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RESEARCH ARTICLE

Agro-morphological Characterization and Digitization of Job's Tears (*Coix lacryma-jobi* L.) Germplasm: A Minor Cereal Crop of Northeastern India

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Abstract

Thirty-seven Job's tears accessions of India's northeastern hill region (NEH) were characterized for nine quantitative and eight qualitative traits. Prominent furrow and elliptic shape of grain in soft-shelled types are supposed to be the most important trait that indicates the domestication trend of the crop in NEH region. Principal component analysis showed that agro-morphological traits, namely time for first heading, days to 80% maturity, seed yield/plant (g), number of culms, and length of culm (cm) have significantly contributed to the diversity. Correlation analysis has shown significant correlations between different yield-contributing traits. Diversity and potential traits in each cluster were also identified through cluster analysis. Grid mapping was done to identify the areas for collection of trait-specific germplasm like higher number of culms, length of culm and hundred seed weight. The germplasm accessions IC0332644, IC0416831 and IC0540173 were identified as promising genotypes.

Keywords: Diversity analysis, Digitization, Job's tears, Northeastern India.

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Introduction

Coix lacryma-jobi L. (2n = 4X = 20) is commonly known as Job's tears as the shape of grain looks like a drop of tear. It is an important potential minor cereal crop that possesses various economic traits. Job's tear is an annual/perennial, monoecious taxa of the Poaceae family in tribe Maydeae but differs from other taxa in terms of fruit and inflorescence characters. Its fruit is a modified bract or hardened floral leaf, also known as a cupule, pseudocarp, or spatheole. Eastern India and Myanmar are considered as the centers of origin of Job's tears (Venkateshwarlu and Changanti, 1973). Its wild (hard-shelled) forms are distributed throughout India (except in extremely hot or dry areas), while the cultivated (soft-shelled) forms are confined to the northeastern hill region (NEH) of India and also reported to be cultivated in many south Asian countries (Jain and Banerjee, 1974; Arora, 1977). Job's tear was a more popular crop than maize as it was grown extensively in the past by aboriginals of Mongolian origin (Burkill, 1953).

Soft-shelled type of Job's tears is consumed in different forms. De-hulled matured seeds are boiled and eaten with cooked rice; flour is blended with water and taken as a cooling drink; grains are used by Garo, Naga and Karbi tribes for brewing a local liquor (Burkill, 1953) and in some places as poultry and animal feeds (Gupta *et al.*,1992). Hard-shelled types are used as ornament (Jiang *et al.*,2008); green leaves as fodder, and dried plants as thatching

material (Jain and Banerjee, 1974). Therapeutically, grains are considered useful for kidney and gall bladder stones, menstrual disorders, catarrhal infection, and roots decoction is used as a vermifuge (Jimo *et al.,*2001). Its kernel is considered a richer source of protein and carbohydrates than rice, wheat, and maize and has lower amount of phytosterols than maize (Moreau *et al.,* 2001). Although Job's tears possess high economic potential, very scanty efforts are done for its genetic improvement (Ma *et al.,*2006). Analysis of genotypic relationships is an important component for varietal development in crop plants, as it provides information on the extent of genetic diversity that serves as a platform for the stratified sampling of the breeding population. The present study aimed at agro-morphological characterization of Job's tears germplasm to know the extent of genetic diversity for utilizing it in crop improvement.

Materials and Methods

Plant material

A total of 37 selected germplasm lines of Job's tears, including three checks (IC0089385, IC0089389, and IC0089390) assembled from different states of Northeastern India (Table 1) were used in the present study. These germplasm accessions were grown in the experimental field located at the Indian Council of Agricultural Research-National Bureau of Plant Genetic Resources, Regional Station, Bhowali, Nainital (Uttarakhand) (29° 24′ 28.7′′N; 79° 30′47.2′′E; 1480 m asl). Following appropriate statistical design, all the selected accessions were sown along with checks in augmented block design with a 45 cm distance between row to row and 15 cm distance between plant and plant.

Data recording

Five plants were randomly selected from each row for recording data, and observations were taken on 17 agro-morphological traits (eight qualitative and nine quantitative) using minimal descriptors and descriptor states developed by UPOV (2012). Qualitative traits were recorded, which include seedling anthocyanin pigmentation, plant range of grain distribution, tillering habit, grain shape, the main color of grain, hardness of grain, furrow on grain, and glossiness of grain. Similarly, quantitative traits were recorded for the number of culms, culm diameter (cm), culm length (cm), length and width of leaf blade (cm), days to first heading, days to 80% maturity, hundred-grain weight (g) and grain yield/plant (g).

Statistical analysis

Statistical analysis was done using ANOVA while the mean was compared with Tukey's honest significance test, which helped determine the accessions significantly different from each other. Descriptive statistics were computed through 'R' statistic software version 3.6.2 (R Core Team, 2019) for each accession, and the mean, standard error, minimum, maximum, standard deviation, and coefficient of variation was calculated for each quantitative trait (Table 2). Principal component analysis (PCA) was calculated using the 'factoextra' package based on the data recorded on quantitative traits. Similarly, correlation analysis was done using the 'corrplot' package. Hierarchical clustering of the 37 accessions was based on the agro-morphological traits using Euclidean distances and a dendrogram was created using the 'cluster package' in R.

