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**Review/Overview Article**

# Production technology and multifarious uses of buckwheat (*Fagopyrum* spp.): A review

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## ABSTRACT

Among the pseudo-cereals grown in India, buckwheat (*Fagopyrum* spp.) is very important. *Fagopyrum esculentum* Moench, which is known as common buckwheat, is the most cultivated species in the hilly region of India out of the 20 species of buckwheat. Besides this, *Fagopyrum tataricum* Gaertn (Tartary buckwheat) also have limited area under cultivation. At remote locations of mountains ecosystems, buckwheat is a livelihood driven crop for small and marginal farmers. Common buckwheat is a short duration, multipurpose and nutritious crop, which can withstand changing climatic conditions and fit well in multiple cropping systems. Owing to relatively low input requirement and less infestation of insect-pests and diseases, it is the most suitable for organic production system of hilly regions of higher elevation. Buckwheat grains are primarily used for human consumption and also for livestock, poultry and piggery feeds. Rural population of hilly region of India use buckwheat sprouts and as pan cakes especially in breakfast, however, the recommended intake of buckwheat sprouts are less than 40 g/day. Furthermore, buckwheat is also grown as a cover crop, green manure crop, fodder crop, fertility restoring crop, honey crop and medicinal plant. The crop is also a good source of rutin (quercetin-3-rutinosid) and fagopyrin that are known to be used in preventing various human disorders. Tartary buckwheat contains 100-fold more rutin as compared to common buckwheat. Owing to improvement in productivity and profitability of others crops, area and production of buckwheat is declining. Hence, there is an urgent need to develop appropriate policy and scientific interventions for exploitation of this climate resilient super food crop for livelihood security of ever increasing population especially in the hill regions.

***Key words :*** Agro-techniques, Buckwheat, Fagopyrin, Jhuming, Phosphorus pump, Pseudo-cereal, Rutin

Among the pseudo and minor-cereals, buckwheat has the potential to meet the ever increasing food demand of rapidly expanding population in hill areas of the country in the changing climatic scenario. Buckwheat is one of the best suited crops for higher altitudes, where crop growing season is very short. It thrives well in different cropping pattern due to its short duration nature (3-4 months) (Rana *et al.,* 2002) and better adaptability in low temperature and moisture stress conditions (Luitel *et al.,* 2017). It is considered a sustainable crop for supporting the livelihoods of millions of hill populace under changing climatic conditions in future (Babu *et al.,* 2016[a], Tolaini *et al.,* 2016). In the higher Himalayan region of India (4500 amsl), this is the only crop grown (Joshi and Paroda, 1991) and occupies about 90% of cultivated land as a pure crop (Singh *et al.,* 2014). Similarly, it has the potential to produce reasonably good yield under rainfed condition of Himalayan ecosystem when soil moisture is not able to support any kind of crop cultivation. Cultivated buckwheat *(Fagopyrum* spp. 2n=16) is a dicot pseudo-cereal belongs to the family, Polygonaceae, which is distinct from the monocot cereals (Family; Poaceae). The grain of buckwheat is botanically achene; structurally the endosperm resembles cereals as it has a non-starchy aleurone layer and a starchy endosperm. Out of the 20 species of genus *Fagopyrum* (Tang *et al.,* 2010 and Shao *et al.,* 2011), only two *F. esculentum*

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(Common buckwheat) and *F. tataricum* (Tartary buckwheat) are cultivated in India (Chauhan *et al.,* 2010). Tartary buckwheat is also called "India wheat" and "Duck wheat". However, among these two species, common buckwheat is grown at lower altitudes, whereas tartary buckwheat is grown at higher altitudes (Babu *et al.,* 2016a). Common buckwheat is gaining more popularity in the Himalayan region due to its palatable taste and shorter growing period as compared to tartary buckwheat. Buckwheat has the potential for fixing atmosphere nitrogen (Alekseyeva, 2002) and solubilizing native soil phosphorus and potassium (Kontturi *et al.,* 2004). It thrives well under poor soil fertility conditions. It is a multiuse crop mainly cultivated to obtain grains for human consumption, livestock, piggery and poultry feeds, as green manures (Tsuzuki, 2001), soil binding crop (Tundup *et al.,* 2017) and as a smother crop (Xuan and Tsuzuki, 2004). Furthermore, it attracts beneficial insects like pollinators and natural enemies for suppressing pests especially whiteflies and aphids (Frank and Liburd, 2005), hence, can be grown in strips as an insectary crop (Valenzuela and Smith, 2002). Its tender leaves are utilized as a leafy vegetable and for making chutneys. It is also a high-yielding honey plant; normally produces nectar only during the morning hours. In certain parts of India popped grains are eaten and the leaves consumed as vegetable (Gohil, 1984). Buckwheat flowers, leaves and seeds are good source of rutin and quercetin (Jiang *et al.,* 2007), which have protective effect against diabetes, anti-inflammatory activity and also used as medical agents for treating the cardiovascular disorders (Brunori and Vegvari, 2007). Tartary buckwheat is richer in rutin and quercetin content as compared to common buckwheat (Kitabayashi *et al.,* 1995 and Fabjan *et al.,* 2003). Seeds of tartary buckwheat are also less husky than the common buckwheat. The seed is also used in a number of culinary preparations as well as alcoholic drinks. Buckwheat flour is known as a *Kuttu ka Atta* in northern part of India and mainly eaten during religious *Upvas* (fast) when cereals and pulses are not permitted to eat (Rana *et al.,* 2011).The protein content (11-14%) in buckwheat seed is of high quality due to its balanced amino acid composition and rich in lysine (5.5-6%) and arginine (9.2 – 10%), which are generally deficit in cereals (Unala *et al.,* 2017). Similarly, its grains has high content of minerals, especially Ca (110 mg/100 g), Mg (390 mg/100 g), P (330 mg/00 g), K (450 mg/100 g), Fe (4 mg/100 g), Mn (3.37 mg/100 g), Cu (0.95 mg/100 g) and Zn (0.87 mg/100 g) (Campbell, 1997) and biologically active compounds like rutin, fygoprin etc. (Wijngaard and Arendt, 2006). Buckwheat is a good dietary food crop as it has high nutritional value owing to bioactive compounds (Krzysztof *et al.,* 2012) like vitamins, macro- and micro-elements, and enzymes. It has unique feature of containing vitamin P (Pirogovskaya *et al.,* 2004). Furthermore, buckwheat flour is free from gluten and can be safely consumed by people with coeliac disease (Mazza and Oomah, 2005; Christa and Soral-Smietana, 2008). Therefore, it may be an important alternative industrial food crop in agriculture (Kreft, 1994). Despite of its so many uses, farmers are losing their interest in buckwheat cultivation due its low productivity and profitability as compared to high value crops like French beans, fruits, flowers, off -season vegetables, spices and medicinal crops (Rana *et al.,* 2012). Hence, there is an urgent need to develop appropriate region/location specific agronomic management practices, high yielding varieties, and post-harvest technologies for ensuring high productivity and profitability to the buckwheat growers. Therefore, appropriate policy and scientific interventions are the need of the day for increasing buckwheat area and production, which may serve as a super food to feed the burgeoning population under the changing climatic condition especially in remote areas of hilly region of the country.

