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RESEARCH ARTICLE

# Morphological Diversity of Buckwheat (*Fagopyrum* spp.) Landraces from Northeast India

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Buckwheat (*Fagopyrum* spp.) is an important crop in the high altitude regions of Northeast Indian Himalayas. The agro-climatic heterogeneity of this region offers a great deal of diversity in agro-morphology of buckwheat species. In the current study, a total of 97 accessions of *Fagopyrum esculentum* and *F. tataricum* were characterized for 16 morphological descriptors. Significant variations were observed for agronomically important traits including days to 50% flowering, days to 80% maturity, primary branches plant$^{-1}$, plant height and 100-seed weight. Wide range of variation was noted for most of the traits in both species. Characterization of buckwheat accessions from Northeast will facilitate in selecting morphologically diverse parents for breeding programmes particularly adapted to Northeast cropping system.

**Key Words: Characterization and conservation, *Fagopyrum esculentum*, *Fagopyrum tataricum*, Northeast India**

## Introduction

Buckwheat (*Fagopyrum* spp.) is grown as a subsistence crop in the mountainous areas of Asia. The tartary buckwheat (*F. tataricum*), because of its frost tolerance, is generally grown at the higher altitudes whereas common buckwheat (*F. esculentum*) is grown at the lower altitudes. The crop is a pseudocereal. The seeds (strictly achenes) are usually classified among the cereal grains because of their similar uses (Campbell, 1997). The grains are generally used as food and feed. It can also be used as a green vegetable, a green manuring crop and as a smother crop. The grains are highly nutritive and the grain proteins are balanced in essential amino acid content, particularly lysine. Flowers and green leaves are the sources of the glycoside Rutin which has medicinal properties (McGregor and McKillican, 1952). Buckwheat protein is presumed to reduce serum cholesterol, suppress gallstones and tumours, and inhibit the angiotensin I-converting enzyme (Koyama *et al.*, 2013). The buckwheat grains are recommended for patients having typhoid and liver ailments. The flavones of buckwheat flower and leaves are found to be effective in improving insulin resistance in type II diabetes (Han *et al.*, 2009).

Buckwheat is widely grown up to an altitude of 4500 m in Northwest (NW) and Northeast (NE) Indian Himalayan regions (Joshi and Paroda, 1991; Joshi, 1999). In NE India, buckwheat is distributed throughout the states of Sikkim and Arunachal Pradesh. It is also grown in small scales in Manipur, Nagaland, Meghalaya and Assam (Hore and Rathi, 2002). In the high altitude areas of NE India buckwheat is grown as a staple food, where cereal crops cannot be grown due to low temperature. The buckwheat is consumed in various ways. The Monpa tribe of Dirang, Arunachal Pradesh prepares noodles from buckwheat flour. Tribal communities of Arunachal Pradesh also prepare local beer from buckwheat grains. In NE region, buckwheat is locally called by different names such as Paphar (meetha Paphar: *F. esculentum* and teeta Paphar: *F. tataricum*) and Khuster in Sikkim; Jheem, Kyap, Brasma, Chikaw, Bherem, Jamu, Dunchung and Grunching in Arunachal Pradesh; Phapar and Demsi in Assam.

Buckwheat germplasm collected from NE India have been conserved in the National Genebank of India. Earlier, a total of 40 buckwheat accessions collected during the period of 1987-2001 from NE India have been characterized (Hore and Rathi, 2002). However, during

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recent years many new accessions have been collected and there is a need for characterizing these germplasm. Therefore, the current study was undertaken to report the distribution of *Fagopyrum* spp. in the NE states of India and to assess the agro-morphological variability in the existing germplasm collections.

## Materials and Methods

### *Plant Materials*

A total of 97 buckwheat landraces (66 accessions of *F. esculentum* and 31 accessions of *F. tataricum*) collected in various exploration trips from different buckwheat growing regions of NE India have been included in this study. The collection sites of the accessions are presented in Fig.1. The indigenous collection (IC) numbers of the accessions are given in Fig. 2.

### *Morphological Characterization*

The field experiments were conducted at ICAR-NBPGR Regional Station, Umiam, Meghalaya (25.6 ºN latitude, 91.9 ºE longitude and 1000 m altitude), during 2011-$^{1}$2 and 2012-$^{1}$3, under rain-fed conditions. The trials were laid out in augmented block design and the accessions were grown in plots of 5 rows × 1.2 m, with a spacing of 30cm (row-to-row) and 20 cm (plant-to-plant). Standard crop management practices were followed to raise a healthy crop. Data were recorded for 16 morphological descriptors, 8 quantitative and 8 qualitative (Table 1) on five plants randomly chosen from the two middle rows of each plot.

