Journal of
Food Chemistry & Nanotechnology

https://doi.org/10.17756/jfcn.2023-s1-033

Review Article

Open Access

A Sustainable Approach in Rice Bean - An Underutilized Potential Multipurpose Grain Legume

Sanchit Thakur[1], Arshdeep Singh[2*], Shimpy Sarkar[3], Anita Jaswal[2] and Iza Fatima[4]

[1]*Department of Plant Breeding and Genetics, MS Swaminathan School of Agriculture, Shoolini University, Himachal Pradesh, India*
[2]*Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India*
[3]*Department of Entomology, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India*
[4]*Department of Entomology and Plant pathology, Oklahoma State University, Stillwater, Oklahoma, USA*

***Correspondence to:**
Arshdeep Singh
Department of Agronomy, School of Agriculture,
Lovely Professional University,
Phagwara, Punjab, India.
E-mail: arshdeep.27269@lpu.co.in

Received: September 18, 2023
Accepted: October 27, 2023
Published: November 01, 2023

Citation: Thakur S, Singh A, Sarkar S, Jaswal A, Fatima I. 2023. A Sustainable Approach in Rice Bean - An Underutilized Potential Multipurpose Grain Legume. *J Food Chem Nanotechnol* 9(S1): S258-S262.

Copyright: © 2023 Thakur et al. This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC-BY) (http://creativecommons.org/licenses/by/4.0/) which permits commercial use, including reproduction, adaptation, and distribution of the article provided the original author and source are credited.

Published by United Scientific Group

Abstract

Background: Rice bean (*Vigna umbellata*) is regarded as a minor food crop in northern India and Nepal and is a neglected legume. The dried seeds are high in nutritional value and are consumed as dal or pulse. Rice beans are an excellent legume crop which produces good yield under a wide range of climatic conditions.

Key features: Rice beans have great potential both for grain yield and forage production and gives descent yield under wide range of climatic conditions. Being a nitrogen fixing legume it can be used as a green manure. In a few areas it is used as a cover crop and is also free from major pests and diseases.

Conclusion: Rice bean is an underutilized multipurpose potential legume crop. Resistancedaptability and resistance to most diseases and pests clearly makes it a crop of choice. Accessions with broad genetic base is the primary need to develop stable high yielding varieties in the crop.

Keywords

Rice bean, Nutritive value, Multipurpose legume, Sustainability approach

Introduction

Like most of the legumes, rice bean (*V. umbellata*) is a warm season annual. Rice beans are perennial legume that typically grows to be between 30 and 100 cm tall but can reach a maximum height of 200 cm. Trifoliate leaves have leaflets that are 6 - 9 cm in length [1]. The brilliant yellow blossom eventually turns into edible fruit. The seeds inside these spherical fruits can range in size from 6 - 8 mm. Rice bean is grown mainly as dried pulse and important as green manure and fodder. Seeds are high in protein and are highly nutritious as they are high in vitamins and minerals. It is cultivated in the countries of Indo-China, South China, Nepal, Bangladesh, and India. Major rice bean farming states in India include Himachal Pradesh, Uttarakhand, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, Madhya Pradesh, and Chhattisgarh [2] as shown in India map (Figure 1).

Apart from many traditional pulse crops, some of the underutilized legume crops such as rice bean have gained importance due to their high nutritional quality (amino acids content shown in figure 2), crude protein (%) (14.00 - 26.10), high grain yield, disease and pest resistance and their multipurpose usage as food, green manure crop, animal feed, etc. [3]. Rice bean is one such underutilized pulse and is a multipurpose grain legume crop. Grains are mostly used as whole dal whereas immature pods and leaves can be used as a vegetable. The green fodder of rice bean contains a higher amount of protein. Other than this, rice bean is



Figure 1: Representing the different states as per the ranking of rice bean cultivation in India.

