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# Rice bean (*Vigna umbellata*) – A Potential Legume under Adverse Conditions

**Nalabolu Vikram and Narayan Chandra Sarkar**

Dept. of Agronomy, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Srinikethan, West Bengal (731 236), India

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**Corresponding** narayanchandra.sarkar@visva-bharati.ac.in

0000-0002-4603-1537

## ABSTRACT

Rice bean is an underutilized legume crop that comes up with many benefits i.e., dried pulse, fodder and green manure thus helps in human, animal nutrition and environmental health. It is a resilient plant that is resistant to a variety of diseases and pests especially to the Bruchids, it can be grown well in less fertile, exhausted, degraded lands and drought prone sloping areas; along with these, Rice bean contains genes for biotic and abiotic stress tolerance, including drought, soil acidity tolerance especially for Aluminum ions. Waterlogging shows a greater negative impact on crops especially on legumes by reducing photosynthesis, plant growth, grain yield; formation, function and survival of nodules, biological nitrogen fixation, and may even causes plant death in severe waterlogged conditions. An insufficient supply of nitrogen or carbohydrates is thought to have hampered flowering plant life and recovery. Waterlogging at any stage has a detrimental impact on seed output. Depending on the conditions, flooding stress can range from transient to permanent. Based on the sort of flooding regime in the habitat, different species, or even different genotypes of the same species, choose an avoidance, escape, or quiescence strategies to overcome stress, among these coping options Rice bean may follow morphological alterations in the escape mechanism. As Rice bean can thrive well in adverse conditions and even in waterlogged conditions, once the exact reason behind this tolerance is explored, that feature can be used in breeding programs for crop improvement.

**KEYWORDS:** Rice bean, underutilized crops, waterlogging, tolerance

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***Data Availability Statement:*** Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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## 1. INTRODUCTION

Food security is the major challenge of the present (Prosekov and Ivanova, 2018). Because of their natural potential for symbiotic nitrogen fixation, grain legumes may offer an unrivalled solution to this challenge, which offers farmers with long-term economic benefits. Furthermore, both humans and livestock benefit from a legume-rich diet (Foyer et al., 2016). In addition to increasing soil fertility, certain legumes have the capacity to solubilize phosphate by excreting organic acids from their roots. When utilized in rotation with non-leguminous crops, legumes also aid in the recovery of soil organic matter and the reduction of pest and diseases (Das and Ghosh, 2012).

Waterlogging shows a greater negative impact especially on legumes by reducing photosynthesis, plant growth, grain yield; formation, function and survival of nodules, biological nitrogen fixation, and may even causes plant death in severe waterlogged conditions (Minchin and Summerfield, 1976). Waterlogging at any stage has a detrimental impact on seed output (Cowie et al., 1996). Flooding is expected to become more common as a result of climate change, particularly affecting the poorly drained arable farmlands (Bailey-Serres et al., 2012). ATP production (Sauter, 2013) and photosynthesis are both hampered as a result of waterlogging (Bailey-serres and voesenek, 2008). Increased amounts of reactive oxygen species (Blokhina et al., 2003), cytosol acidification (Felle, 2006), and a decrease in root hydraulic conductivity are also caused due to excess water (Melcher et al., 2003). Stressed plants will be forced into an energy crisis, with energy allocation rigorously economized to the routes that allow the plant to survive. At different developmental phases, energy distribution varies among and within species (Colmer and Voesenek, 2009).

The term 'Underutilized' refers to species that were either grown extensively in the past or have the potential to be grown in the future but are currently grown in a limited area due to agronomic, genetic, and economic reasons (Gruere et al., 2006). These crops are also known as "orphan" crops because they did not receive adequate attention for research and development and as a result, there is little scientific knowledge about them (Eyzaguirre et al., 1999). In general, underutilized crops are plant species that occur as life support species in harsh environmental conditions and threatened habitats. These species have the genetic tolerance to survive in these conditions and have qualities that are important for nutrition and/or industry for a variety of purposes (Monika, 2014).

