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Gangadasari Sravana Lakshmi
Ph.D. Researcher, Department of Agronomy, University of Agricultural Sciences, Dharwad, Karnataka, India

Hulihalli UK
Professor, Department of Agronomy, University of Agricultural Sciences, Dharwad, Karnataka, India

Bhagyajyothi CK
Ph.D. Researcher, Department of Food Science and Nutrition, University of Agricultural Sciences, Dharwad, Karnataka, India

Vikram Kannamreddy
Ph.D. Scholar, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Girija Prasad Patnaik
Ph.D. Researcher, Department of Agronomy, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Vinita
Ph.D. Researcher, Department of Agronomy, University of Agricultural Sciences, Dharwad, Karnataka, India

Rundan V
Ph.D. Researcher, Department of Agronomy, University of Agricultural Sciences, Dharwad, Karnataka, India

Corresponding Author:
Gangadasari Sravana Lakshmi
Ph.D. Researcher, Department of Agronomy, University of Agricultural Sciences, Dharwad, Karnataka, India

Buckwheat- one of the underutilised and underrated crop with multiple benefits: A review

Gangadasari Sravana Lakshmi, Hulihalli UK, Bhagyajyothi CK, Vikram Kannamreddy, Girija Prasad Patnaik, Vinita and Rundan V

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Abstract
Buckwheat is one among the underutilised crops. *Fagopyrum esculentum* commonly called as buckwheat belongs to family polygonaceae is a pseudocereal. It is a nutririch crop with multiple uses. Buckwheat is a short duration crop and can be grown in marginal soils with very low input requirement. Apart from human consumption, buckwheat can be used for animal feed. It is a nutririch crop with many health benefits compared to many of the cereal crops. Buckwheat flour is gluten free with low glycemic index. It is also rich in protein and fiber.Buckwheat can be used as a cover crop, leafy vegetable, weed control because of its allelopathic effect on weeds.Despite many health benefits and easy to cultivate the area under buckwheat is very less in India because of lack of proper knowledge regarding the production technology, its multiple uses and lack of proper marketing facility. Buckwheat is one of the climate resilient super foods which is neglected and its potential is underutilised, which should be explored further to avail its benefits.

Keywords: Buckwheat, pseudocereal, cultivation practices, underutilised crop, multiple uses, health benefits

Introduction
Among various underutilized crops like fruits and nuts, some fiber crops and pseudo cereals are major and traditionally they are being cultivating in different parts of the world. Buckwheat is one such old world crop which have been originated in China and central Asia, though its domestication dates back about 4000-5000 years in South China (Gondola and Papp, 2010) [30]. The name buckwheat originated from the Anglo-Saxon words boc (beech) and whoet (wheat). The three-sided angular seed looks like a small beechnut. (Kandel, 2019) [39]. The species of buckwheat grown commercially for food in the U.S. is *"Fagopyrum sagittatum"*. Cultivated buckwheat *(Fagopyrum* spp. 2n=16) is a dicot pseudo-cereal belongs to the family Polygonaceae, which is distinct from the monocot cereals. Out of 20 species of genus *Fagopyrum* (Tang *et al.*, 2010 and Shao *et al.*, 2011) [69, 64], only two *F. esculentum* (Common buckwheat) and *F. tataricum* (Tartary buckwheat) are cultivated in India (Chauhan *et al.*, 2010) [14]. However, among these two species, common buckwheat is grown at lower altitudes, whereas tartary buckwheat is grown at higher altitudes (Babu *et al.*, 2016) [6].
Buckwheat is a multipurpose crop and is cultivated as a food and fodder crop in several Asian countries including India. Common buckwheat is chiefly cultivated in Northern hemisphere (Oshini, 2004) [52] mainly in Russia.
Buckwheat is grown for grain which has a great nutritional value. It is used almost like a bread grain crops. The most important ingredients of this plant are flavonoid (rutin). Both species of *Fagopyrum* are used as grains and greens.