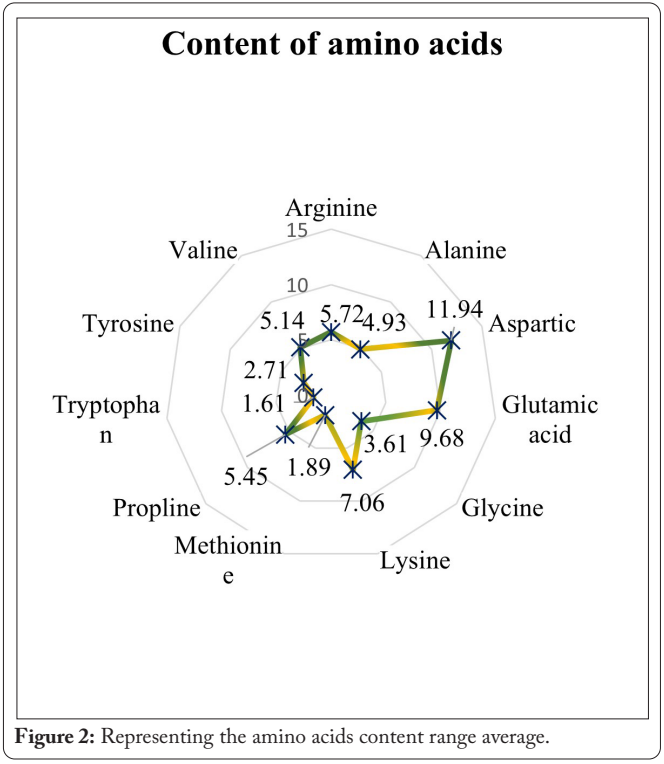

Figure 2: Representing the amino acids content range average.

a potential green manure crop. Rice bean was most probably cultivated in Thailand and neighboring regions and originated from the Indo-China region [4].

Rice beans are a native of Southeast Asia and South Asia. In countries like India, Burma, Malaysia, China, Korea, Indonesia, and the Philippines, it is mainly grown as a cultigen whereas, it is introduced as a cover crop in countries like Fiji, Sri Lanka, Mauritius, Sierra Leone, Ghana, Zaire, Tanganyika, Jamaica, Haiti, and Mexico. It is also cultivated to a limited extent in West Indies, United States of America, Queensland (Australia), and in East Africa [5]. In India, its distribution has mainly been confined to the tribal regions of Northeastern hills, Western and Eastern ghats in peninsular India, often in hilly tracts [6], where it is mainly grown as a cultigen. However, its cultivation and production are limited and restricted to small marginal areas. The effects of different parameters on rice bean cultivation are mentioned in table 1.

Rice bean is a neglected crop which is cultivated mostly as a part of subsistence agriculture in hilly areas of northern India and parts of Southeast Asia [11]. There is scarcity of published literature as far as rice bean is concerned. Crops require minimum or absolutely no inputs and can be grown in exhaustive and marginal soils. The area and production of rice bean in the country is continuously declining due to introduction of high yielding varieties of various crops and easy availability of other pulse crops in local Indian market. There is limited work done for the improvement of rice bean crop regarding plant breeding. Also, there is limited or no institutional support for development and promotion of this crop. Despite all these constrains rice bean can take up the place as a potential food crop and can help in providing improved nutritious diets and food security in different parts of the world with least agricultural inputs figure 1 and figure 2 [12].

