Sub class	: Rosidae
Order	: Fabales
Family	: Fabaceae- Pea family
Genus	: <i>Vigna</i> Savi- Cowpea
Species	: <i>Vigna umbellata</i>

Source: Anonymous (2016)

2 Cultivation

Rice bean is mostly cultivated on small areas of land by poor hill farmers of Northern Nepal, North-east India and various parts of South-east Asia (Mukherjee et al. 1980; Singh et al. 1980; Saikia et al. 1999). Earlier, rice bean was cultivated as a lowland crop using residual soil water after the harvest of long-season rice. Later, it was shifted to the lands where shorter duration rice varieties were grown. Recent studies have documented that it establishes rapidly and thus can be grown effectively on a wide range of soils under high temperatures and low rainfall conditions (Kaur et al. 2013; Katoch 2013; Chandel et al. 1978). Also it has the potential to produce high yield and high quality grain along with nutritious fodder for cattle (Anonymous 2016).

Some important factors to be considered for the effective cultivation of rice bean are given below:

2.1 Type of soil

The crop is well-adapted to the humid-tropics, has high local adaptability, and can be grown with little effort and few inputs in diverse conditions including less fertile, exhausted and degraded marginal land, drought-prone sloping areas and un-irrigated ancient alluvial river fans (Joshi et al. 2006). Rice bean can grow in many types of soil, including gray, black, yellow or cream colored soils, while red soils, having moderate fertility status, are considered best for its cultivation (Khanal and Paudel 2009).

2.2 Area and temperature

Rice bean is mainly grown between 700 and 1300 masl, although it is found in home gardens from 200 m up to 2000 m (Anonymous 2016). Most varieties are photoperiod sensitive, tend to flower late and, in areas with ample water and high humidity, can produce excessive vegetative growth. Warm, south-facing aspects are more suitable for cultivation, whereas the crop fails to grow well on highly fertile soils, under shade and in north facing aspects (Khadka and Acharya 2009).

2.3 Time for sowing and cropping pattern

To promote better germination, seeds are typically soaked in water for 10 to 12 h before sowing. Generally, rice bean is grown as an intercrop with maize, thus, sowing usually extends from April to July. In the USA, a range of planting times has been established. For example, rice beans can be directly seeded from April 15 to June 15 in the Mid-Atlantic region, while April 10–30 is optimal for seeding rice bean in the Southeast/Gulf Coast. Southwest and upper Midwest regions are suitable for seeding of rice bean in April–July and June, respectively (Joshi et al. 2006; Ashworth and Whealy 2012). Some studies have shown that different types of cropping pattern are as follows (Khadka and Acharya 2009; Zaman and Malik 2000; Joshi et al. 2006):

- a. *Mixed cropping.* In this most common cropping pattern, seeds of rice bean are dibbled in between maize plants. Those varieties maturing in 140 to 150 days are used for inter-cropping. In relay cropping with maize, rice bean is sown at the margins of the maize field. Generally mixed cropping is employed when rice beans are to be used as grains or seeds.
- b. *Sole cropping.* When rice bean is produced in home or kitchen gardens for consumption by the family, sole cropping is carried out, the green tender beans being used as fresh vegetables.
- c. *Planting on rice bunds.* In this type of system, small-seeded determinate or semi-determinate rice beans are sown on rice bunds and, after vegetative growth, the plants are guided along the slopes of the terraces.
- d. *Margins of uplands (Bari land).* When maize plants attain approximately knee-height, rice bean seeds are dibbled between them. Later, when rice bean vegetative growth is complete, the plants are guided along the slopes of the *bari land* (Khadka and Acharya 2009).

2.4 Harvesting and recommended seed varieties

The crop is ready to harvest in 120 to 150 days after sowing, when approximately 75% of the pods turn brown. To obtain good yields, the pods are generally harvested in two, three or more pickings and are usually collected either in the morning or late afternoon to avoid seed loss due to shattering (Khadka and Acharya 2009). Mostly well-formed and mature grains, free from pest infestation, are selected for sowing instead of immature, shriveled and old grains. Pods for seeds are usually collected from the middle of the plant rather than the upper portion as they have smaller pods with immature seeds. Some important seed varieties of rice bean, developed and analyzed for their yield by the State Agricultural Universities and Institutes of India, are summarized in Table 1.

2.5 Common weeds, pests, diseases, insects and control measures

Weeds are normally not a major problem for rice bean. However, two or three weeding six weeks after sowing and before the flowering stage are considered beneficial. Rice bean is less prone to disease attack than some pulses but a few common diseases and insects, which can harm the crop are given below:

2.5.1 Common diseases (Khadka and Acharya 2009)

- i) *Rust.* This disease caused by *Uromyces appendiculatus* (Pers.) Unger. infects a wide and heterogeneous range of hosts, from primitive ferns to vegetables, grain crops, ornamental plants and forest trees. It is characterized by whitish, minute and slightly raised pustules on the leaves of the rice bean plant, which slowly turn reddish-brown. To overcome this problem, Maneb (Indofil M 45) can be sprayed at the rate of 3 g/l of water before or immediately after the appearance of rust pustules.
- ii) *Powdery Mildew.* The causative agent is *Oidiopsis taurica* (Lev.) Salmon. Powdery mildew appears as a white powdery coat on the leaves, stem and pods which gradually turn yellow, they dry brown, then die and fall off, resulting in reduced yields, shortened production times, and fruit that has little flavor. Application of Triadimefun Bayletan 25% EC and Carbendazin 0.5 g/l of water has proved beneficial against this disease.
- iii) *Rhizoctonia Blight.* This disease occurs due to the attack of a soil-borne pathogen, *Rhizoctonia solani*, on leaves and pods of the plant. The disease is characterized by the appearance of small, pale greenish spots on leaves and pods resulting in shriveling, browning and drying. It can be effectively controlled by spraying Bavistin at the rate of 1 g/kg of seed.
- iv) *Bacterial Blight.* *Pseudomonas spp.* is responsible for this seed-borne disease, which is characterized by small, round, irregular or flat spots surrounded by greenish-yellow zones on leaves. This can be prevented by using disease free seed or the seeds can be treated with streptomycin.
- v) *Cercospora Leaf Spot.* This disease is caused by *Cercospora spp.* (Deuteromycetes group) and is characterized by small, dry spots on leaves. It can result in significant losses unless protectant fungicides are used as a preventive treatment prior to infection and symptom development. Maneb (Indofil M 45) can be sprayed at the rate of 3 g/l of water before or immediately after the occurrence of dry spots.