Area and distribution of buckwheat
Dissemination of buckwheat in the world is primarily harmonizes at central Asia especially in the south-western China (Zhou *et al.*, 2018) [76]. Therefore, China is considered as center of origin of buckwheat (Farooq *et al.*, 2016) [22]. Buckwheat first cultivated in South-east Asia, around 6000 BC (Ohnishi, 1998) [50]. Globally buckwheat is cultivated in 2.4 million hactares

area with production of 2.4 million tonnes and average productivity of 1 t ha^{-1} (FAO STAT, 2018) [23]. Russia, China, Ukraine, Khazikisthan, Poland, USA, Japan, Brazil, Lithuania and Brazil are the major countries for buckwheat cultivation.

India

In India, Buckwheat is cultivated in Himalayan region (Rana *et al*.,2004) [59]. The occurrence of buckwheat in Jammu and Kashmir, Arunachal Pradesh and Tamil Nadu (Rana *et al.*, 2012) [58]. However, J&K, HP, UK, WB, Sikkim, Assam, Arunachal Pradesh, Meghalaya, Manipur, Kerala, TN and Chhattisgarh are the major buckwheat growing states in India (Babu *et al*., 2018) [5]. In the higher Himalayas, this crop grown and occupies 90 per cent of cultivated land as a pure crop (Singh *et al.*, 2014) [65]. The area and production of buckwheat in India is 60,000 ha and 35,000 tons respectively (Anon., 2018) [3].

Soil and Climate

Being a hardy crop and its ability to survive even in low fertile, rocky and poorly tilled lands buckwheat can be grown in various soil types (Khanh *et al.*, 2005) [40] which is difficult for the other crops to grow. However, it desires well drained sandy soils and acidic soil having pH as low as 4.8 (Jung *et al.*, 2015) [37]. Buckwheat does not grow well in saline and semi-arid regions (Horie *et al.*, 2012) [34]. Common buckwheat is a facultative short day plant, thrives well in cool and moist temperate regions, although seeds can also germinate in very dry regions (Gardner and Boundy, 1983) [25]. Total biomass production, grain yield and quality of buckwheat depends on temperature, rainfall and sunshine hours (Jung *et al.* 2015) [37]. The crop is sensitive to high temperatures and hot dry winds especially under limited moisture condition. Tartary buckwheat is hardy than the common buckwheat; it stands better under poor soil and extreme weather situations. (Drazic *et al.*, 2016) [19]. Temperature is important factor which affects flavonoid and rutin accumulation (Sobhani *et al.*, 2014, Babu *et al*., 2018) [68, 5]. The yield of buckwheat increased with soil moisture although seed set remains the same (Gubbels, 1977) [31]. Buckwheat thrives well in diverse cropping patterns due to its short duration (60 to 70 days) and better flexibility in low temperature and moisture stress conditions (Luitel *et al.*, 2017) [46].

Botany

Buckwheat is not pondered as true cereal, but the seeds contain a cereal type starchy endosperm. Buckwheat belongs to the family polygonaceae and genus *Fagopyrum.* It is a broad leaved, annual, and dicotyledonous crop that attains a maximum height of about 2-5 ft. (Skrabanja *et al*., 2004) [67]. It is characterized by having a single, erect and hollow stem with triangular leaves. Inflorescence is formed by seven to nine blossoms. The colour of flowers varies from white or light green to pink or red (Cawoy *et al*., 2009) [13]. Most of its roots are concentrated in top 10 inches of the soil. Seeds are triangular in shape, botanically called achene and the colour of the seeds may be glossy brown, gray brown, silvery gray, or black (Krkoskova and Mrazova, 2005) [42]. Seed is composed of a thick outer hull and an inner groat that resembles the cereal kernel in its gross chemical composition and structure (Li and Zhang, 2001) [43].