Morphology

Rice bean is an annual legume which comes under subgenus *Ceratotropis* within genus, *Vigna* and it forms a complex taxonomic group along with genus *Phaseolus*. This is known as *Phaseolus-Vigna* complex. According to Soni et al. [13], rice bean and its relatives were shifted to genus *Vigna* from genus *Phaseolus.* Singh et al. [8] followed the same proposal and presented a monograph on *Phaseolus-Vigna* complex. In the above monograph, two varieties are recognized, one is *V. umbellata* var. *umbellate* (cultivated rice bean), and another is *V. umbellata* var. *gracilis* (wild ancestor of rice bean) shown in figure 3 [7]. *V. umbellata* is an annual perennial legume. It has variable habit, i.e., it can be erected, semi-erect or twining. It is usually 30 - 10 cm in height, which can go up to 20 cm and is accompanied by an extensive tap root system. It has finely haired branched stems bearing trifoliate leaves. Flowers are born on axillary raceme which are papilionaceous and yellow colored. Fruits are cylindrical, long pods each bearing 6 - 10 seeds. Seeds are variable in color from greenish yellow figure 4. The comparison of the plant characteristics of *V. umbellata* var. *gracilis and V. umbellata* var. *umbellate* was shown in figure 5 [14]. Table 2 presents biochemical analysis of rice beans and other Phaseolus beans.

Multivariate Biochemical Characterization of Rice Bean Seeds for Nutritional Enhancement

Though referred to as an underutilized legume, rice bean contains about 60% digestible proteins enriched with essential amino acids like methionine, tryptophan, lysine, tyrosine, and valine [9]. National Bureau of Plant Genetic Resources (NBPGR), New Delhi (India), is the front-runner in maintaining more than 1700 accessions. Accessions with broad

Table 1: Effect of different parameters on rice bean cultivation.

S. No.	Parameters	Effects on cultivation of rice bean
1	Climate and adaptation	Rice beans grow well in hot, humid climates and are well distributed in subtropical hilly regions. It grows well in sandy loam to heavy soils [5]. It is also moderately drought tolerant.
2	Photo-thermosensitivity	Many strains exhibit photo-thermosensitivity in terms of flowering and reproduction [3]. They come into bloom during September or October as the day length is reduced. The degree of sensitivity of cultivars to temperature is found to be inversely related to its response to photoperiod.
3	Sowing and spacing	The best sowing time for rice beans is the onset of the first monsoon i.e., mid-June to July. Sowing should be done when there is enough moisture, soil is well pulverized and has good organic matter content [7]. For dwarf erect forms 30 - 45 cm row to row distance is recommended, whereas 60 - 90 cm in case of viny type or throw long whips.
4	Interculture practices and fertilizer requirements	First interculture operation constituting thinning and spacing between the plants should be done at first fortnight to allow the remaining plant population to establish. First interculture operation should be carried out before first irrigation whereas weeding should be done at initial stages [8]. Rice bean is a leguminous crop with good microbial modulation where the existing rhizobium helps in fixing of nitrogen. If the soils are deficient in potash and phosphorus, then fertilizer dose of NPK (40:60:20) is found to be good. Half of nitrogen and entire phosphorous and potash should be applied before sowing and rest of nitrogen must be given at flowering time.
5	Maturity and synchrony	Rice beans take a minimum of about 60 days to mature in case of early maturing types, whereas late maturing ones can take as many as 150 days to complete their life cycle. Rice beans possess good synchrony in their cultivars for pod maturity, whereas asynchrony persists in some wild forms [9].
6	Resistance to disease, pests, and nutritive value of rice bean	As the plant parts are pubescent, this may help to protect rice beans from insects such as white fly. It is remarkably free from yellow mosaic virus and generally resistant to common leguminous diseases. The seed protein in rice beans varies from 14 - 25% [10]. As far as amino acid composition is concerned, methionine and tryptophan are considerably high as compared to other *Vigna* species. It also contains a high quantity of vitamins *viz*., thiamine, niacin, and riboflavin. According to biochemical analysis, calcium and iron content are also appreciably high. Crude fiber content ranges from 3.3 - 4.8 %. Calcium content was high and varied from 315 to 450 mg/10 g.