Table 1: Details of 37 accessions of Job's tears used in the study

Accessions	*No.*	*State*	*Status*
IC0089381, IC0089382, IC0089383, IC0089384, IC0089385, IC0089389, IC0089390, IC0089391, IC0089392, IC0089393, IC0089394	11	Meghalaya	Landrace
IC0334314, IC0334317, IC0334345, IC0374506, IC0416824, IC0416829, IC0416831, IC0416884, IC0416897, IC0332621, IC0332644	11	Arunachal Pradesh	Landrace
KCB/PKM/40	1	Arunachal Pradesh	Wild
IC0524599, IC0524631, IC0540173, IC0540222, IC0540266, IC0591727, IC0591729, IC0591730, IC0591732	9	Nagaland	Landrace
IC0330396, IC0330440, IC0330448	3	Manipur	Landrace
IC0278074, IC0278158	2	Mizoram	Landrace

Grid mapping

Geographical information system (GIS) based grid mapping technique was used to know the diversity-rich areas and occurrence of trait-specific germplasm of Job's tears. Geo-coordinates of collection sites and agro-morphological traits data of the 37 accessions of Job's tears were used for grid mapping. The simple-circular neighborhood technique of DIVA-GIS software version 7.3 was used to carry out grid analysis (Semwal *et al.,*2012; Hijmans *et al.,* 2001). Based on the diversity and area, a grid of 10 x 10 cells (111 x 111 km) size was used.

Results

Job's tears germplasm was characterized to understand the variability using standard descriptors. In the present study, striking variations were recorded for grain distribution, tillering habit, grain shape, main color of grain, grain hardness, furrow, and glossiness (Table 2). It was observed that most of the elliptically shaped grains had soft seed coats. Various categories were observed for grain color-brown (21), white (6), dark brown (6), black (2), and grey

Table 2: Details of qualitative characters of Job's tears

Acc no	*SAP*	*PRGD*	*TH*	*GS*	*GMC*	*GH*	*GF*	*GG*
IC0416831	present	narrow	upright	circular	brown	medium	absent	weak
IC0591732	present	narrow	upright	elliptic	dark brown	soft	present	weak
IC0540222	present	narrow	upright	circular	brown	medium	present	weak
IC0416884	present	narrow	upright	circular	black	soft	present	strong
IC0524599	present	narrow	upright	ovate	brown	medium	present	medium
IC0540173	present	narrow	upright	circular	black	hard	absent	strong
IC0089393	present	narrow	upright	ovate	brown	medium	present	medium
IC0332644	present	medium	upright	ovate	brown	medium	absent	strong
IC0089384	present	narrow	upright	ovate	grey	medium	present	medium
IC0334345	present	medium	upright	circular	white	hard	absent	strong
IC0089392	present	narrow	upright	circular	dark brown	hard	present	medium
IC0089391	present	narrow	upright	ovate	white	medium	present	medium
IC0089394	present	narrow	Semi-upright	ovate	brown	medium	present	weak
IC0334317	present	narrow	upright	ovate	brown	soft	absent	weak
IC0591727	present	narrow	upright	elliptic	brown	soft	present	medium
IC0330440	present	narrow	upright	circular	brown	medium	present	strong
IC0540266	present	narrow	upright	circular	brown	soft	present	medium
IC0416829	present	narrow	upright	circular	brown	soft	present	strong
IC0416897	present	narrow	upright	circular	white	medium	absent	strong
IC0524631	present	narrow	upright	circular	brown	medium	present	medium
IC0330396	present	narrow	upright	circular	brown	medium	present	strong
IC0591730	present	narrow	upright	elliptic	dark brown	soft	present	weak
IC0332621	present	narrow	upright	ovate	brown	medium	present	strong
IC0334314	present	narrow	upright	ovate	white	soft	absent	weak
IC0089382	present	narrow	upright	ovate	brown	soft	present	weak
IC0591729	present	narrow	upright	elliptic	white	hard	absent	medium
IC0089381	present	narrow	upright	elliptic	brown	Medium	present	medium
IC0330448	present	narrow	upright	circular	white	medium	present	weak
IC0089383	present	narrow	upright	ovate	dark brown	medium	present	weak
IC0089385	present	narrow	upright	ovate	brown	medium	present	medium
IC0089389	present	narrow	upright	ovate	brown	medium	present	medium
IC0089390	present	narrow	upright	circular	brown	medium	present	medium
IC0416824	present	narrow	upright	ovate	dark brown	medium	present	weak
IC0278074	present	narrow	upright	elliptic	dark brown	soft	present	medium
KCB/PKM/40	present	broad	spreading	ovate	grey	hard	absent	strong
IC0278158	present	narrow	upright	elliptic	brown	soft	present	weak
IC0374506	present	narrow	upright	ovate	brown	medium	present	medium

(Seedling anthocyanin pigmentation – SAP; plant range of grain distribution – PRGD; tillering habit – TH; grain shape – GS; grain main colour – GMC; grain hardness – GH; grain furrow – GF; grain glossiness – GG)

(2); grain hardness-soft (11), medium (21), and hard-shelled types (5); furrow on grain surface-absent (10) and present (27); and glossiness- little (12), medium (15) and high (10). The presence of traits like soft-shell, furrow on grain surface and an elliptic shape of grain indicate the trend of domestication of the crop in NEH region.