Agronomic practices in production of buckwheat

Sowing time

Sowing time is a single non-monetary input (Das *et al.*, 2016) [18] and buckwheat is not an exception as its sowing time affect on seed germination (Omidbaigi and Mastro, 2004) [51]. Sowing date aims to find the suitable planting time of genotype so that the existing set of environmental factors are suitable for crop germination, emergence and growth (Farooq *et al.*, 2016) [22]. At lower altitudes, buckwheat is usually sown in the months of May-August, while at higher altitudes; April-May is the optimum sowing time of buckwheat (Ratan and Kothiyal, 2011, Kendel, 2019) [60, 39]. Under Mediterranean conditions buckwheat sown in early spring has given higher forage and grain yield but both were affected when sown in late spring season. In India buckwheat sowing starts with onset of monsoon and the crop sown in months of August and July has given the better yields because of favourable environmental conditions throughout the growing period (Hore *et al*., 2002) [33].

Seed Rate

The optimum seed rate required depends on genotype, crop season and the purpose for which the crop is grown. Closer spacing and higher seed rate recorded higher seed yield in non branching crops. Seed rate of 30 kg/ha has been better for higher grain yield and 50-60 kg/ha for vegetable purpose (Hore *et al.*, 2002) [33]. Higher the planting density more is the lodging rate in buckwheat (Xiang *et al*., 2016) [75]. Optimum seed rate for a good plant stand prevents lodging (Kendel, 2019) [39].

Planting Geometry

In non-uniform and high densities, total yield is usually reduced due to low LAI. Hence, optimum spacing will decrease the interplant competition and enhance the share of each plant to absorb the light, water and nutrients from the roots as compared to the crowded planting (Sobhani *et al.*, 2014) [68]. Narrow spacing leads lodging of the crop and wider spacing leads to increased weed infestation (Kolaric *et al.*, 2021) [41]. Planting geometry of 30 x10 cm was given optimum yield in common buckwheat under rainfed (Hulihalli and Shatveerayya, 2018) [36].

Nutrient Management

Buckwheat grows well in fields with lower fertility, and particularly on low-nitrogen (N) and low phosphorus (P) soils. It is particularly adapted to low fertile soils (Ghiselli *et al.*, 2016) [27]. Low productivity was due to poor soil, rainfed situation and winter season cultivation hilly areas. Application of N @ 45 kg ha^{-1} and increased phosphatic fertilizers has shown an increase in the dry matter production and also increased seed yield compared to unfertilized crop (Gairhe *et al*., 2015) [24]. Increased amount of fertilizer application (N-P- K) increased the grain yield (Kolaric *et al.*, 2021) [41]. However, It was a tendency to lodge at higher N rates (Kendel, 2019) [39]. Contrary to this, higher levels of phosphorus results in early maturity and less lodging. Hence, buckwheat requires combined application of N and P for higher grain yield (Saqib *et al*., 2012) [62].

Buckwheat with 1.6 tons grain yield ha^{-1} removes on an average 47 kg N, 22 kg P and 40 kg ha^{-1} (Campbell and Gubbels, 1978) [11]. Farmers of the north-eastern hill region of India are not applying any chemical fertilizer to this crop except basal application of about 1500-2000 kg Farm Yard Manure per ha. Application of 50 kg N, 20 kg P and 40 kg K ha^{-1} was increased the buckwheat yield (Phogat and Sharma, 2000). In Himachal pradesh N and P @ 60 and 40 kg ha^{-1} respectively resulted in higher grain and straw yield (Vinod kumar, 2005) [72]. Application of 35:20:20 NPK kg ha^{-1} recorded significantly

higher growth, yield parameters and seed yield (6.0 q/ha) of buckwheat (Hulihalli and Shantveerayya 2018) [36]. The response to higher of application fertilizer (60: 20: 10 kg N: P_2O_5: K_2O kg ha^{-1}) was still more (Maruti *et al*., 2018) [49].