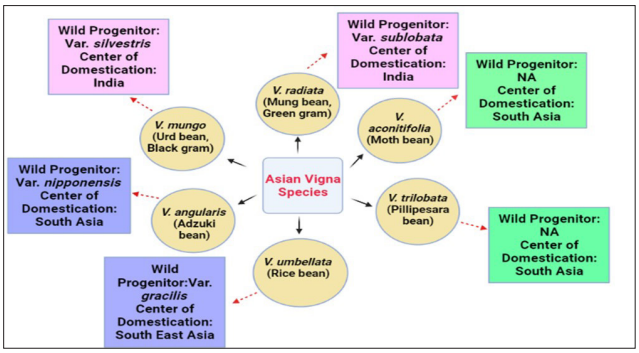

Figure 3: Different *Vigna* species and their progenitors.

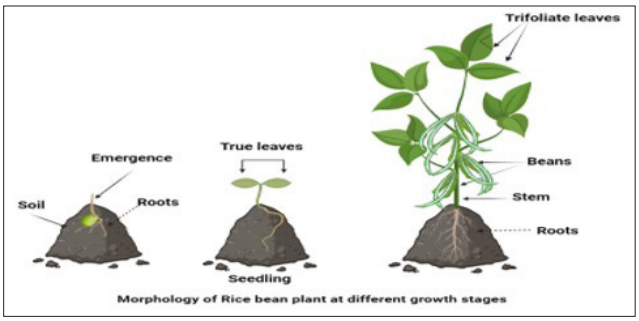

Figure 4: Growth stages of rice bean.

genetic variability is the primary need to develop stable high yielding varieties. This crop is investigated to a small extent for its various physicochemical and biochemical compositions

Table 2: Biochemical analysis of rice beans and other *Phaseolus* beans.

Crop species	Rice bean	P.calcaratus	Mung bean	P. aureus	P. ricciardianus
Moisture %	12.81*	8.47	-	-	8.10
Protein %	19.1	20.65	23.9	-	21.5
Fiber %	5.51	9.13	-	-	6.38
Ether extract %	0.60	1.80	1.30	-	0.50
Ash	4.31	4.16	-	-	3.87
Calcium	0.36	0.64	0.21	-	-
Phosphorous	0.69	0.65	-	-	-
Iron mg/100 ml	10.9	-	7.8	-	-
Riboflavin	0.21	-	0.17	-	-
Niacin	2.4	-	2.0	-	-
Thiamine	0.59	-	0.56	-	-

Note: *Identified at Royal Botanic Garden, Kew; Now Vigna.

and available information in the literature domain is insubstantial as mentioned in table 3 and table 4. To date only 16 different varieties of rice bean are evaluated for nutritional characteristics [15].

Forage Production and Grain yield

Rice beans have great potential both for grain yield and forage production. In the trials conducted at NBPGR, New Delhi (India), grain yields as high as 27 qha^{-1} were reported whereas in West Bengal average seed yield of 185 kgha^{-1} were also obtained [7]. In experimental trials conducted at Shimla

Table 3: Physicochemical properties and chemical composition of rice bean strains.

Crop species	GRRS-1	GRRS-2	GRRS-3	GRRS-4	GRRS-5	GRRS-6
Seed color	Cream	Green	Light	Deep red	Deep red	Green
Moisture content (%)	5.5	5.2	5.1	5.3	5.5	6
100-gram weight (g)	108.2	56.1	131.1	137.6	84.5	94.5
Crude nitrogen (%)	3.02	3.04	3.13	2.85	4.03	3.52
Nitrogen in seed (%)	0.33	0.19	0.41	0.39	0.33	0.33
Crude protein (N x 6.25)	18.86	21.56	19.56	17.81	25.18	22.00
Ash	3.87	4.00	3.81	4.31	4.06	4.02
Soluble ether extract	1.60	1.00	1.06	1.10	1.00	1.06
Crude fiber	4.00	3.30	4.60	3.80	8.50	4.80
Calcium (mg/100 g)	450	405	392	421	315	432
Iron (mg/100 g)	1.00	5.00	1.00	2.00	1.00	2.00
Phosphorous (mg/100 g)	258	393	255	270	210	1.97

Table 4: Other biochemical constituents of various rice bean strains.