Rice bean is versatile example of Underutilized legume crop, it is a lesser-known pulse with well recognized potential, nutrient dense food and fodder, as well as source of genes for biotic and abiotic stress tolerance, such as drought (pattanayak et al., 2019), soil acidity (Yang et al., 2006; Fan et al., 2014), storage pest resistance (Tomooka et al., 2000; Kashiwaba et al., 2003), disease resistance (Arora et al., 1980) and it can grow well in less fertile, exhausted, degraded lands and drought prone sloping areas (Joshi et al., 2008; Dhillon and Tanwar, 2018). Although it has many uses when compared to most of the crops, it is considered as underutilized and its full potential is yet to be utilized (Joshi et al., 2008). Hence there is a need of reviewing the scope of research made on Rice bean special characters. Thus, this review work has been made with the aim of giving information that Rice bean can grow under adverse conditions with special reference to waterlogging unlike most of other legumes.

## 2. IMPORTANCE OF RICE BEAN IN INDIA AND WORLD

Around 30,000 edible plant species have been identified worldwide, with over 7,000 crop species cultivated for food (Garn and Leonard, 1989; Li et al., 2020; Khoshbakht and Hammer, 2008). Currently, less than 150 crop species are commercially grown; 3 crops (Rice, Wheat and Maize) supply greater than 50% of total plant derived calories (Attwood et al., 2017). As a result, tens of thousands of edible plant species are relatively "underutilized" and could be used to supplement the world's food supply (Chivenge et al., 2015). Human consumption of carbohydrates is dominated by three closely related species (Wheat, Rice, and Maize) (Collins and Qualset, 1998; Mayes et al., 2012). Highly productive agricultural land is increasingly being exploited for urban development as a result of population pressure and expanding urbanization, putting great pressure on remaining agricultural land and increasing the danger of deterioration or erosion. Under these circumstances, the environmental benefits of including pulses in crop rotations and also social and economic benefits, such as meeting protein needs, reducing soil degradation, and promoting food diversification should be considered (Singh et al., 2016). But over reliance only on few major legume crops may lead to unsustainability and other adverse effects, so the option to overcome it may be the cultivation of underutilized minor crops, modern production technologies and improved cultivars (Dhillon and Tanwar, 2018).

As a Nitrogen fixing legume, Rice bean enhances the soil's nitrogen status and provide nitrogen to the subsequent crop. When ploughed into the soil, its taproot improves soil structure and adds organic matter and nitrogen. Growing Rice beans before or after a Rice or Maize crop is advantageous (Heuze et al., 2016). Rice bean is used as green manure in tangerine orchards in China which resulted in higher fruit yields than soyabean (*Glycine max*), and mungbean (*Vigna radiata*) (Wen et al., 2011). Rice bean (Vigna umbellata) is One of the top five most widely used green manure/cover crops worldwide, it is known for its quick maturing, heavy producing and uniform seed set (Ju, 2004). Rice bean is tolerant to acidity and hence can be grown in acidic soils (Dwivedi, 1996), Aluminum (Al) induced organic acid anion secretion is a critical Al resistance mechanism for plant species growing on acidic soils (Kochian et al., 2004; Von Uexkull and Mutert,1995; Liu et al., 2018). Rice bean can be used in wide range of cropping systems, i.e., with Maize during summer, as intercrop with Sorghum and Millets, as a sole crop in the uplands, or on terrace rising and on Rice bunds or in the kitchen gardens (Joshi et al., 2008). Rice bean is a versatile crop and it can tolerate pest and diseases (Tomooka et al., 2000 and Kashiwaba et al., 2003). According to Arora et al., (1980) and Palai et al., (2019), it is tolerant to yellow mosaic virus, Cercospora and Bacterial leaf spot. Along with these, Rice bean has the capability of growing in less fertile, exhausted, degraded lands and drought prone sloping areas (Joshi et al., 2008; Dhillon and Tanwar, 2018).

## 3. RICE BEAN AS UNDER-UTILIZED CROP

According to Global Facilitation Unit (GFU) for underutilized species, underutilized plants are “those plant species with under exploited potential for contributing to food security, health (nutritional/medicinal), income generation and environmental services” (Monika, 2014). Although Rice bean has wider range of benefits, like its usage for food, fodder, fiber and other special features of adaptability to wide range of conditions, its cultivation is limited to small areas of hilly regions of Nepal, northern India and parts of SE Asia (Joshi et al., 2008).