## DISTRIBUTION AND AREA OF BUCKWHEAT

### *World*

Genetic resources distribution of buckwheat in the world mainly concurs with central Asia especially in the south-western China (Zhou *et al.,* 2018). Therefore, China is considered as center of origin of buckwheat (Farooq *et al.,* 2016). Common buckwheat was domesticated and first cultivated in inland South-east Asia, possibly around 6000 BC, and later spreads to Central Asia, Tibet, Middle East and Europe (Ohnishi, 1998). The common buckwheat (*Fagopyrum esculentum*) is passionately grown in all the continents of the globe; however the Tartary buckwheat (*Fagopyrum tataricum*) is mainly confined in the hilly and mountain region of China and the Himalayas (Zhou *et al.,* 2018). Globally buckwheat is cultivated in 2.4 Mha areas with average production and productivity of 2.4 million tonnes and 1000 kg/ha, respectively. Among the buckwheat growing countries in world, Russia stood

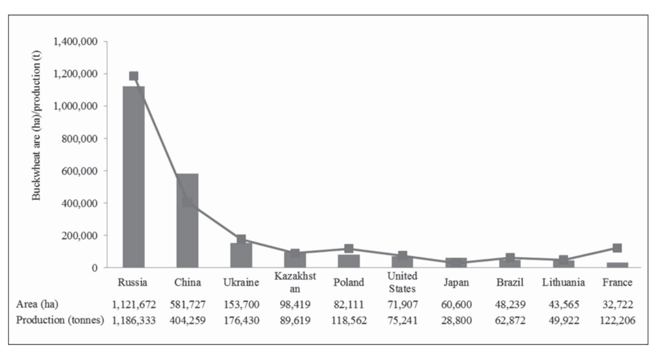


**Fig. 1.** Top ten buckwheat producing country in the world (2016)

first both in buckwheat area (1.12 Mha) and production (1.19 Million tonnes) followed by China and Ukraine. With regards to the productivity, France has the highest buckwheat productivity (3735 kg/ha) in the world (FAO STAT, 2018). Fig. 1 is showing the top ten buckwheat producing countries in the world.

### *India*

Buckwheat is distributed throughout the Indian Himalayan region, but western Himalayan region has more diversity (Rana, 2004). The occurrence of buckwheat ranged from Jammu Kashmir in north to Arunachal Pradesh in east and Tamil Nadu in the south (Rana *et al.,* 2012). However, Jammu Kashmir, Himachal Pradesh, Uttarakhand, West Bengal (Kalimpong, Coochbehar, New Jalpaiguri and Darjeeling region), Sikkim, Assam (Upper Assam), Arunachal Pradesh, Nagaland, Meghalaya (Higher elevation region), Manipur, Kerala, Tamil Nadu (Nilgiris and Palani hills) and Chhattisgarh are the major buckwheat growing states in India (Fig. 2). Among the two commonly cultivated species of buckwheat, tartary buckwheat cultivation is more common at higher altitudes (>2500 m) however, common buckwheat cultivation confined at lower altitudes extended up to 1000 m. Generally, buckwheat is acclimatized to monoculture production. In the high altitude areas of Arunachal Pradesh, Jammu and Kashmir, Himachal Pradesh and Sikkim, only one crop is produced in a year, while two and three crops of buckwheat in a year is grown in the mid and foot hills, respectively.