Strain	GRRS-1	GRRS-2	GRRS-3	GRRS-4	GRRS-5	GRRS-6
Total free amino acid ($\mu mol^{-1}g^{-1}$)	3.05	1.90	2.50	4.40	3.45	1.55
Total phenols (%)	0.09	0.14	0.11	0.12	0.14	0.10
Free reducing sugars (%)	0.084	0.094	0.080	0.098	0.089	0.085
Free non reducing sugars (%)	5.37	5.07	5.19	5.17	5.18	3.71
Tryptophan** (%)	0.80	0.93	0.79	1.10	0.95	0.85
Methionine** (%)	0.94	0.42	0.81	0.94	0.40	0.39
Starch (by diffusion (%))	65.87	64.45	65.34	67.33	60.64	64.03

Note: **Values on crude protein basis.

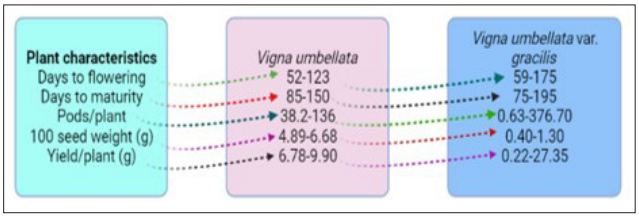

Figure 5: Comparison of the plant characteristics of wild and cultivated varieties of rice bean.

during 1980 - 1982, the new selection obtained yielded up to 23.8, 22.5, and 25.3 qha^{-1}. In similar trials, the varietal differences were not significant, although IC 16751 reported the highest yield of 23.6 qha^{-1} accompanied by IC 16706 whose yield was 21.6 qha^{-1}. The cultivars K1 and K16 developed in West Bengal are specially developed for fodder. Both give yield of 250 - 30 qha^{-1} of fodder yield. In some experimental trials, yield of about 33 tons of green forage yield ha^{-1} was also obtained [16].

Economic Usages: Rice Bean Seeds and Rice Bean Forage

Being rich in protein (18 - 26% dry matter), rice bean seeds contain a limited amount of fiber (4%) and fat (2%). The crop is found to be deficient in sulfur containing amino acids, but rich in lysine. Starch values range from 52 - 57% of dry matter [17], whereas amylose content of the starch ranged from 1.38% to 28.48%. Rice bean forage is extremely rich in protein (17 - 23% dry matter). However, hay and straw are less nutritious (16 - 14% protein dry matter). Rice bean forage is rich in minerals (10% dry matter) more specifically in calcium.

Table 5: Comparison of nutrients in rice bean, cow pea and urad bean (percentage on dry matter basis).

Crop	Rice bean	Cowpea	Urad bean
Stage (%)	Veg.	Veg.	Veg.
Dry matter (%)	16.0	20.0	19.0
Crude protein (%)	18.02	17.93	14.89
Ether extract (%)	1.12	1.40	1.16
Crude fiber (%)	31.46	39.02	34.24
N.F. extract (%)	39.90	32.00	39.73
Ash (%)	9.50	9.63	9.96
Calcium (%)	1.43	1.21	1.11
Phosphorous (%)	0.350	0.507	0.370

Note: *All values on moisture and fat free basis. **Values on crude protein basis [18].

Green Manure and Cover Crop

Being a nitrogen fixing legume, rice bean improves the nitrogen status of the soil, thus, making soil rich in nitrogen. In countries like Thailand, rice bean is sown between the rows of maize before harvesting so that the crop covers enough soil at harvest. Thus, in this way, rice beans are harvested, threshed to obtain seeds, and bring dry plants back to field where they can provide soil cover for the dry season.

Rice Bean a Potential Fodder Crop

Palatability

On the palatability basis rice beans have more palatability than cowpea and urd bean as shown in table 5. At pre-flowering stage, rice bean is soft and palatable to sheep and insects/nematode [10]. Dry matter hay is also palatable for bullocks.