Table 1 Various seed varieties of rice bean from India

Variety	Developed by	Average yield t/ha	Recommended area	Salient features
BRS 1	NBPGR, Bhowali	1.7	Hilly region	Black seed color, high seed yield
PRR 1	GBPUA&T, Ranichauri	1.6	Hills of Uttarakhand	Mature in normal duration, high seed yield
PRR 2	GBPUA&T, Ranichauri	1.5	North-west hilly region	Mature in normal duration, high seed yield
RBL 1	PAU, Ludhiana	1.5	Punjab state	Normal duration, high seed yield
RBL 6	PAU, Ludhiana	1.8	Plains	Normal duration, high seed yield
RBL 35	PAU, Ludhiana	1.5	Plains	Early maturing
RBL 50	PAU, Ludhiana	1.55	Plains	Normal duration, high seed yield, green colored seed

Source: Dua et al. 2010

2.5.2 Common insects (Khadka and Acharya 2009)

- i) *Pod borers. Helicoverpa armigera* Hubner and *Lamides boeticus* L are major pests of rice bean. They cause 77% damage to the pods and 43% damage to grains. These insects lay eggs in small clusters of 10 to 15 on leaves, buds and flowers. The larvae are more destructive than adults and feed from inside the webbed mass of leaves, buds and pods. Margosom Nemarkin spray at the rate of 1.5 ml/l of water is prescribed for *Helicoverpa* and Neem (*Azadirachta indica*) based pesticides or Malathion (0.05%) for *Lamides*.
- ii) *Soybean caterpillar. Hairy Spilarctia casignata* Kollar attacks the lower surface of the leaf of rice bean and the leaf gradually turns papery brownish-yellow in color. It is a serious pest of beans: however, it can either be controlled manually by collecting or destroying the infested plant parts, eggs and young larvae or by spraying artificial Pyrethroids such as Deltamethrin, Cypermethrin or Fenvalerate, or by using Neem.
- iii) *Banded blister beetle, Mylabris pustulata* Thunberg. These are fast moving insects that feed on the flowers and foliage of rice bean. They cause direct damage by feeding on petals, anthers and pollens, thus affecting the yield considerably. Studies on crop losses under field conditions showed that blister beetle caused up to 36% damage to flowers and 53% losses in yield with 1.96 beetles per plant in pigeon pea, and 16% damage to flowers and 36% losses in yield at 1.3 beetles per plant on the mung bean crop (Singh 2012). This pest can be controlled by hand picking or by spraying artificial Pyrethroids.
- iv) *Aphid. Aphis craccivora* Koch is one of the most common aphid species. It has a preference for members of the bean family and causes direct damage to plants by stunting and distorting growth. It feeds by inserting its stylet and removing plant sap in large amounts, which encourages the growth of sooty moulds, and thus restricts photosynthesis. As a result plant foliage curls, turns yellow, flowering is delayed and there is shriveling of pods and finally yield reduction. Dimethoate (0.03%) has been useful in lowering the number of aphids.
- v) *Pod bugs. Anoplocnemis spp.* suck the sap from immature seeds within the pod; consequently the seeds wrinkle and black spots appear due to which seeds lose their ability germinate and are considered unfit for human consumption. Dimethoate and Monocrotophos are effective against this insect.
- vi) *Pod weevils. Young, small and coloured caterpillars of Apion spp.* feed on black immature pods while young adults feed on leaves and adult flowers. Thus, the seed yield, seed quality, seed germination, and market value are all adversely affected. No recommended preventive measures exist to date, however, Dimethoate, Monocrotophos and artificial Pyrethroids are considered beneficial.
- vii) *Green bugs. Both nymphs and adults belonging to Stink Nezara spp.* suck sap from leaves, stems and pods making the whole plant weak. Immature pods and fruits become deformed, seeds become flattened, shriveled and germination is also reduced. Manual management by collecting and destroying the nymphs and adults can be performed.
- viii) *Leaf folder. Leaf feeding insect pests are of major importance because of their ability to defoliate or remove the chlorophyll content of leaves leading to considerable reduction in yield. Hedylepta indicata* Fab. is very destructive as it attacks young leaves. It folds the leaf and forms a web of many leaves. Manual and biological control is most effective, however spraying Monocrotophos and Dichlorvos has been beneficial.

3 Germplasm collections

The World Vegetable Centre (formerly the Asian Vegetable Research and Development Center) based in Taiwan has 197 accessions of rice bean, including eight genotypes from Nepal

and 24 from India. Among these, the Indian genotypes IC 7588, IC 8229, EC 18771, and IC 7506 are reportedly less sensitive to photoperiod (Kim et al. 2015). In India, in addition to the National Bureau of Plant Genetic Resources (NBPGR) containing over 1700 accessions from several Asian countries (World Vegetable Centre 2007), there is a collection held at the Indian Institute for Pulses Research, and the NBPGR station at Bhowali, Uttar Pradesh, where over 300 genotypes are maintained. In Nepal, the Plant Genetic Resources Unit of the NARC maintains a collection of some 300 accessions from various parts of the country (Negi et al. 1996).

4 Nutritional composition

In the human diet, legumes are an excellent source of macro-nutrients - not only carbohydrates but particularly protein as well as healthy fats and dietary fiber. They are also a good source of micronutrients and vitamins (see Fig. 2 and Table 2 for a comparison of macro- and micro-nutrients found in rice bean and five other legumes). Absence of allergens or toxins, low levels of flatulence-producing factors and easy removal of anti-nutritional factors by simple domestic processing makes it an excellent choice for enhancing food and nutritional security in both developed and developing nations. Not surprisingly, with so many advantages, rice bean is garnering worldwide attention (Parvathi and Kumar 2006).