The significance of underutilized crop species in meeting the world’s food demand has been acknowledged by research communities, governments, and policymakers all over the world. The development of underutilized crops, with their vast genetic resources and beneficial traits could be a useful first step toward addressing food security issues by providing a multifaceted agricultural system that includes additional important food resources (Muhammad et al., 2020). Collaborative initiatives to improve Rice bean farming, food trade value and off farm conservation would benefit not only marginal farmers, but also the yet to be explored genetic riches accessible in this hardy pulse (Pattanayak et al., 2019).

## 4. ROLE OF RICE BEAN IN NUTRITIONAL SECURITY

Because of its nutritional potential, Rice bean, a lesser-known and underutilized legume has emerged as a potential legume crop. The protein content in the genotype BRS-2 was 25.57%, with an in vitro digestibility of 54.23%. The fatty acid profile revealed a higher percentage of unsaturated fatty acids, specifically linoleic and linolenic acid, which are nutritionally beneficial in the diet. The majority of proteins were albumins (6.13%–7.47%) and globulins (13.11%–15.56%). Total phenolics (1.63%–1.82%), total tannins (1.37%–1.55), condensed tannins (0.75%–0.80%), hydrolysable tannins (0.56%–0.79%), trypsin inhibitor (24.55–37.23 mg $g^{-1}$), phytic acid (7.32–8.17 mg $g^{-1}$), lipoxygenase activity (703–950 units/mg), and saponin content (1.2%) were the anti-nutritional factors (Katoch, 2013).

It is mostly utilized for food, fodder (Andersen, 2007). Rice beans are traditionally used to make entire dhal and deep-fried appetizers (Khanal et al., 2009). It is used to make healthful and delicious meals in China and Japan, such as soup, gruel, desserts, and pastries (Wei et al., 2015). Rice bean is gaining popularity around the world as a cost-effective alternative to traditional pulses due to its high producing ability, resistance to viral, fungal, and bacterial infections, flexibility to grow in less fertile lands, ease of domestic processing, and nutritional potential. Rice bean can be grown in a range of soils to supply both high-quality grain and highly nutritious livestock fodder, providing a synergistic advantage for human and animal nutrition (Dhillon and Tanwar, 2018). Rice bean is a warm-season annual, like other Vigna species. It is generally grown as a dry pulse, but it is also utilized as a source of fodder and food. They’re full and nutritious and have high lysine content in the protein. They’re a great way to supplement a cereal-based diet. The seeds have a high mineral content, vitamin contents like Ascorbic acid, thiamine, riboflavin, niacin and antioxidants (Dahipahle et al., 2017).

Rice bean plant components are edible and can be utilized in culinary recipes. The dried seeds can be boiled and eaten with Rice, or they can be used in stews and soups instead of Rice. Rice bean, unlike other pulses, is difficult to turn into dhal due to their fibrous mucilage, which prevents the cotyledons from being separated and hulled (Dahipahle et al., 2017). Rice bean is an excellent cattle feed; The seeds can be directly fed to cattle while the vegetative parts can be eaten raw or turned into hay. Rice bean straw is comprised of stems, green parts, empty pods, and some seeds. Farmers in the marginal hills consider Rice bean to be both a grain and a fodder legume, therefore they look for landraces that can be used for both (Khanal et al., 2009).