## CLIMATIC AND SOIL REQUIREMENT

### *Climate*

Common buckwheat is a facultative short day plant (Quinet *et al.,* 2004), thrives well in cool and moist temperate regions, although seeds can also germinate in very dry regions (Gardner and Boundy, 1983). Generally, it is known as undemanding crop (Radics and Mikohazi, 2010). However, total biomass production, grain yield and quality of buckwheat depend on temperature, rainfall and sunshine hours (Jung *et al.* 2015). 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. Buckwheat can germinate and grow well between the temperature ranges of 5°C - 42°C; however, the optimum temperature for buckwheat germination and growth ranges between 24°C -26°C. During flowering stage, temperatures above 30°C result in loss of flower (blasting), fruit desiccation and poor grain yield (Drazic *et al.,* 2016). Temperature is the most important environmental factor which affects flavonoid and rutin accumulation in buckwheat (Sobhani *et al.,* 2014). Adequate soil moisture appears to be essential for good yields. Buckwheat wilts and grows very slowly under poor moisture supply situation. As soon as buckwheat plant receives moisture, the plants will often start to grow again but maturity is delayed. On the contrary, cereals face forced maturity under low soil moisture condition. Low soil moisture levels along with high temperatures can aggravate the situation. The yield of common buckwheat increased with high soil moisture although seed set remained essentially the same (Gubbels, 1978).

### *Soils*

Buckwheat is a very hardy crop and can be grown in various soil types, even infertile, rocky and poorly tilled lands (Khanh *et al.,* 2005), where possibly no other grain crop can be grown (Taylor, 1998). It prefers well drained sandy soils and tolerates acidic soil conditions (pH as low as 4.8) (Jung *et al.,* 2015). Buckwheat does not grow well in saline and semi-arid regions (Horie *et al.,* 2012).

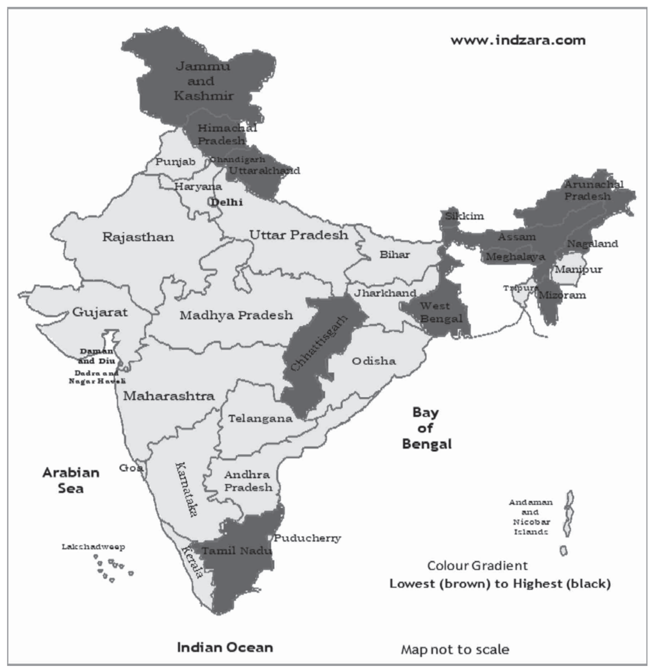


**Fig. 2.** Dark colour denotes major buckwheat producing states of India

## CROP IMPROVEMENT

Indian Council of Agricultural Research, New Delhi started a systematic research programme on under-utilized crops after creation of All India Coordinated Research Project (AICRP) on Underexploited and Unexploited Crops in 1982. Considering the importance of buckwheat, AICRP included this miracle crop under the Umbrella of All India Coordinated Research Network on Potential

Crops (AICRN-PC) during 1984. More than 150 germplasm accessions/ breeding lines were tested for adaptability and yield potentials on various locations across the India (Rana *et al.,* 2012). In India 3 improved varieties of tartary buckwheat, viz. 'Himpriya', 'Himgiri' and 'Sangla B-1' and 2 of common buckwheat, viz. 'VL Ugal-7' and 'PRB-1' have been released by different research organizations.

## IMPROVED CULTIVATION PRACTICES

### *Tillage requirement*

Buckwheat can be cultivated under reduced tillage system. It is considered as a low input crop (Edwardson, 1996); hence can be grown in marginal land and under organic production system. The performance of common buckwheat is relatively poor as compared to tartary buckwheat under no-till system. Overall, this crop requires well prepared seed bed and crumb structure for better germination and emergence. To ensure proper germination, residual soil moisture should be conserved and after harvesting of preceding crop, disking, tilling and rolling is required for proper seed bed preparation.

### *Sowing time*

Sowing time is a single non-monetary input, which affects crop productivity largely (Das *et al.,* 2016) and buckwheat is not an exception as its sowing time has affect on seed germination, days to flowering, length of vegetation period, rutin content and herb and grain yield of buckwheat (Sugimoto and Sato, 1999; Omidbaigi and Mastro, 2004). The sowing of buckwheat in India is generally begin with the onset of the monsoon and continues up to August (Hore and Rathi, 2002). However, it usually varies from place to place because of climatic variability. Fortitude of 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). 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). The optimum sowing time of buckwheat in different region of India is given in Table 1.