4.1 Carbohydrates: Starch, soluble sugar and dietary fiber

Carbohydrates are the major component (50% to 70% of grain dry matter) of legumes and are generally classified as digestible and non-digestible (Bravo 1998). Total carbohydrate content of rice bean is reported to range between 58.15% and 71.99% (Malhotra et al. 1988; Kaur and Kapoor 1992; Buergelt et al. 2009; Sadana et al. 2006; Katoch 2013).

Pulses are good sources of both soluble and insoluble dietary fiber (Ramulu and Udayasekhara Rao 1997) which

includes cellulose, hemicelluloses, pectin, arabinoxylans, beta-glucan, glucomannans, plant gums and mucilages and hydrocolloids, along with smaller but significant amounts of oligosaccharides which are resistant to digestion and absorption but undergo partial or complete fermentation in the large intestine (Cummings and Stephen 2007). The crude fiber in rice bean is reported to range between 3.60% and 5.56%, respectively (Dutta 2000; Buergelt et al. 2009; Katoch 2013; Bajaj 2014). Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) contents of the whole seed of rice bean were 13.0 and 8.5 g/100 g, respectively. Rice bean contains larger amounts of total soluble sugars (5.0–5.6 g/100 g) and non-reducing sugars (4.7–5.3 g/100 g) and less starch (50–55 g/100 g) than faba bean (Saharan et al. 2002 and Katoch 2013). Due to the absence of the enzyme α -galactosidase, oligosaccharides such as raffinose, stachyose, and verbascose cause flatulence in humans. The levels of these oligosaccharides, raffinose (1.56% to 2.58%), stachyose (0.94% to 1.88%) and verbascose (0.85% to 1.23%), in rice bean genotypes, is much less in comparison to soybean (Katoch 2013).

4.2 Proteins and amino acids

Legume crops are important and necessary supplements to other protein sources. The protein content in rice bean seed varies from 14% to 26% (Rodriguez and Mendoza 1991; Kaur and Kapoor 1992; Mohan and Janardhanan 1994; Saikia et al. 1999; Dutta 2000; Saharan et al. 2002; Buergelt et al. 2009; Katoch 2013; Bajaj 2014). Katoch (2013) evaluated 16 different varieties of rice bean and observed the highest protein content to be 25.6% (in the BRS-2 genotype). Katoch (2013) recommended BRS-2 as a highly suitable variety for human consumption. Parvathi and Kumar (2006) recorded the content of protein in RBL-5 as 19.5% in the whole bean and 17.5% in *dhal*.

Proteins are usually classified on the basis of their solubility as water-soluble albumins, salt-soluble globulins, alcohol-soluble prolamins, and acid- or alkaline-soluble glutelins (Utsumi 1992). In rice bean, the composition of various

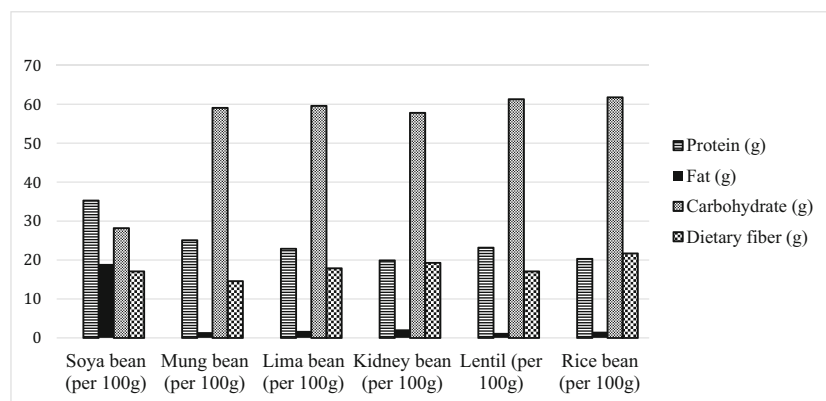


Fig. 2 Macro-nutrient composition of the most-consumed legumes (g/100 g). Source: Anonymous 2004

Table 2 Micro-nutrient content of rice bean in comparison with other pulses and legumes

Nutrients	Soya bean (per 100 g)	Mung bean (per 100 g)	Lima bean (per 100 g)	Kidney bean (per 100 g)	Lentil (per 100 g)	Rice bean (per 100 g)
β -carotene (μ g)	6.0	150	0.0	12	28	22
Vitamin- E (mg)	3.6	0.9	0.5	0.3	1.4	0.7
Vitamin- K (μ g)	18	16	6.0	8.0	14	28
Vitamin- B1 (mg)	0.83	0.7	0.48	0.5	0.55	0.46
Vitamin-B2 (mg)	0.3	0.22	0.18	0.2	0.17	0.14
Vitamin- B3 (mg)	2.2	2.1	1.9	2.0	2.5	1.7
Vitamin- B6 (mg)	0.53	0.52	0.41	0.36	0.54	0.25
Folate (μ g)	230	460	130	85	59	180
Calcium (mg)	240	100	75	130	58	290
Phosphorus (mg)	580	320	200	400	440	340
Iron (mg)	9.4	5.9	6.1	6	9.4	12.5
Zinc (mg)	3.2	4	5.5	2.5	5.1	3
Magnesium (mg)	220	150	170	150	100	230

Source: Anonymous 2004

protein fractions show the globulins (15.56% to 13.11%) to have the highest concentration, followed by albumins (7.47% to 6.13%), glutelins (2.22% to 1.77%), and prolamins (1.97% to 1.45%). Rice bean also contains essential amino acids, including threonine, valine, methionine, isoleucine, leucine, phenylalanine, lysine, histidine and tryptophan in appreciable amounts when compared with other legumes of the family such as mung bean, moth bean, black gram, cowpea and kidney bean (Gopalan et al. 1976; Katoch 2013). Cystine, methionine and tryptophan in rice bean were reported to be in the range of 30.1 to 89.4 mg/g N, 64.6 to 130.1 mg/g N and 53.0 to 102.0 mg/g N, respectively (Singh et al. 1985; Hira et al. 1988 and Sadana et al. 2006).