Selected agro-morphological characters were analyzed using descriptive statistics, which has shown the tremendous variation in the accessions of Job's tears (Table 3). Of these, KCB/PKM/40 (5.0), IC0524599 (2.50) and IC0332644 (2.50) were identified as superior accessions for culm numbers; IC0278084 (14.17 cm), IC0374506 (14.10 cm) and IC0524599

Table 3: Descriptive statistics values for selective morphological parameters of Job's tears

Parameters	*Mean ± SE*	*Minimum*	*Maximum*	*SD*	*CV %*
NOC	1.66 ± 0.078	1	5.0	0.70	42.31
CD	12.49 ± 0.209	9.45	14.17	1.19	9.51
LC	189.12 ± 6.215	49	298	54.00	28.55
LLB	44.85 ± 1.691	26.04	66.9	9.14	20.39
WLB	4.23 ± 0.138	2.56	7.06	0.77	18.12
TFH	130.49 ± 0.795	116	174	8.51	6.52
D80%M	172.51 ± 0.669	167	218	8.36	4.85
100 SW	7.08 ± 0.476	2.54	16.8	2.47	34.92
SYD	2.25 ± 0.526	0.12	11.69	2.79	124.13

OC – Number of culms, CD- Culm diameter (cm), LC- Length of culm (cm), LLB- Length of leaf blade (cm), WLB- Width of leaf blade, TFH – Time for first heading (days), D80%M – Days to 80% maturity (days), 100 SW – 100 seed weight (grams), SYD – Seed yield per plant (grams)].

(14.04 cm) for culm diameter; IC0540173 (298 cm), IC0334345 (290 cm) and IC0416831 (273 cm) for culm length; KCB/PKM/40 (49.0 cm), IC0278158 (64.0 cm) and IC0374506 (75.0 cm) for dwarf plant types; IC0416829 (66.90 cm), IC0089382 (64.08 cm) and IC008 9383 (57.34 cm) for leaf blade length (LLB); IC0540266 (7.06 cm), IC0089382 (5.94 cm) and IC0416829 (5.58 cm) for leaf blade width (LWB); IC0332644 (116 days), IC0332621 (120 days) and IC0416824 (120 days) for time for first heading; IC0332621 (167 days), IC0334314 (167 days) and IC0332644 (168 days) for days to 80% maturity; and IC0540173 (16.80 g), IC0330440 (11.02 g) and IC0332644 (10.47 g) for 100 seed weight. High variation in seed yield per plant, ranged from 0.12 to 11.69 g with an average of 2.25 g per plant was observed, accordingly IC0332644 (11.69 g), IC0416831 (11.39 g) and IC0089383 (8.19 g) were found as high yielders.

Analysis of variance (ANOVA)

The result of the analysis of variance has been presented in Table 4. The mean square was calculated for all the nine characters studied and significant differences ($p < 0.05$) were observed among the treatments and accessions for LC, WLB, TFH, D80%M, and SYD traits. Significant variation was also observed between the blocks for LC and WLB. Similarly, treatment vs. checks also showed significant differences for D80%M and SYD traits. No significant differences were observed among the checks for any of the parameters.

Correlation analysis

The correlation between nine different agro-morphological characters of the selected Job's tears accessions has been depicted in Figure 1. It has been observed that D80%M and TFH (0.83) traits are significantly positively correlated; NOC also has a significant positive correlation with D80%M (0.70) and TFH (0.63); and LLB with WLB (0.45). NOC has a significantly negative correlation with WLB (-0.31) and LC (-0.23), and LC has a significantly negative correlation with TFH (-0.59) and D80%M (-0.40). Similarly, WLB negatively correlates with D80%M (-0.46) and TFH (-0.36). The rest of the traits are non-significantly (positive/negative) correlated with their peers.

Principal Component Analysis (PCA)

Principal component analysis was calculated using nine quantitative traits of 37 accessions of Job's tears to depict

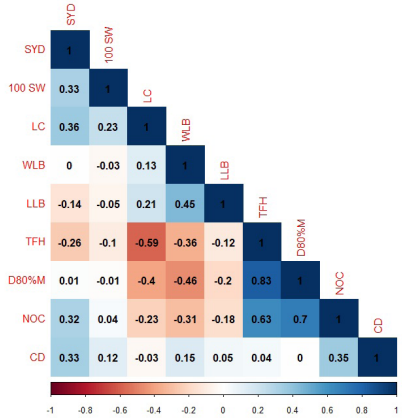

Figure 1: Correlation diagram for 9 morphological parameters of 37 accessions of Job's tears (p = 0.05)

Table 4: Analysis of variance for morphological traits of selected Job's tears accessions (*, Significant at p = 0.05)

Source (df)	*Block (3)*	*Treatment (36)*	*Treatment: Test (33)*	*Treatment: Check (2)*	*Treatment: Test vs. check (1)*	*Error (6)*
NOC	0.13	0.50	0.54	0.01	0.08	0.16
CD (cm)	0.24	1.32	1.42	0.30	0.07	1.09
LC (cm)	2960.5*	2572.8*	2755.2*	337.6	898.8	556.8
LLB (cm)	309.7	104.1	104.3	0.79	293.3	83.43
WLB (cm)	1.28*	0.66*	0.69*	0.22	0.46	0.11
DFH	19.19	67.37*	72.59*	5.25	18.37	6.02
D 80% M	0.44	66.26*	70.51*	6.33	49.79*	3.77
100 SW (g)	1.31	6.79	7.10	5.80	0.03	3.42
SYD (g)	0.43	7.75*	8.32*	0.37	8.14*	0.71

[NOC – Number of culms, CD- Culm diameter (cm), LC- Length of culm (cm), LLB- Length of leaf blade (cm), WLB- Width of leaf blade, TFH – Time for first heading (days), D80%M – Days to 80% maturity (days), 100 SW – 100 seed weight (grams), SYD – Seed yield per plant (grams)].