### *Data Analysis*

The data on 8 quantitative traits were subjected to analysis of variance (ANOVA) and the descriptive statistics (mean, standard deviation, coefficient of variation and range) were worked out. The frequency distribution of buckwheat accessions for the qualitative traits was computed. Analyses were performed using IBM SPSS Statistics version 20.0 for Windows (IBM Corp. 2011; Armonk, NY: IBM Corp.). Cluster analysis was performed in NTSYS-pc version 2.11f (Rohlf, 1993). The data were first standardized using STAND function and then converted into a similarity matrix, using the simple matching coefficient (Sneath and Sokal, 1973), with SIMQUAL function. A dendogram was generated from this similarity matrix by the unweighted pair group method using arithmetic averages (UPGMA) (Sokal and Michener, 1958) with the SHAN function. The cophenetic correlation coefficient was calculated with Mantel test (Mantel, 1967) by comparing the matrix of cophenetic values with the similarity matrix, to determine how well the dendogram represents its corresponding pair wise

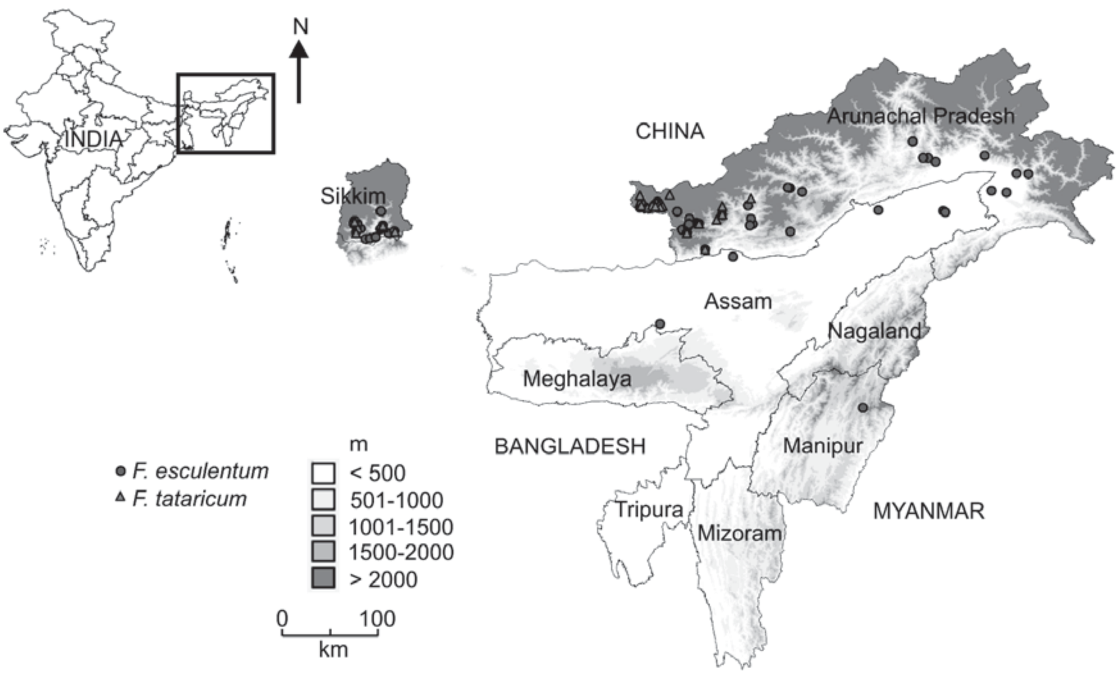


**Fig. 1. Collection sites of 97 buckwheat (*Fagopyrum* spp.) landraces from NE India. *F. esculentum* and *F. tataricum* accessions showed separately. Altitude ranges are indicated by different grey shadings.**