Consumption of protein according to the recommended levels does not ensure the meeting of amino acid requirements, as the protein quality depends on their amino acid composition and digestibility (National Research Council (NRC) 1989). Digestibility of protein is affected by several factors such as fiber, polyphenols, tannins, phytates, oxalates and trypsin inhibitors, which are negatively correlated with digestibility and bioavailability (Admassu Shimelis and Kumar Rakshit 2005; Gilani et al. 2005; 2012). Vegetable proteins have comparatively lower digestibility than proteins of animal origin due to their higher content of anti-nutrients. For example, beans, maize, soy flour, oat meal, rice and wheat have been reported with protein digestibility in the range of 78% to 86%, while eggs, milk, meat and fish proteins have shown digestibility ranging from 95% to 100% (WHO 1985). Rodriguez and Mendoza (1991) evaluated the nutritional quality of rice bean and found 82–85% digestibility (in vitro), which was higher than that of mung bean (80%) and cowpea (74%), probably due to lower levels or absence of trypsin

and chymotrypsin inhibitors. However, Katoch (2013) reported lower protein digestibility of rice bean genotypes in vitro ranging from 51.2% to 55.6%.

4.3 Fats

Total fat content (1.92% to 3.42%) is considerably less in rice bean compared with many other legumes, but the composition of fatty acids is excellent with low levels of saturated fatty acids and large amounts of unsaturated fatty acids (Dutta 2000; Sadana et al. 2006; Buergelt et al. 2009; and Katoch 2013). Unsaturated fatty acids are highly desirable for various metabolic functions and rice bean is reported to be a good source of linolenic acid (39.89% to 44.36% of total fatty acids), linoleic acid (17.24% to 18.98%), oleic acid (15.62% to 17.91%), palmitic acid (14.23% to 16.88%), and steric acid (4.36% to 5.87% of total fatty acids) (Pugalenthi et al. 2004; Katoch 2013).

4.4 Minerals

Rice bean contains minerals, including sodium, potassium, calcium, magnesium, phosphorous, zinc, copper, iron, and manganese in appreciable quantities and has been reported to have larger amounts than many other legumes including Phaseolus bean, pea, lentil, cowpea and chickpea (Dutta 2000; Saharan et al. 2002 and Katoch 2013). Calcium, copper, zinc, manganese and iron were reported to be in the range of 179 to 340 mg/100 g, 0.58 to 1.12 mg/100 g, 2.19 to 3.39 mg/100 g, 0.58 to 0.68 mg/100 g and 3.79 to 5.80 mg/100 g, respectively (Parvathi and Kumar 2006; Sadana et al. 2006).

5 Domestic processing of rice bean cultivars

Legumes are among the most versatile and nutritious foods, however, large amounts of anti-nutritional factors (ANFs) pose limitations such as decreasing the protein quality, and low starch digestibility (Negi et al. 2001), or poor mineral bioavailability (Kamchan et al. 2004). Hence, the removal or lowering of these components is essential for the improvement of the nutritional quality and the effective utilization of their full potential as human food. Simple and inexpensive processing techniques are effective for achieving desirable changes in the composition of seeds. Different authors have reported that soaking, cooking and germination improve the quality of legumes because of the removal of some anti-nutritional factors. Among all the domestic processing methods, soaking is the best to minimize anti-nutritional factors such as phytic acid and tannins. Soaking also reduces cooking time and saves fuel (Manoj Kumar et al. 2014). Numerous studies have investigated the influence of processing on the nutritional aspects of rice bean. Bajaj (2014) tested the effect of soaking for 12 h and pressure cooking (for 15 min) on four rice bean varieties (RBL-1, RBL-2, RBL-35 and RBL-50) and found that both methods significantly improved the nutritional composition of the cultivars by reducing their phytic acid, trypsin inhibitor, polyphenol and saponin contents. In another study, Kaur and Kapoor (1990) assessed various domestic processing methods such as soaking, sprouting, ordinary cooking and autoclaving for improving the nutritional quality of both soaked and un-soaked seeds of five high yielding varieties (RB-4, RB-32, RB-37, RB-40 and RB-53). The investigators found that soaking and sprouting not only decreased the anti-nutritional factors but also led to a progressive and significant increase in both in-vitro starch metabolism (from 29.3 mg to 36.5 mg maltose released/g of meal) and protein digestibility (from 57.2 to 62.8%). Kaur and Kawatra (2000) concluded that dehulling results in a significant reduction in raffinose and stachyose content. Germination, followed by pressure cooking with fermentation and frying of fermented batter causes maximum reduction in raffinose and stachyose content.

In another study by the same authors, the bioavailability of zinc in kidney, spleen and liver of rats was assessed by feeding the rats differently-processed rice bean diets, i.e. soaked and pressure cooked; sprouted; sprouted and pressure cooked and dehulled and pressure cooked. Among all the groups, the rats fed on sprouted and pressure cooked rice bean had higher body weights, femur zinc and retention of zinc in liver, kidney and spleen (Kaur and Kawatra 2002a, b).

6 Role in raising food and nutritional security in crop systems

The economic and nutritional importance of legumes is globally recognized and they are thus considered to be a major source of dietary protein in developing countries (Sadana et al. 2006). Although India has a prime position in pulse production, there has been a continuous decline in per capita availability of pulses from 69.0 g/day in 1961 to 39.4 g/day in 2011 (Sachdeva 2014). During the year 2011–12 in India, the production of pulses (17.09 million tonnes) was much less than the requirement (21.3 million tonnes), showing a wide gap between demand and supply (Swaminathan and Bhavani 2013). Several workers have reported that decreased legume consumption due to low purchasing power among poor people leads to several nutritional disorders (Malla 1999; Gebrelibanos et al. 2013; Ricardo 1983; Maphosa and Jideani 2017). Rice bean possesses great potential to fill this need and maintain food and nutritional security if cultivated by farmers in marginal, non-irrigated and currently uncultivated areas as well as contributing to the conservation of biodiversity (Gautam et al. 2007).