Bullocks first hesitated, but later showed increased dry matter consumption [19]. It is also relished by cattle.

Rice bean hay, forage, fodder and as a feed

Twenty-two-month-old calves when fed on a mixture of Sudan grass, mustard leaves, and rice bean forage (54:46 fresh weight basis) for 64 days had dry matter intake of 1.9 kg dry matter/100 kg LW daily and weight gains of 456 g/day [13]. Hay is used to supplement poor quality roughage-based diet in ruminants. In the case of swamp buffalo, when diet was supplemented with rice bean hay, it led to increased dry matter intake, digestible protein, and nitrogen retention. On rumen microflora, it had a positive effect, which resulted in increased volatile fatty acid production and lesser methane emissions. When rice bean hay was added then it led to increased cellulolytic rumen bacteria which improved the utilization of high fibrous and oil feeds with mustard leaves/seeds in buffalo diets [20]. A trial conducted with bulls revealed that rice bean hay had a moderate organic matter digestibility (50%) but contained nitrogen, calcium, and phosphorus in sufficient amounts to meet the needs of adult cattle [21]. Seeds can be fed to buffalo calves or sheep to provide energy. So, it can replace half the cereals and half the de-oiled cakes present in the concentrate that is fed to buffalo calves [22]. When rice been seeds replaced oat's 50% metabolized energy then there was no deleterious effect on nitrogen balance and was considered as positive change [23].

Conclusion

From above review it can be concluded that rice bean is a multipurpose potential legume crop which can be used as a pulse, fodder, green manure or as a cover crop and can be grown on a wide range of environments with a lesser incidence of diseases and pests. Thus, appropriate focus on the crop should be given to establish it as a potential legume crop.

Acknowledgements

None.

Conflict of Interest

None.