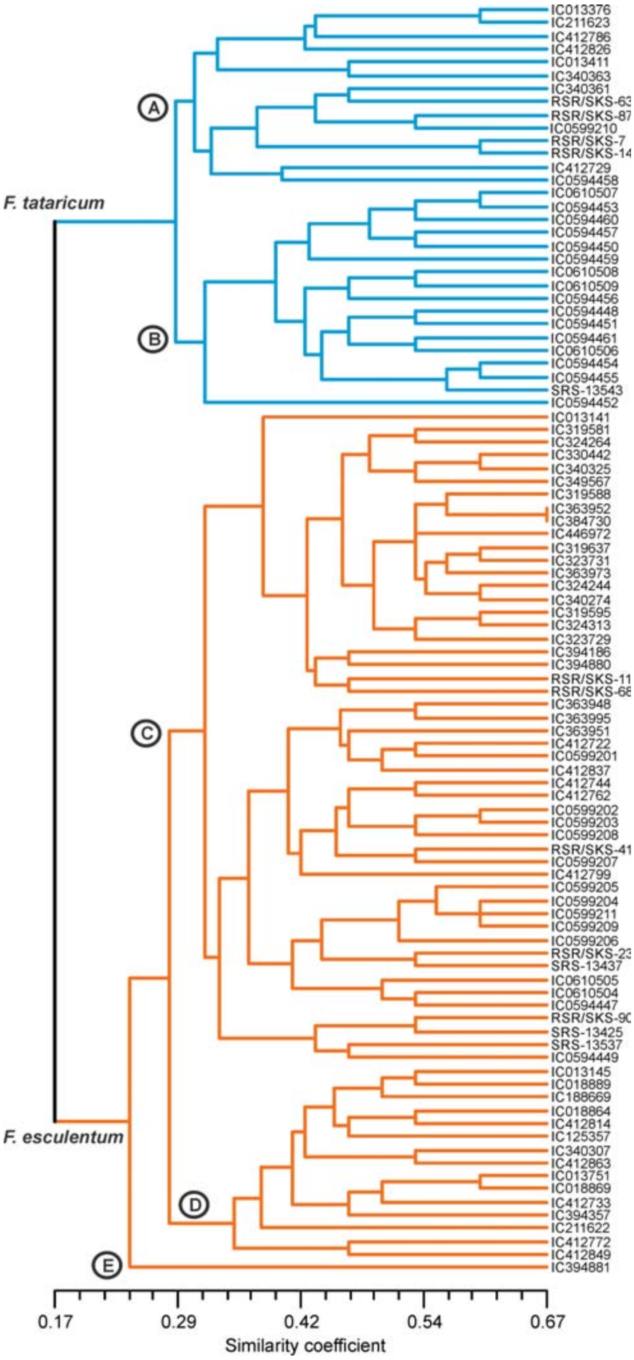


**Fig. 2. The UPGMA dendrogram based on morphological data of 97 buckwheat accessions. Similarity values were calculated with the simple matching coefficient. Mantel test r = 0.79854, p = 1.0**

**Table 1. List of descriptors used for characterization of buckwheat germplasm. For qualitative features, each descriptor is followed by a numerical code in parentheses**

| Serial number | Descriptor | Units/ States |
|---|---|---|
| Quantitative descriptors | | |
| 1 | Days to 50% flowering | Days |
| 2 | Days to 80% maturity | Days |
| 3 | Leaf length | cm |
| 4 | Leaf width | cm |
| 5 | Primary branches plant$^{-1}$ | - |
| 6 | Plant height | cm |
| 7 | 100-seed weight | g |
| 8 | Seed yield plant$^{-1}$ | g |
| Qualitative descriptors | | |
| 1 | Plant growth habit | Erect (3); Semi-erect (5); Spreading (7) |
| 2 | Leaf colour | Green (3); Pink (5); Red (7) |
| 3 | Leaf margin colour | Green (3); Pink (5); Red (7) |
| 4 | Stem colour | Green (3); Pink (5); Red (7) |
| 5 | Leaf blade shape | Ovate (1); Hastate (2); Sagittate (3); Cordate (4) |
| 6 | Flower colour | White (1); Greenish yellow (3); Pink (5); Red (7) |
| 7 | Seed coat colour | Grey (3); Brown (5); Black (7); Mottled (9) |
| 8 | Seed shape | Triangular (1); Ovate (2); Conidial (3) |

distance matrix. This was performed with the COPH and MXCOMP modules. Principal component analysis was done using SPSS.