Rice bean has the potential to play a major role in intercrop systems, and can also be grown on the edges of terraces or sloping hillsides, as well as on rice bunds and under shifting cultivation on hillsides. At present, it is widely grown as an intercrop, particularly with maize, but in the past it was also widely grown on residual water after rice (LI-BIRD 2008). In addition to the ability of rice bean to utilize atmospheric nitrogen through symbiotic nitrogen fixation (which plays a key role in maintaining soil fertility), it is also effective in mitigating the problem of soil erosion by increasing the organic matter content of soils, which improves the water infiltration and holding capacity of soil and leads to less runoff after rainfall (Fageria et al. 2005). The crop is adaptable, growing where soil moisture stress is a limiting factor for the growth and development of other crops, has high nodulating capacity and is resistant to foliar diseases and stored grain insect-pests (Joshi et al. 2006; Gruere et al. 2006; Buergelt et al. 2009; Gill and Kumar 2017). Furthermore, as indicated earlier, this crop is also tolerant of drought and high temperatures (NAS 1979) and, to some degree, of waterlogging (de Carvalho and Vieira 1996). All of these characteristics may be useful for developing stress tolerant varieties of rice bean for specific areas.

The crop also contributes towards flourishing remote rural markets in developing countries such as India, as the highest mean price (Indian Rupees (INR) 26.40/–) was noticed in villages compared with urban markets of mid-sized towns and large city markets (INR 19.17/– and 21.97/–, respectively (Buergelt et al. 2008). Thus, the crop aids food security for the masses by adding to their food baskets in times of food shortage in areas with limited livelihood options. Although the crop

does not usually contribute directly to household income it does help to decrease expenditure on other pulses, the purchase of seeds for the next season and of animal feed and fodder, and other needs (Otim 2009). Also, it is neither neglected on cultural grounds nor subject to food taboos. Therefore, it holds great potential as a ‘high quality, low cost food’ for vulnerable members of society.

7 Promotion and awareness

The commercialization and consumption of rice bean has received little attention and both farmers and consumers are still largely unaware of its enormous potential to support food and nutritional security. The germplasm base of old varieties should be used to provide diversity in new varieties and flexibility in seed selection. Breeding and on-farm trials should be conducted for the continued improvement and deployment of the crop. Sources of seeds (in networks and markets) should be well located for convenient distribution and availability of seeds. Access can be improved through informing wider groups about the crop, distributing seed kits at fairs and at block level by farm science centers in countries such as India. Furthermore, making farmers aware about local seed production and quality (in terms of germination and disease resistance) is essential. Additionally, timely dissemination of knowledge on the adaptation, growing methods and utilization of rice bean is needed. Non-government organizations can be involved in the marketing process. Value addition and better packaging can also be used in improved marketing strategies. Rice bean should be introduced at popular food outlet chains (Sthapit 2010). For further research, chemical, nutritional and sensory evaluations along with market surveys should all be done for various varieties at specified intervals. The most preferred varieties in terms of their traits and processing should be introduced and extended widely. This could lead to the development of novel foods from rice bean, which may help to reduce malnutrition.

8 Future research

Rice bean is a traditional but underutilized “orphan” pulse in India and Nepal. “Orphan” crops are locally plentiful but globally rare; little scientific information about them is available and their current use is limited relative to their potential (Buergelt et al. 2008). It is essential that the existing germplasm is catalogued accurately and disseminated widely. Although some research has been done on the genetic improvement of rice bean, this crop needs to be further improved by breeding varieties with different

characteristics as a means of generating food and sustainable income for local farmers. The crop also broadens the research options for less-fertile lands such as arid zones of developing countries. In Nepal, for instance, the area of rice bean has been decreasing due to its poor yields (200–300 kg/ha). The Indian varieties reported in this paper have higher yield potential (1500–1700 kg/ha), and these can be introduced into Nepal. There are possibilities of promoting this crop as a low pesticide or organic farming option in developing nations owing to its adequate resistance against viral, fungal and bacterial diseases, and this aspect requires further research.

There is an urgent need to focus on rice bean as a food item and various studies should be undertaken to find the varieties that consumers prefer with better taste and cooking/processing qualities. Additionally, studies can be undertaken on enhancing the bio-availability of nutrients by reducing anti-nutritional factors in the crop. Also, value addition of rice bean can be initiated by incorporating it into traditional food items, which could pave the way for the development of nutritional snack foods, which might achieve both normal and therapeutic nutritional goals. Very little is known about the socio-economic factors of the crop which affect adoption by farmers and far more should be done in this area. A few studies have been carried out in India and Nepal under FOSRIN (Food Security through Rice Bean Research in India and Nepal) and recently a multi-disciplinary research approach focusing on nutritional aspects and socio-economics has been initiated with the aim of improving the status of rice bean in several areas.

9 Conclusion

Dietary diversification along with better associations among crop production, consumption and human nutrition is a cost effective and sustainable approach to tackle malnutrition and strengthen local food systems. Rice bean is a good source of protein, vitamins and minerals, and is suitable for degraded soils and adverse climatic conditions. Its multipurpose uses as human food, fodder and manure represent it as a promising healthy and economic addition to farms in under-developed communities. However, there are many gaps in current research and promotion of rice bean and much more work is warranted. Policies should be developed to facilitate research projects on local underutilized plant species such as rice bean and the participation of farmers in them should be encouraged. To enhance its cultivation, researchers should develop varieties that farmers and consumers prefer and should plan dissemination activities to highlight their value to such people in developing countries that are facing the burden

of malnutrition, including Guatemala, Tanzania, Sierra Leone, South Africa, and India.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