## 5. ADAPTABILITY OF RICE BEAN IN ADVERSE CONDITIONS

Rice bean is a resilient plant that is resistant to a variety of diseases and pests especially three Bruchid species, *Callosobruchus chinensis* L., *Callosobruchus maculatus* F., and *Callosobruchus analis* F, (Kashiwaba et al., 2003). It can be grown in less fertile lands, exhausted, degraded lands and drought prone sloping areas (Joshi et al., 2008; Dhillon and Tanwar, 2018). Rice bean is an N-fixing legume that improves the soil's nitrogen status and so provides nitrogen to the next crop. Its taproot improves soil structure and returns organic matter and nitrogen to the soil when ploughed in. As a result, it can be utilized as a green manure crop. Though it can grow in the same conditions as Cowpea it can withstand more adversity; it is very hardy (including drought, water logging and acid soils), Aluminum (Al) induced organic acid anion secretion is a critical Al resistance mechanism for plant species growing on acidic soils, which account for nearly half of today's potentially arable lands (Kochian et al., 2004; Von Uexkull and Mutert,1995; Liu et al., 2018). According to Ma et al., (2001); Liu et al. (2018), there are two patterns of organic acid secretions, in the first pattern there is no discernible delay between the onset of Al stress and the onset of significant organic acid anion secretion. In Pattern II, however, there is a lag phase between the two processes. Rapid organic acid anion secretion in Pattern I plants (e.g., wheat and barley) is thought to involve the activation of preexisting transporters (Sasaki et al., 2004; Furukawa et al., 2007; Liu et al., 2018). In those who fit in Pattern II, however, transcriptional activation of genes encoding organic acid transporters is required for species like *Arabidopsis* (Kobayashi et al., 2007; Liu et al., 2018), sorghum (Magalhaes et al., 2007; Liu et al., 2018), and Rice bean (Yang et al., 2011; Liu et al., 2018). Soil salinity, heavy metal (Cu, Pb) stress does not have much negative impact on Rice bean germination percentage, but the former has adverse effect on the speed of germination, and among the two heavy metals Cu and Pb, Copper toxicity produces more adverse effects on root elongation, anti-oxidative enzymes (e.g., catalase, guaiacol peroxidase) production than Lead (Atta and pal et al., 2021). Rice bean some show special characteristics in root growth and development in wet conditions. In an observation at Visva-Bharati University, Rice bean inherently produces tap root system under normal conditions, but surprisingly under water logging, mat type fibrous roots are seen in well-developed condition (Figure 1 and 2).

Figure 1: Growing fibrous root under waterlogging

Figure 2: Mat type fibrous roots grown

Depending on the conditions, flooding stress can range from transient to permanent. Depending on the sort of flooding regime in the habitat, different species, or even different genotypes of the same species, choose an avoidance, escape, or quiescence strategy (Colmer and Voesenek, 2009; Van Veen et al., 2013). The plant's escape strategy undergoes morphological and anatomical changes that allow it to obtain more oxygen from the outside environment and transfer it to its interior tissues (Bailey-Serres and Voesenek, 2008; Colmer and Voesenek, 2009). These morphological changes include shoot elongation, as well as aerenchyma and adventitious root formation etc. Both morphological and growth alterations related with the escape strategy are reduced by the quiescence approach (Colmer and Voesnek, 2009; Bailey-Serres and Voesenek, 2008). To tolerate waterlogging Rice plant follows escape mechanism in slow flooding conditions in which internode elongation act as a morphological change; under flash flooding, it undergoes quiescence in which it reserves the energy by restricting the shoot elongation (Bashar et al., 2019; Bailey-Serres et al., 2012; Fukao and Xiong, 2013). In Rice these approaches are mutually incompatible and they cannot coexist in the same genotype (Soltani et al., 2017). According to Colmer and Voesenek (2019), under continuous flooding conditions, escape strategy is preferred and under short-term flooding conditions quiescence is preferred. In Rice bean the development of mat type fibrous roots may be attributed to the morphological alterations under excessive moisture and it may follow escape mechanism to tolerate the waterlogging stress.

Mono or demethylated compounds, such as D-Ononitol or D-pinitol plays an important role in the water stress protection (Ishitani et al., 1996). Rice bean in response to drought stress accumulates D-Ononitol more in the leaves than shoot and is linearly related to the enzyme myo-inositol 6-O-methyl transferase, which is more present in the shoots than leaves under drought stress (Wanek and Richter., 1997). With the accumulation of these compounds under water stress conditions Rice bean may tolerate drought stress to some extent at later stages of growth. Whereas during the initial stages, drought had adverse impact on both germination percentage and speed of germination in Rice bean cultivar Bidhan 1 (Atta and Pal et al., 2021).

## 6. CONCLUSION

Rice bean (*Vigna umbellata*) can tolerate waterlogging unlike most of the other legume species and can be grown well in low to marginal fertility, acidic soils. These features may open the windows for the cultivation of Rice bean crop on a large scale in less fertile lands, exhausted, degraded lands, drought prone sloping areas and water-logged lands for its contribution towards the food security by meeting the nutritional requirements.

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