Weed Management in Buckwheat

Productivity of buckwheat is inversely associated with weed count and biomass (Rana *et al.,* 2004) [59]. Buckwheat is a fast growing crop, generally emerges within 4-5 days after sowing, so critical period to keep the crop weed free during early period of growth (20-30 days) (Kendel, 2019) [39]. In some areas, higher seed rates i. e. 2-2.5 times that of normal rate is generally used to suppress the weed flora and protecting the soil from erosion in hilly regions of India (Hore *et al*., 2002; Choudhury and Prem, 2007, Podolska 2006) [33, 15, 56]. In order to reduce the drudgery of hand weeding and make the buckwheat production more profitable, application of alachlor @ 1.50 kg ha^{-1} was recommended to minimize the weed losses in buckwheat (Rana *et al.,* 2004) [59]. Alachlor @ 0.75 kg ha^{-1}+ hand weeding resulted in minimum weed index (-12.0) in Tartary buckwheat and alachlor 1.50 kg/ha in common buckwheat (-41.7). (Rana *et al*., 2004) [59]. Buckwheat should not be grown after using herbicides like Atrazine, imazethapyr, halosulfuron, fomesafen, Pursuit (Bjorkman and Shail, 2013) [8]. Seed and straw yield were higher with one hand weeding + one intercultivation at 25-30 DAS and it was at par with pre-emergent application of pretilachlor 50 EC @ 1.0 kg a.i. ha^{-1}*fb* one intercultivation at 25-30 DAS (Huddar, 2021).

Weed Management with Buckwheat

Buckwheat have allelopathic effect which could suppress weeds (Golisz *et al.* 2007) [29]. In addition, the buckwheat foliage and stem contain 3 natural phytotoxins namely fagomine, 4-piperidone, and 2-piperidinemethanol, those suppress the weed growth and development (Khanh *et al.* 2005, Golishz *et al*., 2007) [40, 29].

Allelopathy and Weed Management

Buckwheat is generally said to have allelopathic affect and suppress weeds which might be due to different mechanisms like allelochemicals released from incorporated buckwheat or buckwheat used as a mulch or cover crop or the allelochemicals extracted and sprayed. Falquet *et al*., 2015 [21] reported that buckwheat cover crop can help to control weeds by affecting their emergence and the seed bank in the soil. Wirth and Gfeller, (2016) [74] reported that interaction of buckwheat and pigweed roots under the field conditions lead to suppression of the pigweed growth which was due to competition for light and the release of chemicals by the buckwheat roots. Golisz *et al*.,2007 [29] reported that inflorescence, leaves and stem of buckwheat have allelochemicals in different concentration and the highest was in leaves followed by inflorescence and lowest in stem.

Insect Pest and Diseases

Buckwheat is fairly free from various insecs and disease problems. Among the insect-pests, cut worms and aphids are important one, but extensive losses are rare (Babu *et al*., 2018) [5]. Several pathogenic disorders have also been reported in buckwheat. These include stern rot due to *Botrytis cinerea*; root rots due to Fusarium spp., (Singh and Atal, 1982) [66].

Harvesting

Buckwheat is a short season crop with life cycle of 70-90 days (Campbell, 1997) [12]. Buckwheat has an indeterminate growth habit, which means both reproductive and vegetative stages are overlapping and not all the seeds mature at one time. Buckwheat is harvested when majority of the grains are matured and plant including leaves turns brown. Thumb rule of harvesting the crop when 70-75 per cent of the seeds are brown and the groat inside is firm. Harvesting before 75 per cent of the seeds are matured will result in excessive amounts of high moisture green seeds and plant fragments that will cause problems in storage. The crop can be harvested manually with machines. Delay in harvesting leads to high shattering. Artificial drying is likely to be necessary for direct-cut buckwheat (Wilcke, 1997) [73]. The main concerns for harvest timing are lodging and shattering. The risk of lodging increases quickly as the seeds get heavier, the leaves fall and the winds become stronger. Shattering occurs in over-mature plants to the extent of 20-25 per cent (Bjorkman *et al*., 2008) [8].