- Admassu Shimelis, E., & Kumar Rakshit, S. (2005). Antinutritional factors and in-vitro protein digestibility of improved haricot beans (*Phaseolus vulgaris* L.) varieties grown in Ethiopia. *International Journal of Food Science and Nutrition*, 56(6), 377–387.
- Anonymous (2004). Food composition database. Laboratory of Food Function, Department of Food and Nutrition, School of Life Studies, Sugiyama Jogakuen University, Japan. http://database.food.sugiyama.ac.jp/index_asia.php
- Anonymous (2016). Natural Resources Conservation Service; United States Department of Agriculture. <https://www.nrcs.usda.gov/>
- Ashworth, S. & Whealy, K. (2012). Seed to seed: Seed saving and growing techniques for vegetable gardeners. Seed Savers Exchange, Decorah, Iowa. ISBN 9781882424580.
- Bajaj, M. (2014). Nutrients and antinutrients in rice bean (*Vigna umbellata*) varieties as effected by soaking and pressure cooking. *Asian Journal of Dairying and Foods Research*, 33(1), 71–74.
- Bravo, L. (1998). Polyphenols: Chemistry, dietary sources, metabolism, and nutritional significance. *Nutrition Reviews*, 56(11), 317–333.
- Buergelt, D., von Oppen, M., & Mueller, R. A. E. (2008). Contribution from economics towards the improvement of an underutilized pulse in India and Nepal. In *Presentation at the International Conference on Agri-Food Business: Global Challenges, Innovative Solutions* held at Halle, Germany.
- Buergelt, D., von Oppen, M., & Yadavendra, J.P. (2009). Quality parameters in relation to consumer's preferences in ricebean. In *Presentation at the International Conference on India*, February 14–16, 2009. Grain legumes: Quality improvement, *Value Addition and Trade* held at IIPR, Kanpur.
- Chandel, K. P., Joshi, B. S., Arora, R. K., & Pant, K. C. (1978). Rice bean: A pulse with high potential. *Indian Farming*, 28, 19–22.
- Cummings, J. H., & Stephen, A. M. (2007). Carbohydrate terminology and classification. *European Journal of Clinical Nutrition*, 61, S5–S18.
- De Carvallho, N.M. & Vieira, R.D. (1996). Rice bean (*Vigna umbellata* (Thunb.) Ohwi et Ohasi). In: Nwokolo E. & Smartt J. (Eds) Food and feed from legumes and oilseeds. Springer, Boston, MA, USA. ISBN: 978-1-4613-8050-4, pp 222–228.
- Dua, R. P., Phogat, B. S., & Raiger, H. L. (2010). *Two decades of coordinated research on Rice bean in India – an overview*. Nepal: A presentation from final workshop in Nagarkot.
- Dutta, M. (2000). *Rice bean in India with particular emphasis on the Himalayan region*. Nepal: A presentation from final workshop in Nagarkot.
- Fageria, N. K., Baligar, V. C., & Bailey, B. A. (2005). Role of cover crops in improving soil and row crop productivity. *Communications in Soil Science and Plant Analysis*, 36(19–20), 2733–2757.
- Gautam, R., Kumar, N., Yadavendra, J.P., Neog, S.B., Thakur, S., Khanal, A., Bhandari, B., & Hollington, P.A. (2007). Food security through rice bean research in India and Nepal (FOSRIN). Report 1: Distribution of rice bean in India and Nepal. Local initiatives for biodiversity, research and Development (LI-BIRD), Pokhara, Nepal and CAZS natural resources, College of Natural Sciences, Bangor University, Wales, UK.
- Gebrelibanos, M., Tesfaye, D., Raghavendra, Y., & Sintayeyu, B. (2013). Nutritional and health implications of legumes. *International Journal of Pharmaceutical Sciences and Research*, 4, 1269–1279.
- Gilani, G. S., Cockell, K. A., & Sepehr, E. (2005). Effects of antinutritional factors on protein digestibility and amino acid availability in foods. *Journal of AOAC International*, 88(3), 968–987.
- Gilani, G. S., Wu Xiao, A., & Cockell, K. A. (2012). Impact of antinutritional factors in food proteins on the digestibility of protein and the bioavailability of amino acids and on protein quality. *British Journal of Nutrition*, 108(2), S315–S332.
- Gill, R. K., & Kumar, A. (2017). Genetic analysis of yield attributes in rice bean (*Vigna Umbellata* Thunb.) under hot and humid climatic conditions. *International Journal of Agriculture, Environment & Biotechnology*, 10(1), 11.
- Gopalan, C., Sastri, B.R., & Balasubramanian, S.C. (1976). Nutritive value of Indian foods. National Institute of nutrition, Indian Council of Medical Research. Hyderabad, India.
- Goyal, A., & Siddiqui, S. (2014). Effects of ultraviolet irradiation, pulsed electric field, hot water dip and ethanol vapours treatment on keeping and sensory quality of mung bean (*Vigna radiata* L. Wilczek) sprouts. *Journal of Food Science and Technology*, 51(10), 2664–2670.
- Goyal, A., Siddiqui, S., Upadhyay, N., & Soni, J. (2014). Effects of ultraviolet irradiation, pulsed electric field, hot water and ethanol vapours treatment on functional properties of mung bean sprouts. *Journal of Food Science and Technology*, 51(4), 708–714.
- Gruere, G., Giuliani, A., & Smale, M. (2006). *Marketing underutilized plant species for the benefit of the poor: A conceptual framework, IFPRI-discussion paper*, 154. Washington, DC, USA: IFPRI.
- Hira, C. K., Kanwar, J. K., Gupta, N., & Kochhar, A. (1988). Cooking quality and nutritional evaluation of the rice-bean (*Vigna umbellata*). *Journal of Food Science and Technology*, 25(3), 133–136.
- Joshi, K.D., Bhandari, B., Gautam, R., Bajracharya, J., & Hollington, P.A. (2006). Rice bean: A multipurpose underutilised legume. 5th international symposium on new crops and uses: Their role in a rapidly changing world. 3–4 September 2007, Southampton University, UK.
- Kamchan, A., Puwastein, P., Sirichakwal, P. P., & Kongkachuichai, R. (2004). In-vitro calcium bioavailability of vegetables, legumes and seeds. *Journal of Food Composition and Analysis*, 17, 311–320.
- Katoch, R. (2013). Nutritional potential of rice bean (*Vigna umbellata*): An underutilized legume. *Journal of Food Science*, 78(1), C8–C16.
- Kaur, D., & Kapoor, A. C. (1990). Some antinutritional factors in rice bean (*Vigna umbellata*): Effects of domestic processing and cooking methods. *Food Chemistry*, 37(3), 171–179.
- Kaur, D., & Kapoor, A. C. (1992). Nutrient composition and antinutritional factors of rice bean (*Vigna umbellata*). *Food Chemistry*, 43(2), 119–124.
- Kaur, M., & Kawatra, B. L. (2000). Effect of domestic processing on flatulence producing factors in rice bean (*Vigna umbellata*). *Molecular Nutrition and Food Research*, 44(6), 447–450.
- Kaur, M., & Kawatra, B. L. (2002a). Effect of domestic processing on zinc bioavailability from rice bean (*Vigna umbellata*) diets. *Plant Foods for Human Nutrition (Formerly Qualitas Plantarum)*, 57(3), 307–318.
- Kaur, M., & Kawatra, B. L. (2002b). Evaluation of iron bioavailability from rice bean (*Vigna umbellata*) by using anaemic rats. *Nutrition Research*, 22(5), 633–640.
- Kaur, A., Kaur, P., Singh, N., Virdi, A. S., Singh, P., & Rana, J. C. (2013). Grain, starch and protein characteristics of ricebean (*Vigna umbellata*) grown in Indian Himalaya region. *Food Research International*, 54(1), 102–110.