Table 5: Eigenvalues, the proportion of variability, and agro-morphological traits that contributed to the first three principal components (PCs) of the plant

Components	*PC1*	*PC2*	*PC3*
NOC	-0.435	0.324	-0.209
CD	-0.051	0.412	-0.501
LC	0.348	0.318	0.175
LLB	0.215	-0.113	-0.568
WLB	0.332	-0.041	-0.533
TFH	-0.514	-0.125	-0.182
D80%M	-0.512	0.047	-0.032
100 SW	0.053	0.430	0.177
SYD	0.041	0.638	0.055
Eigen values	3.075	1.854	1.318
% of Variance	34.168	20.599	14.649
Cumulative%	34.168	54.7667	69.415

[NOC – Number of culms, CD- Culm diameter (cm), LC- Length of culm (cm), LLB- Length of leaf blade (cm), WLB- Width of leaf blade, TFH – Time for first heading (days), D80%M – Days to 80% maturity (days), 100 SW – 100 seed weight (grams), SYD – Seed yield per plant (grams)].

the overall diversity in the crop. The PCA (Table 5) indicates that the majority of the required information can be drawn from the first three PCs having an Eigenvalue above 1, which have cumulatively contributed about 69.42% of the total variation. The traits TFH, D80%M and NOC have significantly contributed toPC1. This indicated that PC1 with an Eigenvalue of 3.08 and 34.17% variance of the total variation, has contributed mainly to ontogeny and vegetative growth of the crop. In PC2, SYD and 100SW traits have contributed more to yield parameters, with an Eigenvalue of 1.85 and 20.60% variance of total variation observed in the studied genotypes. The traits like LLB, WLB, and CD have contributed more in PC3 for the plant's vegetative growth with an Eigenvalue of 1.32 and 14.65% variance. In the bi-factorial plane, the contribution and correlation of the agro-morphological traits are indicated inside the circle. Morphological characters TFH, D80%M, SYD, NOC, and LC contributed more to the variability (Figure 2).

Cluster analysis

The agro-morphological traits of Job's tears accessions used in the present study were grouped into six different clusters using the hierarchical Euclidean cluster analysis method (Figure 3), while the mean of each cluster is presented in Table 6. Cluster I consists of only one accession KCB/PKM/40 (wild), represented from Arunachal Pradesh, showing above the mean cluster value for NOC (5.0), TFH (174 days), and D80%M (218 days) traits. Cluster II, which consists of three accessions (IC0332644, IC0416831, and IC0540173) representing Arunachal Pradesh (2) and Nagaland (1) have shown higher mean cluster value for NOC (2.15), CD (13.45 cm), LC (271.33 cm), TFH (121 days), 100SW (11.08 g) and SYD (9.76 g) traits. Cluster III, which consists of 12 accessions (IC0089382, IC0089383, IC0089384, IC0089385, IC0089389, IC0089390, IC0089393, IC0334345, IC0416829, IC0524599, IC0540222 and IC0540266) representing Meghalaya (7) and Arunachal Pradesh (5) have shown above mean cluster value for LC (210.48), LLB (53.92 cm) and WLB (4.67 cm) traits. Cluster IV, which consists of only one accession

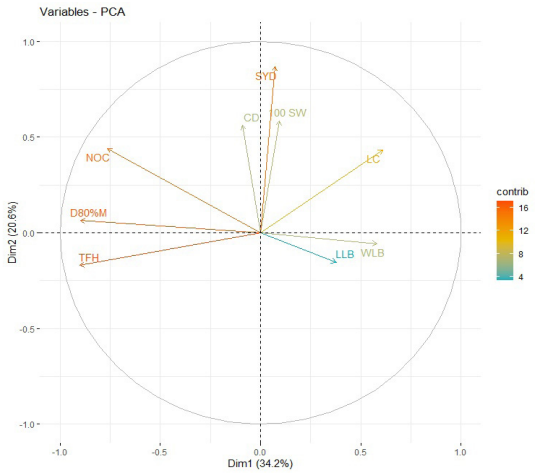

Figure 2: Principal component and variable correlation plot for 9 agro-morphological traits

Table 6: Cluster means for various agro-morphological traits of Job's tears

Parameters	*Cluster I*	*Cluster II*	*Cluster III*	*Cluster IV*	*Cluster V*	*Cluster VI*
NOC	5.00	2.15	1.73	1.00	1.15	1.59
CD	12.95	13.45	12.99	9.45	11.42	12.67
LC	49.00	271.33	210.48	154.00	187.55	162.88
LLB	33.00	40.65	53.92	51.86	45.07	37.10
WLB	2.56	4.02	4.67	3.60	4.33	3.97
TFH	174.00	121.00	130.02	133.00	128.75	130.67
D80% M	218.00	171.00	171.08	182.00	169.63	171.67
100 SW	6.07	11.08	6.75	10.41	5.35	7.38
SYD	1.09	9.76	2.38	0.80	0.85	1.40

[NOC – Number of culms, CD- Culm diameter (cm), LC- Length of culm (cm), LLB- Length of leaf blade (cm), WLB- Width of leaf blade, TFH – Time for first heading (days), D80%M – Days to 80% maturity (days), 100 SW – 100 seed weight (grams), SYD – Seed yield per plant (grams)].