Processing

The hull is removed during milling. The second milling removes the middlings and produces a light brown buckwheat flour. White flour can be produced with more milling. The groats are light coloured when fresh and begin to darken a few months after harvest. (Wilcke 1997) [73].

Nutrient Composition and Health Benefits of Bukwheat

Buckwheat is considered to be a good source of nutritionally valuable protein, lipid, dietary fiber and minerals, and in combination with other health-promoting components, such as phenolic and bioactive components (Gimenez-Bastida *et al*., 2015) [28]. Buckwheat is a good source of proteins and which are rich in arginine and lysine, the primary amino acids limiting in cereals (Christa and Soral-Smietana, 2008) [16]. Buckwheat seeds contain 12-15 per cent protein **(**Bonafaccia *et al*., 2003**,** Alvarez-Jubete *et al*., 2010) [10, 1]. Nutritive value of buckwheat varies from hulled grains and dehulled grains. Hulled grains are rich in protein, fibre, fat and total minerals compared to dehulled grains.

Health Benefits of Buckwheat

Buckwheat has gained worldwide importance because of the bioactive constituents such as rutin, orientin, vitexin, quercetin, besides other essential components like fagopyritols find vast potential for glycemic control in type II diabetics (Verardo *et al*., 2011) [71]. Flavonoids are phytonutrients acting as antioxidants and with chelating properties (Bojnanska *et al*., 2009) [9]. They act as cardioprotective through inhibition of lipid peroxidation, chelate redox-active metals, and mitigate other processes involving reactive oxygen species. Buckwheat contains many flavonoid compounds, known for their effectiveness in reducing blood cholesterol, keeping capillaries and arteries strong and flexible, and helping the prevention of a high blood pressure (Santos *et al*., 1999, Fabjan *et al.*, 2003) [61, 20].

Multiple Uses of Buckwheat

Quick Cover and Green Manure

Its rounded pyramid-shaped seeds germinate in just three to five days. Buckwheat typically produces only 2 to 3 tons of dry matter per acre, but it does so quickly in just six to eight weeks (Pavek, 2014, Geneau *et al*., 2011) [53, 26]. Green manuring of buckwheat improves soil aggregate stability and scavenges nutrients especially phosphorus and calcium (Arcand *et al*., 2010) [4].

Weed Suppressor

Buckwheat's strong weed-suppressing ability makes it ideal for smothering warm-season annual weeds (Marshall and Pomeranz, 1982).

Buckwheat as a Medicinal Plant

Rutin constituent of buckwheat is used in averting edema, haemorrhagic diseases, and stabilizing high blood pressure (Omidbaigi and Mastro, 2004) [51]. Rutin is used in medicine in the treatment of increased capillary fragility with associated hypertension, leading to hemorrhage, purpurea and bleeding from kidney. Rutin also has potent anti-carcinogens properties. Fagopyrin is a naphthodianthrone substance with photosensitizing effect. The photosensitizing effect of fagopyrin is recently uses in photodynamic therapy for the treatment of microorganism and cancer cells (Dai *et al*., 2009) [17]. Tartary buckwheat can be processed into different kinds of teas, which have functions of reducing blood pressure and lowering sugars and lipids.