### *Seed rate, spacing and sowing depth*

The seed rate mainly depends on the type of genotype, environmental and management condition. The optimum seed rate of buckwheat is about 35–40 kg/ha for grain crop and 50–60 kg/ha for smoother, vegetable, or fodder crops (Hore and Rathi, 2002). Higher seeding is detrimental, as overly thick plant stands produce spindly plants with short stems and few seeds (Tolaini *et al.,* 2016); hence, thinning is recommended at 15–20 days after sowing to get desired plant population. Optimum plant population is the key for obtaining the higher yield and income especially in indeterminate crops like buckwheat. Optimum plant density is the driver for proper utilization of available resources with least competition throughout the crop growth period, which ultimately decides the phenotypic and genotypic expression of the crop. The planting geometry of buckwheat mainly depends on soil type, varieties, management practices and climatic conditions. The maximum grain yield of tartary buckwheat under rainfed condition of hilly region of India was reported with 40 cm × 10 cm planting geometry (Saini and Negi, 1998; Rana *et al.,* 2002; Rana *et al.,* 2005). However, the planting geometry of 30 cm × 10 cm was found suitable in case of common buckwheat (Babu *et al.,* 2016[b]; Hulihalli and Shantveerayya, 2018). Depth of sowing also plays an important role for determining the optimum plant population and crop yield. The recommended seeding depth of buckwheat is about 4–6 cm; however, deeper seeding may be done under drier conditions (Bjorkman, 2012).

### *Nutrient management*

Buckwheat has been regarded as a crop of poor fertility soils (Rana *et al*., 2003). Its nutrient requirement is fairly low (Radics and Mikohazi, 2010) and generally cultivated on residual soil fertility. Under very fertile soil, the crop is prone to lodging and damage is severe under strong winds and heavy rains. Under higher dose of nitrogen, risk of lodging is high owing to decrease in lignin

**Table 1**. Sowing time of buckwheat in different parts of India

| Sl. No. | Regions | Sowing time |
|---|---|---|
| 1. | North-Western hills | June–July (Rainy season) ad March–April (spring season) |
| 2. | North-Eastern hills including Assam | August–September, (October–November in Sikkim under intensive cropping systems) |
| 3. | Nilgiri hills (Tamil Nadu) | April–May |
| 4. | Plani hills (Tamil Nadu) and Kerala | January |
| 5. | Chhattisgarh | September–November |

(Joshi, 1999 and Babu *et al.,* 2016[a]) content and related enzymes activities (Wang *et al.,* 2015). It also causes poor seed setting and delay in maturity. Contrary to this, higher doses 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). Low and imbalanced application of macro nutrients coupled with low organic matter content of the soil limit the full potential of yield (Tandon, 1992). Alekseyeva (2002) reported that buckwheat has the ability to fix atmospheric nitrogen (N) into the rhizospheric soil which may play a vital role in sustainable crop production. In organic agriculture, N is the most limiting nutrient for crop production as a result of limited ability of soils to supply N as compared to large need of the plant (Lazanyi and Loch, 2009), hence buckwheat is the most important crop for organic management condition. A significant variation in the seed yield of buckwheat was reported under different nutrient management practices. Buckwheat with 1.6 tonnes grain yield/ha removes on an average 47 kg N, 22 kg P and 40 kg K/ha (Campbell and Gubbels, 1978). 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 (FYM)/ha (Phogat and Sharma, 2000). The highest seed and straw yield of buckwheat was recorded under 75% RDF (RDF is 40 : 20 : 20 kg N : $P_2O_5$ : $K_2O$/ha) and 25% substitution through vermicompost + *azotobacter* in West Bengal region of India (Saha *et al*., 2017). In pea-buckwheat cropping system, Kumar *et al*. (2016) studied the residual effect of nutrients applied to pea, and reported that seed yield of buckwheat under FYM 20t/ha, vermicompost 3.0 t/ha, vermicompost 4.5 t/ha, vermicompost 1.5 t/ha + FYM @10 t/ha, vermicompost 3.0 t/ha + FYM 10 t/ha and inorganic nutrient management treatment (RDF is 20 : 60 : 30 kg N : $P_2O_5$ : $K_2O$/ha) was 26.3, 79.6, 95.4, 94.4, 100.6 and 40.9% higher over control. Effect of micro-organism inoculation on growth, yields, quality and soil biological properties of common buckwheat under hilly ecosystems was also tested and it was found that the double inoculation of *Azotobacter* spp. and *Azospirillum* spp. was found most efficient inoculants under acidic soil condition of Sikkim Himalayas and recorded significantly higher values of yield attributing characteristics, grain yield (1.23 Mg/ha), total phenolic and flavonoids content in seed, soil microbial biomass carbon (SMBC) and dehydrogenase activities over single inoculation of common buckwheat (Singh *et al.,* 2014). Slavol (organic fertilizer) inoculation+ hydrogel along with foliar application of the microbiological fertilizer recorded the highest yield of buckwheat (1.5 t/ha) in hilly-mountainous region of Germany (Oljaca *et al.,* 2012). Combined application of vermicompost 2.5 t/ha + mustard cake 2.5 t/ha + poultry manure 2.5 t/ha + FYM 4 t/ha improved seed yield of buck wheat by 500 kg/ha over recommended dose of inorganic fertilizers in West Bengal (Mahata *et al.,* 2018). In Sikkim, application of 1.5 t vermicompost/ha recommended for profitable buckwheat production (Babu *et al.,* 2016a). Sharma (2005) reported the significant increase in yield and yield attributes of buckwheat with increasing level of nitrogen. However, Campbell (1997) recommended the use of 60 kg N/ha for fetching the optimum grain yield of buckwheat. Saini and Negi (1998) reported that the optimum dose of N for buckwheat is 60 kg N/ha under hilly ecosystems of Himachal Pradesh. Buckwheat has the ability to take up P which is released back into the soil in available form following incorporation of buckwheat residue into the soil (Zhu *et al*., 2002; Bowman *et al*., 1998). Plant height and branches/plant were not affected by P application, whereas grains/plant and test weight increased significantly with each increase in P-level from 0 to 40 kg $P_2O_5$/ha. Application of 40 kg $P_2O_5$/ha increased grain yield by 20.2% and 9.5% of tartary buckwheat and 36.8% and 10.2% of common wheat over 0 and 20 kg $P_2O_5$/ha (Sharma, 2005). Application of 50:40:40 kg NPK/ha found suitable in Karnataka for harvesting the optimum yield of buckwheat (Tummaramatti *et al.,* 2014). Buckwheat also has the ability to grow well in soils those are high in aluminium due to its ability to exude oxalic acid from root. Zhu *et al*. (2002) reported that this resistance may be related to immobilization and detoxification of aluminum by P in the root tissues.