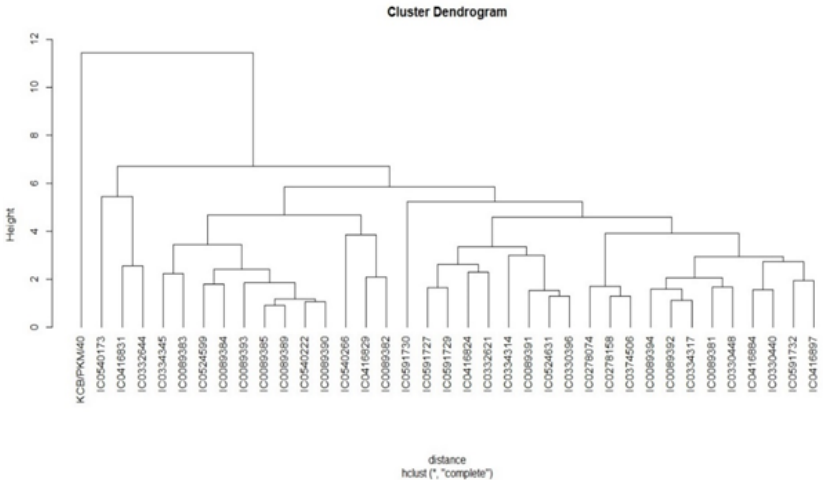

Figure 3: Cluster diagram for 9 morphological parameters of 37 accessions of Job's tears

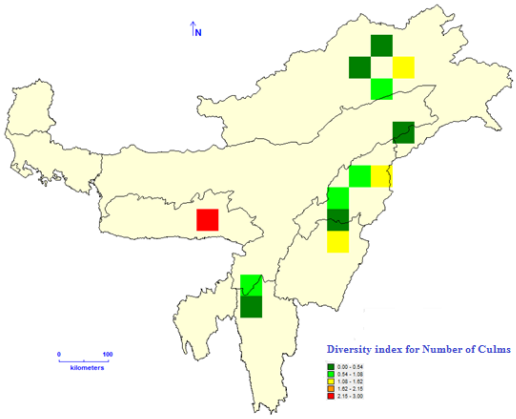

Figure 4: Grid map showing trait-specific germplasm for number of culms from different regions of north-eastern India

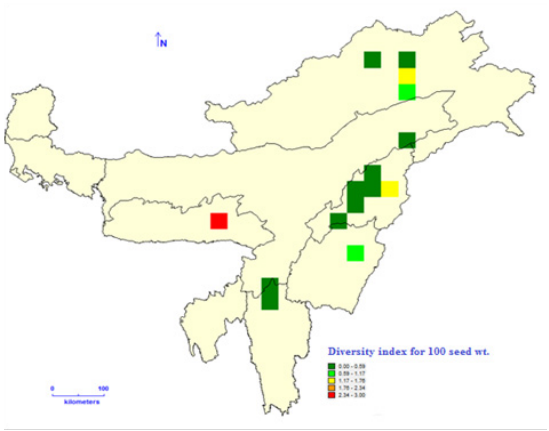

Figure 6: Grid map showing trait-specific germplasm for 100 seed weight from different regions of north-eastern India

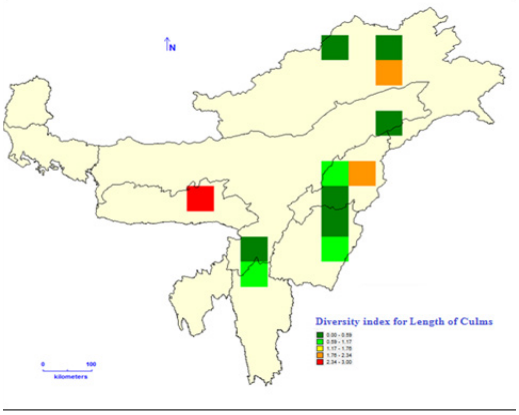

Figure 5: Grid map showing trait-specific germplasm for the length of culms from different regions of north-eastern India

(IC0591730) representing Nagaland, has shown an above-average cluster mean for LLB (51.86 cm) and 100SW (10.41 g) traits. Cluster V consists of eight accessions (IC0089391, IC0330396, IC0332621, IC0334314, IC0416824, IC0524631, IC0591727 and IC0591729), representing Arunachal Pradesh (3), Nagaland (3), Meghalaya (1) and Manipur (1). Cluster VI consists of twelve accessions (IC0089381, IC0089392, IC0089394, IC0278074, IC0278158, IC0330440, IC0330448, IC0334317, IC0374506, IC0416884, IC0416897 and IC0591732), representing Arunachal Pradesh (4), Meghalaya (3), Manipur (2), Mizoram (2) and Nagaland (1) states. Both clusters V and VI showed below-average cluster mean values for most of the traits.