## Results and Discussion

Buckwheat is widely grown in the Indian Himalayas, ranging from Jammu and Kashmir in the NW to Arunachal Pradesh in the NE India. About 340 accessions of these two species (*F. esculentum*: 294 and *F. tataricum*: 46) have been collected from the NE India by ICAR-National Bureau of Plant Genetic Resources, with the highest number of collections from Arunachal Pradesh. The passport data of past collections showed that only *F. esculentum* and *F. tataricum* germplasms are prevailing in NE Indian Himalayas. The buckwheat germplasm used in the present study fairly represent the entire buckwheat growing agro-climatic regions in NE India (Fig. 1). The collections have been made from an altitude range of 103 m (Kamrup, Assam) to 2971 m (Tawang, Arunachal Pradesh). The common buckwheat landraces are grown up to 2782 m altitude, while tartary buckwheat landraces are cultivated up to 2971 m (as recorded during exploration trips).

## Morphological Characteristics

Descriptive statistics for the traits are given in Table 2. Among the buckwheat accessions, highly significant

**Table 2. Comparative performance of different quantitative traits species-wise of buckwheat landraces**

| Descriptor | Species | Mean±SD | Range | Variance |
|---|---|---|---|---|
| Days to 50% flowering | All | 30.8±3.72 | 25.0-45.0 | 13.8 |
| | *F. esculentum* | 30.5±3.34 | 25.0-39.5 | 19.3 |
| | *F. tataricum* | 31.5±4.40 | 26.0-45.0 | 11.2 |
| Days to 80% maturity | All | 78.3±9.98 | 61.0-99.0 | 103.7 |
| | *F. esculentum* | 73.8±8.41 | 61.0-93.0 | 88.7 |
| | *F. tataricum* | 85.1±5.44 | 76.3-99.0 | 70.8 |
| Leaf length | All | 5.6±0.86 | 3.3-8.0 | 0.7 |
| | *F. esculentum* | 5.7±0.93 | 3.4-8.0 | 0.3 |
| | *F. tataricum* | 5.3±0.59 | 3.3-6.1 | 0.9 |
| Leaf width | All | 4.9±0.62 | 3.0-6.4 | 0.4 |
| | *F. esculentum* | 4.8±0.68 | 3.0-6.4 | 0.2 |
| | *F. tataricum* | 5.0±0.42 | 4.0-5.8 | 0.5 |
| Primary branches plant$^{-1}$ | All | 9.7±3.96 | 2.8-$^{1}$8.2 | 16.7 |
| | *F. esculentum* | 8.5±4.04 | 2.8-$^{1}$6.0 | 16.4 |
| | *F. tataricum* | 12.4±1.98 | 8.2-$^{1}$8.2 | 16.3 |
| Plant height | All | 68.4±15.44 | 34.9-99.7 | 235.5 |
| | *F. esculentum* | 75.6±12.09 | 36.5-99.7 | 234.9 |
| | *F. tataricum* | 53.0±9.32 | 34.9-70.5 | 146.3 |
| 100-seed weight | All | 2.4±0.58 | 1.2-3.1 | 0.3 |
| | *F. esculentum* | 2.6±0.41 | 1.2-3.1 | 0.3 |
| | *F. tataricum* | 1.8±0.54 | 1.2-2.9 | 0.2 |
| Seed yield plant$^{-1}$ | All | 26.5±10.90 | 3.6-54.6 | 124.4 |
| | *F. esculentum* | 27.9±12.71 | 3.6-54.6 | 40.4 |
| | *F. tataricum* | 23.6±4.21 | 16.4-32.6 | 161.5 |

variations were recorded for days to 50% flowering, days to 80% maturity, number of primary branches, plant height and 100-seed weight. Variation in the rest of the traits such as leaf length, leaf width and seed yield plant$^{-1}$ was non-significant.The average days to maturity was higher in *F. tataricum* accessions (85.1 days) than that of *F. esculentum* germplasm (73.8 days). Wide variance for days to 80% maturity was noted in both species. Number of primary branches plant$^{-1}$ varied from 2.8 to 16.0 in *F. esculentum* germplasm and from 8.2 to 18.2 in *F. tataricum* germplasm. Large variance was recorded for plant height in both species, while the tartary buckwheat accessions recorded the lowest average plant height. Both species exhibited wide variation for 100-seed weight. Tartary buckwheat accession with smaller seeds recorded the lowest average 100-seed weight (1.8 g). Although the difference for seed yield plant$^{-1}$ among the buckwheat accessions was statistically non-significant, wide range of variation was noted in the common buckwheat germplasm (3.6-54.6 g). Frequency distributions of 66 *F. esculentum* and 31 *F. tataricum* accessions for eight qualitative variables showed considerable variations for plant growth habit, leaf blade shape, stem colour, flower colour, seed shape and seed coat colour both within and among the species (data not shown).