### *Buckwheat in cropping systems*

Buckwheat is a short duration multipurpose crop, so fits well in intensive cropping systems in mid-hills and plain regions as a catch crop (Baniya *et al.,* 2000). In India, it is grown as a summer crop at higher altitudes, an autumn crop in mid altitudes and as a winter crop in the plains and foot-hills. In the high-hills, mono-cropping prevails due to short growing season.. In the mid- hills, buckwheat follows maize under upland conditions and rice in the lowlands. Multiple cropping and crop diversification is a potential armament to combat climate change and for enhancing land profitability and farmer's income (Joshi, 1999). There are ecological as well as economic advantages to increase the land-use efficiency. Under organic management condition of mid hill rainfed ecosystem of Sikkim, buckwheat is the most efficient alternative crop in intensified cropping systems (300% cropping intensity) (Babu *et al.,* 2016b and Singh *et al.,* 2017). Similarly, at higher altitude regions of Himachal Pradesh, vegetable pea–buckwheat system is found most remunerative over single cropping of vegetable pea (Kumar *et al.,* 2016). Intercropping of buckwheat with Sikkim mandarin is also found very remunerative in mid-hill ecosystem of Sikkim Himalayas.

Buckwheat can also be a potential crop for 1.50 Mha areas under Jhuming/slash and burn system of north-east India (Nath *et al.,* 2016), owing to its soil and water conserving characters. Initially the Jhuming cycle was too large (20-30 years) but now-a-days due to increased population pressure, jhuming cycle has reduced to 3-6 years leading to more exploitation of land and forest resources (Saha *et al.,* 2012). Owing to its short duration (90-100 days), good performance under poor fertility and water scarce conditions (Rana *et al.,* 2005), multipurpose features and tolerance to insect, pest and disease infestations (Krzysztof *et al.,* 2012), buckwheat can be grown in large scale without the use of agrochemicals in abandoned shifting cultivation areas in north-eastern hill NEH region under changing climate. The farmers of (NEH) region especially *jhumias* are unable to purchase the costly production inputs. Therefore, they can easily adopt the crop for higher income and livelihood improvement. Some of the promising buckwheat based- cropping systems of Himalayan region is given hereunder in Table 2.

### *Weed management*

Productivity of buckwheat is negatively associated with weed count and weed biomass (Rana *et al.,* 2003; Rana *et al.,* 2004). Therefore, weeds pressure should be below the economic threshold level (Parodi and Nebreda, 1998). Buckwheat is a fast growing crop, generally emerges within 4–5 days after sowing, so critical period to keep the crop free from weed is 20–30 days only. In some areas, higher seeding rates, 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 and Rathi, 2002; Choudhury and Prem, 2007). In addition, the buckwheat foliage and stem contain 3 natural phytotoxins namely fagomine, 4- piperidone, and 2-piperidine-methanol, that suppress the weed growth and development (Xuan and Tsuzuki 2004; Khanh *et al.* 2005). Although, buckwheat is a very good weed suppressing crop, weed control during establishment phase is very challenging under diverse production systems (Jakubiak 2005; Podolska 2006). Buckwheat is suffered by various weed floras; *Digitarias anguinalis* is the most competitive weed species in Himachal Pradesh (Rana *et al.,* 2004) and *Amranthus retroflexus*, *Ambrosia temisiifolia*, *Chinopodium album* are the common weed flora of buckwheat in Sikkim. Hence, weeding once at 20–30 DAS is recommended to minimize the weed infestation. However, manual weeding is tedious, time consuming and uneconomical. In order to reduce the drudgery of hand weeding and make the buckwheat production more profitable, application of alachlor 1.50 kg/ha is recommended to minimize the weed losses in buckwheat (Rana *et al.,* 2004).