Phosphorous Pump

Buckwheat is known as a **"**phosphorus pump**"** because it is assumed the roots solubilize phosphorus from phosphate precipitates in the soil profile and subsoil (Gardner and Boundy, 1983) [25]. Under the low P fertilized soils there was an organic anion exudation from the roots of buckwheat (Possinger *et al.*, 2013) [57] whose pH was acidic which lead to increased solubility of FeP04 and MnO_2 to (Aman and Amberger, 1988) [2]. Due to this mechanism soil bound Phosphorous gets solubulised and moves to the available pool (Teboh and Franzen, 2011) [70]. Under moderate levels of soil P buckwheat was found to have removed more P compared to other crops (Schelfhout *et al*., 2018) [63]. This mechanism happens to a maximum extent in the soils with higher total phosphorous and less P fertilizer application and does not takes place in the soils with low P (Hallama *et al.,* 2019, Hallama *et al*., 2019) [32, 32]. Buckwheat with P to the succeeding crop is similar to the legumes with N to further crop Lopes *et al*. (2021) [45].

Buckwheat and Insect Biodiversity

Buckwheat with long duration of flowering period attracts many of the insects which helps in cross pollination and also many natural enemies, predator insects which reduce the insect pests on cultivated crops. This might be one of the reason for the very much reduced use of pesticides in buckwheat crop compared to other crops. Buckwheat either grown as sole crop or intercrop attracts many group of insects which inturn increase the insect biodiversity in the field. In squash and buckwheat intercropping, reduced pesticide application was recorded due to increased natural enemy population, similarly buckwheat intercrop or live mulches reduced white fly incidence due to increased natural enemies and also flowering attracted beneficial insects (Liburd, 2013) [44]. Honey bees, wasps and solitary bees are involved in buckwheat pollination and hence considered buckwheat as excellent plant for bee pasture and insect garden (Mader *et al.* 2011) [47]. Kambrekar *et al.* (2018) [38] studied the pollination fauna with buckwheat in North Karnataka and reported that hymenoptera were the most abundant pollinators (little bee, Apis florea, Apis dorsata) which visited buckwheat during the flowering period due the yield of buckwheat increased twice in case of pollination by honeybees compared to isolated plants by covering plots without honeybees which indicated the increased insect diversity (Bavec and Bavec, 2015) [7]. Because of the ability of buckwheat to attract many of the pollinators and especially honeybees, whose nectar is made into honey it is called a honey crop.

Reasons for Low Yield

Several physiological and ecological traits are responsible for its low yield, which are sensitivity to frost, lodging, self-incompatibility and female sterility. (Farooq *et al*., 2016) [22]
Reasons for the low yield include embryo, flower abortion and heterogeneity of its maturation (Plazek *et al*., 2019) [55].

Reasons Why Buckwheat Is Being Considered as an Underutilised Crop

Even though buckwheat being a short duration crop and can be fitted in almost all the cropping systems, the climate favourable for its growth and development is found rarely under Indian conditions. The notion in India is that it is a temperate crop and prefers cool and humid regions rather than tropical and dry regions. Apart from the climate the genotypes suitable for different soil and climatic regions are not being developed. Lack of awareness among farmers about its production technology and benefits. Buckwheat being grown under marginal soils with low or no inputs and chemicals, as it can sustain production even under such conditions but not to its maximum potential which is not taken into consideration by farmers. Even after the crop production lack of mechanical method and machines for harvest which requires much human labour. The shape of the seed is one factor which makes the processing more difficult compared to other cereals. Hence there is a need for the development of processing machinery suitable to the shape of the seed. Despite the yielding potential and ease in the production method buckwheat still remains the underutilised crop because of the lack of proper market facility available. No open market is made available for the farmers to sell their produce. No government policy is made as of that for other cereals and millets so that the crop still remained as an underutilised crop and being grown as a subsistence crop by a group of framers in some particular places and not on commercial scale. Much research and concentration from government is needed to change this underutilised crop to a miracle crop so that the impeccable benefits of this crop can be harnessed.

Conclusion

Buckwheat is an important pseudocereal crop with multiple benefits. Lack of proper knowledge with respect to the production technology and health benefits of buckwheat are some of the reasons for its lesser production and negligible area under its cultivation in the country. There is a need to encourage the cultivation of such nutririch crops which can combat the climate change and also help to meet the nutritional requirement of the increasing population.

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