Digitization of trait-specific germplasm

The promising accessions identified with superior characteristics for the length of culm, number of culms, 100 seed weight and seed hardness were mapped using grid mapping to identify the areas for the collection of trait-specific germplasm from the northeastern hill regions of India. The regions represented by red color depict high diversity for the number of culms (Figure 4), length of culm (Figure 5), 100 seed weight (Figure 6), and the regions represented by dark green color depict high diversity soft-shelled seed types (Figure 7). Grid map also showed that Job's tears accessions identified as promising for traits like

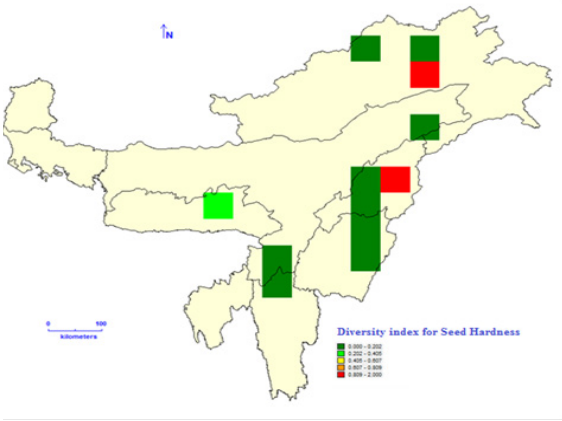

Figure 7: Grid map showing trait-specific germplasm for seed hardness from different regions of north-eastern India

the number of culms, length of culm, and 100 seed weight can be collected from East and West Khasi Hills districts of Meghalaya (Figure 4, 5 & 6); germplasm for soft-shelled type can be collected from Upper Siang and Dibang Valley districts of Arunachal Pradesh; Kohima and Phek districts of Nagaland; and West Imphal, Ukhrul and Kamjong districts of Manipur (Figure 7).

Discussion

Studying agro-morphological characters is the first step in the characterization of the germplasm of any crop (Smith *et al.,* 1991). Proper characterization of germplasm helps in understanding the unambiguous segregation between accessions, distinguishing redundancies and checking genetic change during maintenance. Hence, the characterization of genetic diversity is essential to identify suitable parents for breeding programs (Karihaloo, 2004). Job's tears is considered as a distant relative of maize (Celarier, 1957). Furthermore, unlike its occidental relative maize, Job's tears have not lost the wild types from which the cultivated types arose so it is still possible to study the reasons for its transition from wild state to domesticated state and the causal factors. The soft-shelled forms presently grown in the NEH region result from conscious folk domestication and must have been selected for easy hulling and desired kernel type. Taxonomically, *C. lacryma-jobi* var. *lacryma-jobi* is considered as wild and *C. lacryma-jobi* var. *ma-yuen,* as domesticated form (Pradheep *et al.,* 2014). The involucre of the wild type is hard and non-striated, whereas it is soft and striated in cultivated form (Jain and Banerjee, 1974). Similar results were obtained in the present study also (Table 2), hence can be concluded that the presence of prominent striation and seed softness are the probable traits of domestication.

The present study has revealed tremendous variation in traits like SYD, 100 SW, NOC, and LC (Table 3), which provides enough opportunities for utilizing them in the improvement of Job's tear. Plant height is positively correlated with seed yield per plant (Azarpour *et al.,* 2012), but sometimes dwarf plants also indirectly add to the harvest index towards the yield per plant (Avila *et al.,* 2007). In some accessions, variation in the length of the culm was recorded from 49 cm (KCB/PKM/40) to 298 cm (IC0540173), which was different than the results obtained by Kumar *et al.,* (2017). Culm length and its diameter are hardly affected by planting density (Nakano *et al.,* 2013), because higher planting density lowers the stem growth, which in turn affects the yield. According to a study by Kumar *et al.*,(2017), D 80% M is around 149 days, while in the present study 167 days were recorded in IC0332621 and IC0334314, which are found to be late in maturity. It indicates that the environment plays a significant role in the period of crop maturity. The trait 100 seed weight determines yield per plant, whereas seed yield per plant is determined by a combination of factors like 100-grain weight, grain number, and effective panicles (Yao *et al.,* 2013). The present study identified IC0332644 (11.69 g) and IC0416831 (11.39 g) as superior accessions for the trait SYD.