### *Water management*

Water requirement of buckwheat is quite low as compared to cereal crops (wheat, maize and rice), which render it ideal crop for water thirsty rainfed areas. About 225–315 liters of water is required to produce 1 kg of buckwheat seeds (Jacquemart *et al.,* 2012) as against 800–1000 liters for wheat seed. Hence, under changing climatic conditions, buckwheat has the capacity to adopt under moisture scarce condition and improved water productivity (output per water input) to meet food requirements of ever increasing population. Intermittent application of water causes a reduction in dry matter production and an increase in rutin content in the vegetative parts of buckwheat (Ghouzhdi *et al.* 2009). Buckwheat crop grown with supplemental irrigation had failed to affect the crop yield significantly over the control (no irrigation) (Maksimovic *et al.,* 2013). Hence, they have suggested that buckwheat tolerates drought well, without drastic yield reduction, while responding quite well to irrigation. Farmers of north-east India generally cultivated buckwheat as a rainfed crop with zero irrigation. However, one or two irrigations, if available at flowering and grain formation stage should be given for profitable and quality buckwheat production.

### *Insect-pests and diseases*

Buckwheat is relatively free from serious insect-pest and disease problems. Among the insect-pests, cut worms and aphids are important one, but extensive losses are rare.

**Table 2.** Buckwheat based-cropping systems prevailing in the Himalayan Region

| High Himalaya | Mid Himalaya | Lower Himalayan region and foot- hills |
|---|---|---|
| Buckwheat–Fallow | Buckwheat–Wheat | Potato–Buckwheat–Barley |
| Pea–Buckwheat | Buckwheat–Pea | Cabbage–Buckwheat–Wheat |
| Potato–Buckwheat | Buckwheat–Mustard | Tomato–Buckwheat–Pea |
| | Buckwheat–Lentil | Potato–Buckwheat–Mustard/Lentil |
| | Maize/Rice–Buckwheat | |
| | Maize (Green cobs)–Pahenlo dal–Buckwheat | |

Melon aphid *(Aphis gossypii)* has been found to frequently infest buckwheat leaves (Tahir *et al,* 1985). If aphid infestation is heavy, it may cause leaves to yellow and/or distorted, necrotic spots on leaves and/or stunted shoots. Aphids secrete a sticky, sugary substance called honeydew, which encourages the growth of sooty mold on the plants. In case of heavy infestation Petroleum servo Agrospray @ 7 ml/liter or Neem oil (1500 ppm) @ 3 ml/liter can be sprayed for effective management of aphids (Babu *et al.,* 2014). Several pathogenic disorders have also been reported in buckwheat. These include: aster yellows caused by *Mycoplasma;* stern rot due to *Botrytis cinerea;* root rots due to *Fusarium* spp.., *Botrytis* spp.; and *Rhizoclonia* spp.; chlorotic leaf spot due to *Alternaria allernals;* stipple spot disease caused by *Bipolaris sorokiniana;* blight due to *Phyloplhora parasilka* and downy mildew caused by *Peronospora* spp. (Singh and Atal, 1982). Attacks of several viruses also cause reduction in plant height and losses in grain yield. Buckwheat is damaged by a complex of weevils, the rice (*Sitophilus oryzae*), granary (*Sitophilus granarius*), and maize (*Sitophilus zeamais*) weevils during storage. Prevention is the best strategy to avoid insect problems in storage of buckwheat grains. Proper drying of grains is necessary to reduce infestation. Before introduction of new grains, the old storage bin should be cleaned properly. After the bin is cleaned, the floor and wall surfaces both inside and outside the bin should be treated with Neem oil (1500 ppm) @ 5 ml/liter and grain should be placed after proper drying of bin (Babu *et al.,* 2014).

### *Harvesting and threshing*

Buckwheat is an indeterminate crop and did not have synchronized maturity hence; swathing is a necessary operation to minimize the shattering losses. Shattering causes about 20–25% yield loses in buckwheat (Campbell and Gubbels, 1986). Some researchers have pointed out that tartary buckwheat is more prone to shattering losses than common buckwheat (Tahir and Farooq, 1988). Hence, the crop should be cut when 70–80% of the seeds have turned brown (physiological maturity) and place in windrows to facilitate drying till the seed head reaches to 16–18% moisture content. Thereafter make the bundles to minimize the shattering losses of grain. Swathing should be done in the early morning when the dew is present, or in foggy weather to reduce the shattering losses. The harvesting time of buckwheat varies according to agro-ecological conditions and type of genotypes grown. The harvesting period is not limited in Tartary buckwheat as compared to common buckwheat. However, under normal conditions it can usually be harvested approximately 90–100 DAS. However, under unfavourable conditions the crop duration increases up to 5 months (Michiyama and Hayashi, 1998). During the harvesting period, seeds of all stages, namely, mature seeds, immature seeds, and a few flowers are present at the same time period (Farooq and Tahir, 1982). Yield potential of buckwheat mainly depends on genotypes and environment interaction. However, well managed buckwheat crops yielded about 1000–1500 kg grain/ha. Buckwheat should not be stored for longer time because grain is susceptible to rancidity. The seeds must be well dried. Over matured seeds when come in contact with high moisture, germinate quickly as the seeds have vivipary characteristics. Buckwheat can be stored safely at 13% moisture content for longer time. When short-term storage is required buckwheat can be stored at lower temperature about 10$^{o}$C with <15% moisture in grain. The drying temperature of grain should not exceed 45$^{o}$C otherwise grain quality is badly hampered (Olson, 2001).