The characterization results revealed wide variation for days to 50% flowering, days to 80% maturity, primary branches plant$^{-1}$, plant height and 100-seed weight. Similar range of variation was also recorded in the NW Indian Himalayan buckwheat germplasm for primary branches plant$^{-1}$, plant height and seed yield plant$^{-1}$ (Senthilkumaran *et al.*, 2008). The *F. esculentum* accessions used in the current study were mostly semi-erect type, while the accessions of *F. tataricum* were both semi-erect and spreading types. Among the qualitative characters, considerable variations between *F. esculentum* and *F. tataricum* accessions were noted for leaf blade shape, flower colour, seed shape and seed colour. While, in NW Indian buckwheat landraces major variations were recorded for seed shape and seed colour (Senthilkumaran *et al.*, 2008).

### *Grouping of Buckwheat Accessions*

The UPGMA dendogram based on morphological similarity values (simple matching coefficients) is presented in Fig. 2. The two buckwheat species formed two distinct clusters at 17% similarity level. Within

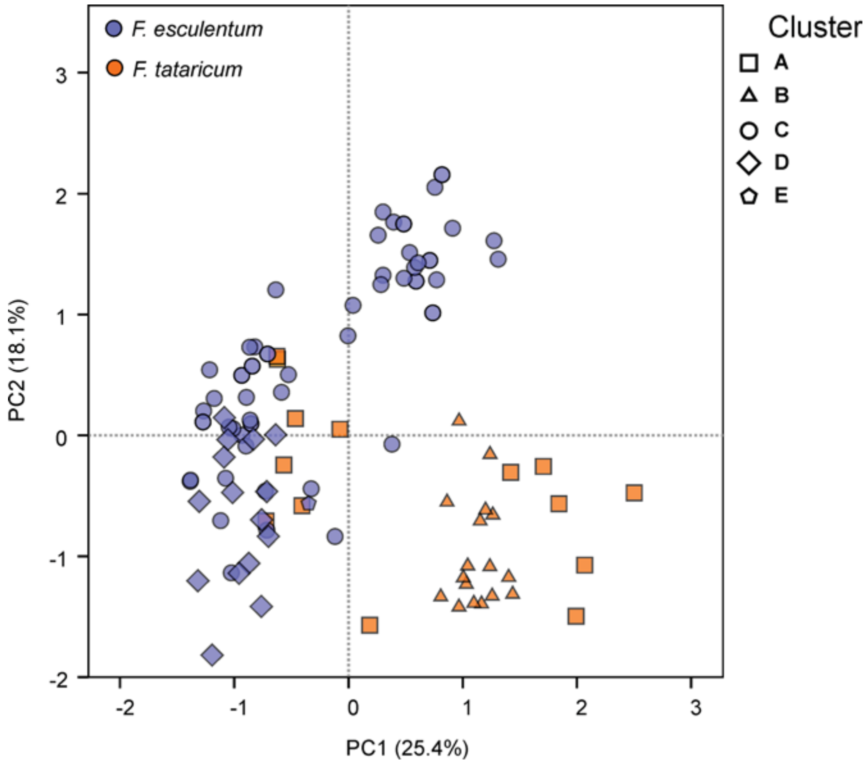


**Fig. 3. PCA biplot of 97 buckwheat accessions. Accessions belonging to different sub-clusters (A-E), as in clusters analysis (Fig. 2), are indicated with different shapes.**

the tartary buckwheat accessions, two sub-clusters can be discerned. Cluster A contains 14 accessions (seven each from Arunachal Pradesh and Sikkim), which was characterized by spreading plant architecture and triangular to ovate seeds. The accessions of this sub-cluster recorded the highest values for days to 50% flowering (32.6 days) and moderately high maturity duration (80.7 days). Rest 17 tartary buckwheat accessions with the highest average values for days to 80% maturity (88.8 days), number of primary branches (12.6) and the lowest average values for plant height (55.7 cm), 100-seed weight (1.6 g) and seed yield plant$^{-1}$ (23.6 g) formed sub-cluster B. The accessions of this sub-cluster were characterized by semi-erect plants and triangular seeds. Sixty six *F. esculentum* accessions clearly separated into three sub-clusters at approximately 30% morphological similarity. Cluster C grouped 50 common buckwheat accessions collected from Arunachal Pradesh, Sikkim, Assam and Manipur. This sub-cluster possessed accessions with the highest 100-seed weight and low seed yield plant$^{-1}$. Cluster D grouped 15 accessions having the highest average values for seed yield plant$^{-1}$ (37.8 g), 100-seed weight (2.6 g) and plant height (81.1 cm), and the lowest average values for days to 50% flowering (29.4 days) and days to 80% maturity (68.0 days). A single *F. esculentum* accession having spreading growth habit, less number of primary branches plant$^{-1}$ (3.2) and the smallest leaves formed cluster E.