The analysis of variance provides a basis for the test of significance (Dospekhov, 1984). Among the accessions studied, a significant difference was observed for the traits: LC, WLB, TFH, D80%M, and SYD. This indicates that enough heritability is available for conducting varietal development trials of the crop. A non-significant difference was also observed among the checks, which indicates that the performance of all the checks was similar (Nurmala *et al.,* 2017). The traits like TFH and D80%M are significantly positively correlated; it shows that early flowering accessions can be considered as early maturing types while Job's tears is generally a late maturing crop. NOC has a significant positive correlation with D80%M and TFH, which shows that if NOC increases then much time will be required for the maturity of the crop. LLB is significantly positively correlated with WLB; it indicates that with the increase of LLB, WLB will be automatically increased. An increase in leaf area index indicates an increase in the seed weight (Shakoor *et al.,* 2007). NOC has a significant negative correlation with LC and WLB, which means as the number of tillers increases, a decrease in the height of the plant and size of the leaf can be seen, which shows that the higher the number of tillers, the partition of energy between vegetative and reproductive growth stages may be difficult, which leads to reduced growth. This was mainly observed in wild accession (KCB/PKM/40) of the Job's tears. Similarly, a significant negative correlation of LC and WLB was also observed for TFH and D80%M, which means dwarfness of the plant leads to late maturity. Only wild accession (KCB/PKM/40) has shown such a tendency, which may be clearly due to genetic factors. Hasan *et al.,* (2011) has also observed similar results in the case of cultivated and wild rice accessions.

Principal component analysis (PCA) was carried out to know about the impact of individual traits on the overall

variability. It helps in trait-specific breeding by recognizing the important economical traits and is an effective method of crop evaluation (Wang *et al.,* 2013). In the present study using the PCA method, nine morphological traits were reduced to three main components with a cumulative variance of 69.42%. Traits like TFH, D80%M, and NOC contributed much in the generation of variability (Figure 2) and are categorized as PC1 (Table 5). Being an important contributor of the variability, SYD (Figure 2) and 100SW were categorized in PC2 (Table 5). LC, a major contributor to overall diversity (Figure 2) didn't load much in any single PC (Table 5). Hence, nine agro-morphological characters can be reduced to five comprehensive traits to delineate the original data as well as to reveal the relationship among the parameters. Such traits are helpful in parental selection in a breeding program (Li *et al.,* 2010).

Hierarchical clustering helps to assess the degree of relationship between the genotypes (Ward, 1963). In the present study, 37 accessions were grouped into 6 clusters (Figure 3). The clustering pattern did not show any relationship between geographical distribution and genotypic diversity as accessions of different geographical origins formed one cluster. Similar result was observed by Forsberg *et al.,*(2015). This shows that location differences do not influence genetic variations, while germplasm from the same locality can be genetically different (Li *et al.,* 2010). In cluster I, KCB/PKM/40 has the highest number of tillers but is late maturing accession. Cluster II contains accessions IC0332644, IC0416831, and IC0540173, which have high mean cluster values for most of the traits. Hence, these accessions are considered superior and can be selected as parents for further crop improvement programs. Cluster III has accessions with high vegetative growth traits like LC, LLB, and WLB, which can be used in forage breeding programs.

Grid maps are generated to recognize the areas with species richness or niches where Job's tears is predominantly grown (Semwal *et al.,* 2012). Using grid maps, areas for future exploration and collection of trait-specific germplasm have been identified. Germplasm of Job's tears having traits like high number of culms, high culm length, and high 100 seed weight (Figures 4-6) can be collected from East and West Khasi Hills of Meghalaya, and soft-shelled type (Figure 7) from Upper Siang and Dibang Valley districts of Arunachal Pradesh; Kohima and Phek districts of Nagaland; and West Imphal, Ukhrul and Kamjong districts of Manipur.

Conclusion

Agro-morphological characterization of Job's tears showed high variability among the selected genotypes. Data analysis of characterized genotypes has indicated that the accessions IC0332644, IC0416831, and IC0540173 were superior among the studied germplasm and, hence can be utilized in the improvement of Job's tears. Principal component analysis has shown that five comprehensive traits can delineate the original data and indicate the relationship among the parameters. The clustering pattern did not show any relationship between geographical distribution and genotypic diversity. The present study indicates that there is a need to enrich the National Genebank by undertaking more explorations in the NEH region to collect germplasm, as many remote localities are still unexplored.

Moreover, fine grid surveys are also required to undertakefor the collection of trait-specific germplasm, considering the promising accessions identified. The inhabitants also need to be made aware of the importance of Job's tears as it is a nutritionally rich minor cereal. Hence, on-farm crop conservation is required to face the challenges of climate change.

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References

Arora, R.K. (1977). Job's tears (*Coix lacryma- jobi*) - a minor food and fodder crop of North-eastern India. *Econ. Bot*., **31**: 358-366.

Avila, C.M., Atienza, S.G., Moreno, M.T. & Torres A.M. (2007). Development of a new diagnostic marker for growth habit selection in faba bean (*Vicia faba* L.) breeding. *Theor. Appl. Genet*., **115**: 1075-1082.

Azarpour, E., Bidarigh, S., Moraditochaee, M. Danesh, R.K., Bozorgi, H.R. & Bakian, M. (2012). Path coefficient analysis of seed yield and its components in faba bean (*Vicia faba* L.) under nitrogen and zinc fertilizer management. *Int. J. Agric. Sci*., **4**: 1559-1561.

Burkill, I.H. (1953). The Hooker Lecture: Habits of the man and origin of the cultivated plants of the old world. In Proceedings of the Linnean Society of London, **164(1)**:12-42.

Celarier, R.P. (1957). Cytotaxonomy of the Andropogoneae II Subtribes Ischaeminae, Rottboelliinae, and the Maydeae. Cytologia, **22**: 160-183.

Dospekhov, B.A. (1984). Field experimentation: statistical procedures. Mir Publishers, Moscow.