## MULTIFARIOUS USES OF BUCKWHEAT

### *Buckwheat as a soil productivity restoring crop*

Buckwheat perform multitude functions as a break crop (breaks the life cycle of insect, pests and diseases), green manure crop, smother crop (suppress weeds), nutrient conserving crop (enhanced nutrients uptake, reduces nutrients leaching and immobilization), gourd crop (protecting main crop from wild animal), cover crops (soil protection against water and wind erosions) and as land reclamation crop. Buckwheat is an ephemeral green manure crop which germinates in 3–5 days (Bjorkman and Shail, 2010), flowers within 30–45 days and matures completely within 90–110 days (Bjorkman *et al.,* 2008). During its growth period, it reaches a height of 70–80 cm, and produces about 5–7 tonnes of biomass/ha (Pavek, 2016). Nutrients release patterns of buckwheat biomass after green manuring largely depend on growth stage at which crop is incorporated in to the soil. Early flowering or late vegetative stage is the right stage for green manuring and after cutting the residue is either left on the surface or incorporated into the soil, depending on the purpose. Mulch left on the surface helps in maintaining soil stability, and suppress weeds. Green manure crop of buckwheat tightens up the on-farm nutrient cycle by soaking up the leachable nutrients. Green manuring of buckwheat improves soil aggregate stability and scavenges nutrients especially phosphorus and calcium (Clark, 2007). Buckwheat residues had a narrow C: P ratio (175) with high P concentration (2.7 g/kg), which enhances P availability in residue amended soil (Arcand *et al.,* 2010). Buckwheat had high carbon: nitrogen ratio (C:N = 34), hence causes immobilizing of nitrogen during decomposition and reduces soil N availability. When buckwheat residue is incorporated into the soil, it rapidly breaks down and releases nutrients for uptake by the subsequent crop (Oplinger *et al.,* 1989) especially potassium (Kumar *et al.,* 2008). In addition, buckwheat also has the potential to suppress root pathogens (Magdoff and van Es, 2009) and insect-pests cycle.

### *Buckwheat as a "Natural Phosphorus Pump*

Buckwheat has an excellent ability to scavenge phosphorus, calcium and some minor nutrients from the soil, which otherwise are unavailable to other crops, and return it in a more plant-friendly form to other crops in the system, hence considered as a "natural phosphorus pump". Phosphorus (P) uptake of buckwheat is about ten times higher than wheat (Zhu *et al.,* 2002). Buckwheat produces exudates with a lower *p*H in P deficient conditions (Simpson *et al.,* 2011), acidify rhizospheric soil and absorb P beyond its metabolic requirement (Amann and Amberger, 1989), showed luxury consumption of P (Bekele *et al.,* 1983). Similarly, Zhu *et al* (2002) reported that buckwheat has high P-uptake efficiency in calcareous soils but is less effective in soils dominated by Fe and Al phosphates (Otani and Ae, 1996). The roots of buckwheat have a high storage capacity for inorganic P. As a result, when buckwheat plants are incorporated in the soil, they decay quickly, making phosphorus and other nutrients available to the succeeding crop (Valenzuela and Smith, 2002). Under phosphorus deficient condition, buckwheat root increases the release of protons and P solubilizing substances and enhances P uptake (Zhu *et al.,* 2002). The roots exudates of buckwheat contains several mild acids *e.g.* phosphatases and has the ability to extract phosphorus from organic sources (Gardner and Boundy, 1983) and make available to succeeding crops (Valenzuela and Smith, 2002; Tolaini *et al.,* 2016). These acids also mineralize the slow release organic fertilizers like rock phosphate and make available to plant (Bjorkman and Shail, 2010).

### *Buckwheat as a body building/protective/quality food*

The economic importance of buckwheat is mainly due to high nutritive value of its grains and the presence of rutin in foliage. In general buckwheat grain contains about 10–14% protein which is more than most of the cereals (Nicholson *et al.,* 1976). Buckwheat protein is also superior in quality than cereals, due to high concentration of most essential amino acids especially lysine, threonine, tryptophan and the sulfur containing amino acids (Eggum *et al.,* 1981), with about 80% digestibility. Thacker *et al.* (1983) suggested that buckwheat may be a valuable supplement to cereal grains as its high lysine content compensates for the limiting lysine content in diets consisting predominantly of cereals. Prolamins content in buckwheat grain is very low as compared with other cereals including wheat (Francischi *et al.,* 1994). Buckwheat flour is free from gluten and used in treating the celiac disease in human being (Tummaramatti *et al.,* 2016). The biological value of tartary buckwheat has been found to be lower than common buckwheat due to high tannin content and a high hull percentage, (Tahir and Farooq, 1985). Buckwheat grains contain a high quality slowly digested starch (Tahir and Farooq, 1985), helps to treat diabetics. Buckwheat flour also contains a good proportion of high quality fat. Palmitic, oleic and linolenic acids constitute about 95% of the total fatty acids in buckwheat grains (Joshi and Paroda, 1991). Buckwheat grain is very rich in trace elements like Zn, Cu, Mn and Se as compared to cereal crops (Kreft *et al.,* 1996).