PCA extracted five principal components (PCs) which accounted for 70% of the total morphological variation. The first principal component (PC1) explained 25.4% of the total variance. The variables days to maturity, flower colour and leaf width had high positive loadings. In contrast, plant height, flower colour, seed weight and seed yield plant$^{-1}$ had high negative loadings. The PC2 explained an additional 18.1 % of the total variance. Variables such as leaf length, stem colour, leaf blade shape, seed shape and seed coat colour had high positive loadings. However, primary branches plant$^{-1}$ and seed yield plant$^{-1}$ had high negative loadings. PC3 explained 11.5% of the total variance and had high positive loadings for primary branches plant$^{-1}$, seed yield plant$^{-1}$, leaf length and leaf width. PC4 and PC5 contributed around 8% and 7% of the total variance, respectively. The first two PCs were plotted to observe relationship between the clusters (Fig. 3). Although two buckwheat species showed obvious separation on the biplot, the distinction among the five clusters was not clear. Majority of the tartary buckwheat accessions belonging to cluster A and B, had high positive coefficients of PC1 but negative coefficients of PC2, and thus occupied bottom right corner of the biplot. Majority of common buckwheat accessions belonging to cluster C had positive coefficients of PC2 and negative coefficients of PC1.

In this current study, both cluster and PCA revealed useful information about the morphological variability present in the buckwheat germplasm of NE Indian Himalayas. Both these analyses have separated the germplasm according to the species with equal effectiveness. The sub-clusters which were obtained in cluster analysis were also detected to some extent in PCA. Overall, form the current results it appeared that considerable variations in the morphological traits exist among and within the buckwheat species which contributed to the grouping of germplasm into two species-wise clusters and then grouping into sub-clusters. Significant differences were obtained for days to maturity, number of primary branches, plant height and 100-seed weight among the two buckwheat species. These analyses generated a classification of buckwheat accessions based on variations in morphological traits and this will be useful for selecting diverse parents in breeding programmes. Senthilkumaran *et al.* (2008) grouped NW Indian buckwheat germplasm through cluster analysis and principal component analysis on a set of 46 buckwheat populations using quantitative traits. Similar study was conducted by Cepková *et al.* (2009) with a set of 77 accessions. Both the studies have analysed *F. esculentum* and *F. tataricum* accessions separately.

In NE India buckwheat is acclimatized to monoculture production and it is the only crop which can be grown successfully in higher Himalayan ranges (above 2,500 m). *F. tataricum* in particular because of its frost tolerance is preferred over *F. esculentum* in many marginal areas of production. Evaluation of tartary buckwheat accessions for frost tolerance would be an important objective in future characterization programmes. Due to the invasion of other commercial crops, the cultivated area of buckwheat is gradually declining and there is need for continuous collection of accessions and devising strategies for ex situ and on farm conservation of the buckwheat landraces of this region. During recent exploration trips, it has been observed that the many farmers in East Kameng district and the Monpa and Sherdukpen tribes of West Kameng district of Arunachal Pradesh are growing tomato in place of buckwheat. Considering the diversity in the NE Indian buckwheat germplasm, systematic efforts need to be initiated to promote in situ (on-farm) conservation of the landraces with specific adaptations from diversity rich areas. This on-farm conservation could complement crop improvement in the region, especially in the case of F. tataricum (Senthilkumaran *et al.*, 2008). Characterization and evaluation of the germplasm along with high yielding and adaptive check varieties would result in identification of superior genotypes for wide-scale cultivation in NE region. In conclusion, the current study provides an understanding on the distribution of common and tartary buckwheat germplasm in NE Indian states and the level of agro-morphological variability among and within two buckwheat species.

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