References

1. Ecoport Database. [http://www.ecoport.org/] [Accessed October 31, 2023]
2. Kaur A, Kaur P, Singh N, Virdi AS, Singh P, et al. 2013. Grains, starch and protein characteristics of rice bean (*Vigna umbellata*) grown in Indian Himalaya regions. *Food Res Int* 54(1): 102-110. https://doi.org/10.1016/j.foodres.2013.05.019
3. Khadka K, Acharya BD. 2009. Cultivation Practices of Rice Bean. Local Initiatives for Biodiversity. Research and Development. Pokhara, Nepal.
4. Zargar SA, Fayaz H, Wani AA, Saggoo MIS, Mir RA, et al. 2021. Genetic and Genomic Resources in Rice Bean (*Vigna umbellata* Thunb.): Availability, Advancements, and Applications. In Zargar SM, Masi A, Salgotra RK (eds) Neglected and Underutilized Crops - Towards Nutritional Security and Sustainability. Springer, Singapore, pp 191-202.
5. Katoch R. 2020. Rice Bean: A Potential Underutilized Legume. In Katoch R (ed) Ricebean: Exploiting the Nutritional Potential of an Underutilized Legume. Springer, Singapore, pp 55-79.
6. Atta K, Adhikary S, Mondal S, Mukherjee S, Pal A, et al. 2022. A Review on Stress Physiology and Breeding Potential of an Underutilized, Multipurpose Legume: Rice Bean (*Vigna umbellata*). In Jha UC, Nayyar H, Agrawal SK, Siddique KHM (eds) Developing Climate Resilient Grain and Forage Legumes. Springer, Singapore, pp 235-253.
7. Sangma HCR, Parameshwari S. 2023. Health benefits of black rice (*Zizania aqatica*)-a review. *Mater Today Proc* 80: 3380-3384. https://doi.org/10.1016/j.matpr.2021.07.257
8. Singh G, Gudi S, Upadhyay P, Shekhawat PK, Nayak G, et al. 2022. Unlocking the hidden variation from wild repository for accelerating genetic gain in legumes. *Front Plant Sci* 13: 1035878. https://doi.org/10.3389/fpls.2022.1035878
9. Singh P, Pandey B, Pratap A, Gyaneshwari U, Nair RM, et al. 2022. Genetic and genomics resources of cross-species *Vigna* gene pools for improving biotic stress resistance in mungbean (*Vigna radiata* L. Wilczek). *Agronomy* 12(12): 3000. https://doi.org/10.3390/agronomy12123000
10. Zia-Ul-Haq M, Iqbal S, Ahmad S, Imran M, Niaz A, et al. 2007. Nutritional and compositional study of desi chickpea (*Cicer arietinum* L.) cultivars grown in Punjab, Pakistan. *Food Chem* 105(4): 1357-1363. https://doi.org/10.1016/j.foodchem.2007.05.004
11. Joshi KD, Bhanduri B, Gautam R, Bajracharya J, Hollington PB. 2008. Ricebean: A Multipurpose Underutilized Legume. In Smart J, Haq N (eds) New Crops and Uses: Their Role in a Rapidly Changing World. Centre for Underutilised Crops, United Kingdom, pp 234-248.
12. Singh M, Rundan V, Onte S. 2020. Ricebean. *Indian Farm* 70(6): 27-31.
13. Soni JK, Lalramhlimi B, Kumar A, Navik O, Lungmuana, et al. 2023. Coix: an underutilized functional food crop of Mizoram. *Genet Resour Crop Evol* 70: 2143-2159. https://doi.org/10.1007/s10722-023-01587-8
14. Bullock LA, Alcalde J, Tornos F, Fernandez-Turiel JL. 2023. Geochemical carbon dioxide removal potential of Spain. *Sci Total Environ* 867: 161287. https://doi.org/10.1016/j.scitotenv.2022.161287
15. Okolie PI, Itohan ME, Okolie EC, Obadina A. 2023. Amino acid profile and protein quality of starter cultures fermented African Yam bean (*Sphenostylis sternocarp*) seed condiment. *Croatian J Food Sci Technol* 15(1): 28-36. https://doi.org/10.17508/CJFST.2023.15.1.04
16. Chandora R, Rana JC. 2023. Moth bean (*Vigna aconitifolia*): a minor legume with major potential to address global agricultural challenges. *Front Plant Sci* 14: 1179547. https://doi.org/10.3389/fpls.2023.1179547
17. Craine EB, Şakiroğlu M, Peters TE, Barriball S, Schlautman B. 2023. Nutritional quality of *Onobrychis viciifolia* (Scop.) seeds: a potentially novel perennial pulse crop for human use. *Legume Sci* e189. https://doi.org/10.1002/leg3.189
18. Pattanayak A, Roy S, Sood S, Iangrai B, Banerjee A, et al. 2019. Rice bean: a lesser known pulse with well-recognized potential. *Planta* 250: 873-890. https://doi.org/10.1007/s00425-019-03196-1
19. Sarkar S, Singh A. 2021. Biodiversity of nematodes in soil and their impact on soil environment. *Plant Cell Biotechnol Mol Biol* 22(37-38): 266-270.
20. Bray F. 2023. The Rice Economies: Technology and Development in Asian Societies. University of California Press.
21. Goenaga I, García-Rodríguez A, Goiri I, León-Ecay S, De Las Heras J, et al. 2023. Vegetable by-products as alternative and sustainable raw materials for ruminant feeding: nutritive evaluation and their inclusion in a novel ration for calf fattening. *Animals* 13(8): 1391. https://doi.org/10.3390/ani13081391
22. Patel SD, Pata BA, Mathukiya GP. 2023. Recent advances in feeding practices in cattle and buffalo: a review. *Pharma Innov J* 12(3): 5839-5841.
23. Sarkar S, Singh A, Jaswal A, Ghosh P. 2023. A sustainable approach to improve the mustard (*Brassica juncea*) yield and quality parameters by bees visitation in the regions of Punjab-India. *Indian J Agric Res* 1: 1-6.