- Khadka, K., & Acharya, B.D. (2009). Cultivation practices of rice bean. Research and Development (LI-BIRD), local initiatives for biodiversity, Pokhara, Nepal.
- Khanal, A.J., & Paudel, I. (2009). Food security through ricebean research in India and Nepal (FOSRIN). Report 3. Farmers' local knowledge associated with the production, utilization and diversity of rice bean (*Vigna umbellata*) in Nepal, Pokhara, Nepal. Local Initiatives for Biodiversity, Research and Development (LIBIRD), Rampur, Chitwan, Nepal, Institute of Agriculture and Animal Sciences, and Bangor, Wales, UK, CAZS Natural Resources, College of Natural Sciences, Bangor University. <http://www.ricebean.org/deliverables/deliverable%204%20-%20indigenous%20knowledge.pdf>. Accessed 4 June 2017.
- Kim, S. K., Nair, R. M., Lee, J., & Lee, S. H. (2015). Genomic resources in mung bean for future breeding programs. *Frontiers in Plant Science*, 6, 1–12.
- LI-BIRD (2008). Food security through ricebean research in India and Nepal (FOSRIN). Periodic activity report. Local Initiatives for Biodiversity, Research and Development (LI-BIRD), Pokhara, Nepal.
- Malhotra, S., Malik, D., & Dhindsa, K. S. (1988). Proximate composition and antinutritional factors in rice bean (*Vigna umbellata*). *Plant Foods for Human Nutrition*, 38(1), 75–81.
- Malla, S. (1999). *Child complementary feeding in urban areas of Nepal: Practices and nutritional implications*. Kathmandu, Nepal: Udaya Books.
- Manoj Kumar, A., Panchalaraju, M., & Sai Krishna, S. (2014). Effect of soaking on functional properties of Rice bean - a review. *International Journal of Scientific Research*, 3(9), 1240–1245.
- Maphosa, Y. & Jideani, V. A. (2017). The role of legumes in human nutrition. Functional food- improve health through adequate food, M. Chavarri (Ed), In tech, <https://doi.org/10.5772/Intechopen.69127>. <https://intechopen.com/books/functional-food-improve-health-through-adequate-food/the-role-of-legumes-in-human-nutrition>
- Modgil, R., Mankotia, K., Gupta, R., Malhotra, S. R., & Tanwar, B. (2012). Carbohydrates, minerals, antinutritional constituents and *in vivo* protein quality of domestically processed cow peas (*Vigna unguiculata*). *Legume Research*, 35(3), 214–219.
- Mohan, V. R., & Janardhanan, K. (1994). Chemical composition and nutritional evaluation of raw seeds of six ricebean varieties. *Journal of the Indian Botanical Society*, 73(3–4), 259–263.
- Mukherjee, A. K., Roquib, M. A., & Chatterjee, B. N. (1980). Ricebean for the scarcity period. *Indian Farming*, 30(26), 8.
- National Academy of Sciences (NAS) (1979). Ricebean, Tropical legumes, resources for the future. pp. 80–85.
- National Research Council (NRC). (1989). *Recommended dietary allowances* (10th ed.). Washington, D.C., USA: National Academy Press.
- Negi, K. S., Pant, K. C., Muneem, K. C., & Mal, B. (1996). Evaluation of rice bean genetic resources. *Indian Journal of Forestry*, 19, 156–163.
- Negi, A., Boora, P., & Khetarpaul, N. (2001). Starch and protein digestibility of newly released moth bean cultivars. Effect of soaking, germination and pressure cooking. *Nahrung*, 45(4), 251–254.
- Otim, J.J. (2009). Climate change and agriculture in Nepal: Rice bean as an alternative crop for adaptation, a case of Western development region. M.Sc. Thesis, Bangor University, UK.
- Parvathi, S., & Kumar, V. J. F. (2006). Value added products from rice bean (*Vigna umbellata*). *Journal of Food Science and Technology-Mysore*, 43(2), 190–193.
- Pugalenth, M., Vadivel, V., Gurumoorthi, P., & Janardhanan, K. (2004). Comparative nutritional evaluation of little known legumes, *Tamarindus indica*, *Erythrina indica* and *Sesbania bispinosa*. *Tropical and Subtropical Agroecosystems*, 4(3), 107–123.
- Rachie, K. O., & Roberts, L. M. (1974). Grain legumes of the lowland tropics. *Advances in Agronomy*, 26, 1–132.
- Ramulu, P., & Udayasekhara Rao, P. (1997). Effect of processing on dietary fiber content of cereals and pulses. *Plant Foods for Human Nutrition (Formerly Qualitas Plantarum)*, 50(3), 249–257.
- Ricardo, B. (1983). World needs improved nutrition and the role of vegetables and legumes. Asian Vegetable Research and Development Center, 10th anniversary monograph series, Shanhua, Taiwan, Republic of China.
- Rodriguez, M. S., & Mendoza, E. M. T. (1991). Nutritional assessment of seed proteins in rice bean [*Vigna umbellata* (Thumb.)] Ohwi and Ohashi. *Plant Foods for Human Nutrition (Formerly Qualitas Plantarum)*, 41(1), 1–9.
- Sachdeva, A. S. (2014). Net availability of cereals and pulses. www.data.gov.in
- Sadana, B., Hira, C. K., Singla, N., & Grewal, H. (2006). Nutritional evaluation of rice bean (*Vigna umbellata*) strains. *Journal of Food Science and Technology-Mysore*, 43(5), 516–518.
- Saharan, K., Khetarpaul, N., & Bishnoi, S. (2002). Variability in physico-chemical properties and nutrient composition of newly released rice bean and faba bean cultivars. *Journal of Food Composition and Analysis*, 15(2), 159–167.
- Saikia, P., Sarkar, C. R., & Borua, I. (1999). Chemical composition, antinutritional factors and effect of cooking on nutritional quality of rice bean [*Vigna umbellata* (Thunb; Ohwi and Ohashi)]. *Food Chemistry*, 67(4), 347–352.
- Schmidt, M., Lam, N.T., Hoanh, M.T., Padulosi, S., & Quy, G.L. (2010). Promoting neglected and underutilised tuberous plant species in Vietnam. *Looking East Looking West: Organic and Quality Food Marketing in Asia and Europe*, Wageningen academic publishers, Wageningen, the Netherlands. ISBN: 9789086860951, pp. 183–193.
- Singh, G. (2012). *Crop losses by blister beetle (Mylabris pustulata Thunberg) (Coleoptera: Meloidae) on pigeon pea and mung bean and its management*. PAU Ludhiana, India: Doctoral dissertation.
- Singh, S. P., Misra, B. K., Chandel, K. P. S., & Pant, K. C. (1980). Major food constituents of rice-bean (*Vigna umbellata*). *Journal of Food Science and Technology, India*, 17(5), 238–240.
- Singh, S. P., Misra, B. K., Sikka, K. C., Chandel, K. P. S., & Pant, K. C. (1985). Studies on some nutritional aspects of rice bean (*Vigna umbellata*). *Journal of Food Science and Technology*, 22(3), 180–185.
- Sthapit, B. (2010). How to maximize useful diversity of rice bean and other UPS for the well-being of people: Some inputs for next phase. FOSRIN: Food security through rice bean research in India and Nepal. A presentation from final workshop in Nagarkot, Nepal.
- Sultana, R., Choudhary, A.K., Pal, A.K., Saxena, K.B., Prasad, B.D., & Singh, R. (2014). Abiotic stresses in major pulses: Current status and strategies. In *Approaches to Plant Stress and their Management* (pp. 173–190). Springer India.
- Swaminathan, M. S., & Bhavani, R. V. (2013). Food production and availability – essential prerequisites for sustainable food security. *The Indian Journal of Medical Research*, 138(3), 383.
- Thongram, S., Tanwar, B., Chauhan, A., & Kumar, V. (2016). Physicochemical and organoleptic properties of cookies incorporated with legume flours. *Cogent Food and Agriculture*, 2(1), 1172389.
- Tomooka, N., Lairungreang, C., Nakeeraks, P., Egawa, Y., & Thavarasook, C. (1991). *Mung bean and the genetic resources, the subgenus Ceratotropis*. Tsukuba, Japan: Tropical Agriculture Research Center.
- Utsumi, S. (1992). Plant food protein engineering. *Advances in Food and Nutrition Research*, 36, 89–208.
- World Health Organization (1985). Protein digestibility corrected amino acid score. https://Wikipedia.org/wiki/Protein_Digestibility_Corrected_Amino_Acid_Score
- World Vegetable Centre (2007). AVRDC Vegetable Resources Genetic Resources Information System, <http://avrdc.org/>