Forsberg NE, J Russell, M Macaulay, MW Leino & J Hagenblad (2015) Farmers without borders-genetic structuring in century-old barley (Hordeum vulgare). Heredity, **114**: 195-206.

Gupta, J.J., Gupta, H.K. & Yadav, B.P.S. (1992). Decorticated Job's tears (Coix lacryma- jobi) grain as poultry feed. *Indian. J. Anim. Sci.*, **62**: 699-700.

Hasan, M.J., Kulsum, M.U., Akter, A., Masuduzzaman, A.S. & Ramesha, M.S. (2011). Genetic variability and character association for agronomic traits in hybrid rice (*Oryza sativa* L.). Bangladesh. *J. Plant Breed. Genet*., **24**: 45-51.

Hijmans, R.J., Guarino, L. Cruz, M. & Rojas, E. (2001). Computer tools for spatial analysis of plant genetic resources data: 1. DIVA-GIS. Plant Genetic Resources Newsletter, pp15-19.

Jain, S.K. & Banerjee, D.K. (1974). Preliminary observations on the ethnobotany of the genus *Coix*. *Econ. Bot*. 38-42.

Jiang, H.E., Wang, B. Li, X. Lü, E.G. & Li, C.S. (2008). A consideration

of the involucre remains of Coix lacryma-jobi L. (Poaceae) in the Sampula Cemetery (2000 years BP), *Xinjiang, China. J. Archaeol. Sci.*, **35**: 1311-1316.

Jimo, P.V., Singh, R.A., Achuni, T.I. & Singh, P.I. (2001). Job's tears: an under-exploited and medicinal crop of North-East Hill region. *Nat. Agric. Sci. Cong*., pp: 49.

Karihaloo, J.L. (2004). Advances in molecular characterization of plant genetic resources and assessment of diversity. Plant Genetic Resources Management, Narosa Publishing House, New Delhi, pp: 266-274.

Kumar, R., Yhokha, K., Rajesha, G. & Deka, B.C. (2017). Performance of Job's tears lines (Coix lacryma-jobi) under foothill condition of Nagaland. *Environment & Ecology*, **35**: 440-444.

Li, S., Li, X., Wang, S. & Zhang, Z. (2010). Clustering and principal component analysis of introduced black pericarp rice germplasm based on agronomic traits. Southwest China. *J. Agric. Sci*., **23**:11-15.

Ma, K.H., Kim, K.H., Dixit, A., Yu, J.W., Chung, J.W., Lee, J.H., Cho, E.G., Kim, T.S. & Park, Y.J. (2006). Newly developed polymorphic microsatellite markers in Job's tears (*Coix lacryma-jobi* L.). *Mol. Ecol. Notes*., **6**: 689-691.

Moreau, R.A., Singh, V. & Hicks, K.B. (2001). Comparison of oil and phytosterol levels in germplasm accessions of corn, teosinte, and job's tears. *J. Agric. Food Chem*., **49**: 3793-3795.

Nakano, H., Ujihira, Y. & Ishida, K. (2003). Correlation of planting density with yield and yield components in Job's-tear plant (*Coix lacryma-jobi* L. var. frumentacea Makino). *Jpn. J. Crop Sci*., **72(1)**: 32-37.

Nurmala, T. & Wicaksono, F.Y. (2017). Growth and yield of job's tears (*Coix lacryma-jobi* L.) response to different types of Oldeman climate classification and row spacing in West Java Indonesia. J. Agron., **16**: 76-82.

Pradheep, K., Bansal, K.C. & Bhandari, D.C. (2014). Wild relatives of cultivated plants in India. Directorate of Knowledge Management in Agriculture, Indian Council of Agricultural Research, p 728.

R Core Team. (2019). R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. *https://www.R-project.org/*

Semwal, D.P., Bhandari, D.C., Bhatt, K.C. & Singh, R. (2012). Diversity distribution pattern in collected Germplasm of Rapeseed-Mustard using GIS in India. *Indian J. Plant Genetic Resources*., **26**: 76-81.

Shakoor, M.S., Akbar, M. & Hussain, A. (2007). Correlation and path coefficients studies of some morphophysiological traits in maize double-crosses. *Pak. J. Agri. Sci*., **44**: 213-216.

Smith, S.E., Al-Doss, A. & Warburton, M. (1991). Morphological and agronomic variation in North African and Arabian alfalfas. *Crop Sci*., **31**: 1159-1163.

UPOV document TG/18/1. (2012). Guidelines for the conduct of tests for distinctness, uniformity, and stability (DUS).

Venkateswarlu, J. & Chaganti, R.S.K. (1973). Job's tears (*Coix lacryma-jobi* L.). ICAR Tech. Bull, p 44.

Wang, S., Zhang, S., He, J., Lu, G. & Yang, Z. (2013). The principal component analysis and cluster analysis of Coix resource characteristics. Journal of Yunnan Agricultural University, **28**: 157-162.

Ward, J.H. (1963). Hierarchical grouping to optimize an objective function. *J. Am. Stat. Assoc*., **58**: 236-244.

Yao, F., Yin, G., Mo, G., Luo, Y. and Yuan, J. (2013). *Coix lacryma-jobi* L. growth and yield response to different sowing dates in Sichuan *China. J. Sci. Applic. Biomed*., **1**: 8-14