### *Buckwheat as a medicinal plant*

Buckwheat grain has very pleasant aroma and salicylaldehyde (2–hydroxybenzaldehyde) is mainly responsible for buckwheat aroma (Janes and Kreft, 2008). Rutin (quercetin-3-rutinosid) constituent of buckwheat is used in preventing edema, haemorrhagic diseases, and stabilizing high blood pressure (Omidbaigi and Mastro, 2004). Rutin content in buckwheat various with genotypes and growing condition. However, rutin content in buckwheat foliage range 3–6% of dry weight. Generally, tartary buckwheat contains about 100 fold more rutin than common buckwheat (Suzuki and Morishita, 2016). Rutin is mainly located in flowers and in green parts of buckwheat plant. In seeds there is less rutin than in leaves, but there could be some rutin as well in buckwheat flours. The rutin content higher than quercetin in buckwheat seeds, range from 0.05 to 1.35% of buckwheat seeds, while quercetin content varied from 0.01 to 0.17% (Bai *et al.,* 2015). 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, isolated by Brockmann and Lackner for the first time in 1943 from the foliage of common buckwheat (*Fagopyrum esculentum*), however it exclusively found in cotyledons (Kreft *et al.,* 2013). The chemical structure of Fagopyrin is similar to that of hypericin (Benkovic *et al.,* 2013), differing only in the presence of two symmetrically placed 2-piperidinyl groups in fagopyrin (Sytar *et al.,* 2016). The photosensitizing effect of fagopyrin is recently uses in photodynamic therapy for the treatment of microorganism and cancer cells (Dai *et al.,* 2009). Peoples of hilly region of India also used buckwheat sprout especially in breakfast, however, the recommended intake of buckwheat sprouts is less than 40 g per day (Kreft *et al.,* 2013). Buckwheat also contains plentiful Cu, which can improve the function of Fe and prevent hypohemia in human beings. Tartary buckwheat can be processed into different kinds of teas, which have functions of reducing blood pressure and lowering sugars and lipids. Farmers of remote locations of north-east India traditionally use tartary buckwheat to treat livestock suffering from foot and mouth disease.

### *Buckwheat for sustaining livelihood security of hill regions*

Buckwheat is a multipurpose crop but in India primarily grown for its grains. However, tender shoots and leaves are also used as leafy vegetables. The seed is used in a number of culinary preparations as well as alcoholic drinks; the husk is used in stuffing pillows. The grain is generally used as human food, the flour used in the preparation of chapattis, pancakes, biscuits and noodles etc. People in main land consume buckwheat during religious fasting days. It is also used as a livestock, poultry and piggery feeds. Tartary buckwheat also used in place of tea in hill region The straw is fed to cattle immediately after threshing, when it is still green/fresh. Buckwheat flower produces a good quality of honey and can also cultivate for honey crop. Buckwheat crops can also be grown as an insect trap crop with other economically important crops to reduce the insect-pests infestation in main crops.

## PROSPECTS AND POTENTIAL OF BUCKWHEAT IN INDIA

Buckwheat is an underutilized and neglected crop, however, it has many advantages for growers and the consumers. It is a climate resilient crop with the ability to grow in poor and marginal soils and even under environmental stress conditions. It is speculative that a good diversity of buckwheat occurs in Indian Himalayan region and hence crop specific missions need to be undertaken to collect the diverse and unexploited germplasm and systematic characterisation and documentation of buckwheat germplasm collections made for future exploitation. Buckwheat has a very short growing season and well suited to high hill rainfed ecosystems. It is also a suitable crop for aberrant weather situation as a contingency crop. The buckwheat is a good candidate crop for sustainable diversification and intensification programmes. Buckwheat, with its high quality protein balanced with amino acids, is an indispensable protein source for the tribal farmers inhabited in remote hilly locations, where there is limited access to transportation. As compared to common buckwheat, tartary buckwheat is not utilized in the international trade due to its bitterness and poor palatability. Dehulling in tartary buckwheat is difficult due to tightly adhering hull. Therefore, suitable hulling machines should be designed for profitable cultivation of buckwheat in India especially under remote hilly locations. The genetics and the effects of the environment on the bitter component of tartary buckwheat require further research. An evaluation of existing germplasm is required to determine the identity and function of this compound and if it can be eliminated from this very desirable crop. Buckwheat grain is full of dietary fibre, lipids, minerals and vitamin especially P, E and B complex (Boafaccia *et al.,* 2003) with high rutin and fagopyrin content those have various medicinal properties. Hence, buckwheat is a kind of super food to the hill farmers of India. It is, thus, desirable that buckwheat should be an integral crop of agricultural production systems of mountain agriculture in order to maintain nutritional standards of small and marginal farmers. Resources requirement for buckwheat cultivation is very less as compared to others cereals, hence it is a good candidate crop for rainfed ecosystems, organic farming, zero-budget farming and for jhum areas in north-east India. It is useful as cover crop in maintaining agro-ecosystem by storage of water and preventing soil erosion. Therefore, this crop could become an important component of the agriculture system of hill region for achieving nutrients self-sufficiency for the rural populace at regional level.

Buckwheat is short duration multipurpose crops which can withstand against various kinds of biotic and abiotic stresses and fit well in various multiple cropping systems. Buckwheat grain is a very rich source of dietary starch, proteins, vitamins and micro nutrients. Hence, can be serves as a very good nutrition supplement to the children's and women. Furthermore, buckwheat plant is also a source of good quality rutin and fagopyrin, which is used as a medical agent for curing various human disorders. Hence, buckwheat can be the future food crop for feeding the mankind in fragile hill ecosystems. In order to arrest the declining interest of farmers in buckwheat cultivation in hilly regions, immediate attention of researchers, developers and policy makers is required for developing and advocating location specific scientific interventions and policies.

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