Zaman, Q., & Malik, M. A. (2000). Ricebean (*Vigna umbellata*) productivity under various maize-ricebean intercropping systems. *International Journal of Agricultural and Biology*, 2, 255–257.



Piverjeet Kaur Dhillon completed her Masters in Food and Nutrition in 2008 from Punjab Agricultural University, Ludhiana. She has earned experience in clinical dietetics from S. P. S. Apollo Hospitals, Ludhiana and also developed her knowledge and skills in the field of teaching, research and extension while working as a teaching assistant in the Department of Food and Nutrition in Punjab Agricultural University, Ludhiana. Ms. Dhillon has published her original research and re-

view papers in reputed journals along with presenting her work in national and international conferences. Presently, she is a Ph. D student at Lovely Professional University, Phagwara, Punjab, India. Her areas of interest are public health nutrition, dietetics and food product development.



Dr. Beenu Tanwar is an Assistant Professor in the Department of Dairy Technology. Previously, she was an Assistant Professor at Lovely Professional University, Jalandhar, India. She is a researcher and author, having published numerous peer-reviewed articles in the fields of Food Science & Technology and Nutrition. Her Master of Science in Food Technology was awarded by Sri Sathya Sai Institute of Higher Learning, Anantapur, India and her Doctorate in Food

Science and Nutrition was obtained from CSK Himachal Pradesh Agricultural University, Palampur, India. She received a Junior Research Fellowship Award from the University Grants Commission (UGC), New Delhi, India and has attended subject-specific skill-oriented courses, training sessions and several seminars, conferences, and workshops, receiving several best poster paper awards for her presentations. She is a member of the Indian Association for Parenteral and Enteral Nutrition (IAPEN), Indian Science Congress Association (ISCA), Indian Dairy Association (IDA) and Association of Food Scientists and Technologists India (AFSTI). Additionally, she is dynamically involved in teaching (graduate and doctorate students) and has supervised about 15 students for their Masters' and Doctorate research work in Food Technology and Nutrition & Dietetics.