Characterization of Chickpea Germplasm

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Summary

In plant breeding, genetic diversity is an important component for crop improvement. An experiment was conducted at Ishurdi, Pabna (Bangladesh) to study the diversity and variability within the core germplasm collection of 93 chickpea accessions, and a total of 13 qualitative and 12 quantitative characteristics were studied. Among the qualitative characteristics more significant variations were observed in plant pigmentation, growth habit, flower color, seed color, seed shape, and texture. A total of 93 accessions were divided into eight clusters. The genotypes in Cluster IV and Cluster VIII were crossed with genotypes in Cluster I and Cluster VII for better yield performance. Correlation co-efficient study was done among the 12 quantitative characters with yield performance of the studied chickpea germplasm. Significant and positive correlation was observed among the days to 50% flowering, branches per plant, pods per plant, seeds per pod, straw yield, but significant and negative correlation was observed among the days to maturity, plant height, canopy width and hundred seeds weight within the yield performance of studied chickpea germplasm. Simultaneously, a more distinguished morphological diversity was found in number of pods per plant, grain yield per plant(g), 100-seed weight (g), harvest index and plant canopy height (cm) among the twelve quantitative traits of 93 chickpea accession. The chickpea accessions BD-6051, BD-6058, BD-6557, BD-6214, BD-6221, BD-6235, BD-6460, BD-6461, BD-6470, BD-6471, BD-6472, BD-6473, BD-6478, BD-6480, BD-6481, 6483, BD-6484, BD-6488, BD-6491, BD-6500, BD-6505, and BD-6513 could be considered for crop improvement through the future breeding program of chickpea.

Key words

Cicer arietinum L., characterizarion, germplasm, morphological diversity

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Introduction

Chickpea (*Cicer arietinum* L.) is an important leguminous crop rich in protein (20 - 26%), carbohydrates (62%), fats (4%), and trace elements, and is also a vital source of minerals such as calcium, copper, and iron and niacin (Bodake et al., 2014). Additionally, it is a well known source of vitamin A, B, C, and essential amino acids. This eco-friendly crop is able to fix as much as 70 % of atmospheric nitrogen through symbiotic process (Bodake et al., 2014), making it a significant component of different cropping systems for soil health improvement. Chickpea is the most popular pulse crop in Bangladesh. Several years ago, chickpea was the most widely cultivated crop in five districts of Bangladesh viz. Pabna, Rajshahi, Faridpur, Jeshore, and Kustia under rice/jute-fallow-chickpea and rice-chickpea cropping pattern (Choudhury et al., 2014). However, in recent times acreage and production of this crop has declined due to many biotic and abiotic factors. Biotic constraints are mostly in a form of disease, for instance Botrytis Grey Mold (BGM) that is the major disease constraining chickpea production not only in Bangladesh, but all over the subcontinent. Among the abiotic factors, salinity, drought and high temperatures are the major constraints for chikpea production in Bangladesh. Moreover, reducing the land area due to urbanization, as well as replacement with other crops are also responsible for reducing the chickpea production. However, improving the chickpea variety for high yielding ability and developing BGM resistance or tolerance are the biggest challenges to chickpea breeders worldwide. Identification of potential genotypes is the prerequisite for improvement of any crop from existing germplasm. Recent technological advances in exploring desired characters and their corresponding gene/s have revealed enormous opportunity to accelerate varietal development. Careful selection of germplasm and intelligent assessment of characters are key steps in developing the desired variety able to cope with climate change. Characterization is particularly important for identifying germplasm or varieties with their distinct morphology playing a significant role in seed production, seed certification and genetic purity testing. For identification of potential germplasm from Plant Genetic Resources Centre (PGRC) core collection, and identification of distinguishing traits closely associated with chickpea improvement, the present experiment was conducted at Regional Plant Genetic Resource Centre (RPGRC), Regional Agricultural Research Station (RARS), Ishurdi, Pabna.

Materials and Methods

A total of 93 chickpea accessions were collected from PGRC, Bangladesh Agricultural Research Institute (BARI), Gazipur. The experiment was conducted at Regional Plant Genetic Resource Centre, RARS, Ishurdi, Pabna during 2017 and 2018 consisting of 93 accessions, including three check varieties viz. BARI Chola-5, BARI Chola-6, and BARI Chola-9 following Augmented Design with four replications per check variety. The trial was sown on 06 December 2017 and unit plot size was three rows 4 m long. Row to row distance was 50 cm, with continuous seeding and plot to plot distance 75 cm. For better crop establishment, Pulses Research Centre (PRC), Bangladesh Agricultural Institute (BARI) recommended fertilizers (Urea 30 kg ha^{-1}, TSP 100 kg ha^{-1}, MOP 30 kg ha^{-1}, Zypsum 52.50 kg ha^{-1} and Boric acid 7.50 kg ha^{-1}) were applied as a basal dose during the final land preparation (Alam et al., 2014). Post sowing irrigation was applied to ensure germination. All intercultural operations such as weeding, thinning and applying pesticides were performed when necessary. Data were recorded only on morphological traits following Descriptors for Chickpea (*Cicer arietinum* L.), IBPGR/ICRISAT/ICARDA (1993). The chickpea accessions used in the present study are listed in Table 1. Quantitative data was analyzed using R.3.3.3 statistical software program (R Core Team, 2017).

Passport Descriptors

Accession number: According to the Descriptors of Chickpea (*Cicer arietinum* L.), IBPGR/ICRISAT/ICARDA (1993), the accession number is used as a unique identifier for the accession of any crop, and is also assigned by curators/gene bank scientist when the accession is entered into the core collection. Once assigned, this number should never be used for another accession in the collection. Even if an accession is lost, the number is never re-assigned 'BD' letter has been used as a symbol before the number, to identify the accession originaitng from the PGRC, BARI, Gazipur, Bangladesh.

Descriptors list chickpea germplasm

Qualitative characteristics based on the scale

The present study was conducted based on thirteen morphological qualitative characters such as plant pigmentation, plant hairiness, plant growth habit, leaflets per leaf, leaf size, flower colour, no. of flowers and pods per peduncle, pod length, pod dehiscence, seed shape, seed texture, seed colour, absence/presence of minute black dots on seed, and testa type. Characterization was done according Descriptors for Chickpea, IBPGR/ICRISA/ICARDA (1993) on whole plot basis. Characterization stages and scale used are are presented in the Table 2.

Quantitative characteristics with using scale

The germplasm was characterized based on twelve morphological quantitative characters such as days to 50% flowering, days to maturity, plant canopy height (cm), canopy width (cm), branches per plant, pods per plant, 100 seeds weight (g), seed yield per plant(g), straw yield per plant, harvest Index, and grain yield (kg ha^{-1}). All quantitative data were recorded as mean data of randomly selected five plants except for yield (kg ha^{-1}). Whole plot yield was recorded and then converted in to the kg ha-1. Stage of recorded quantitative data and measuring scale/method are presented in Table 3.

Results and Discussion

Qualitative traits

Distinguishing traits based on genetic purity as well as true to true cultivars are significantly important for crop improvement, maintenance breeding, and multiplication of seed of any crop and this is also equally essential for plant breeders, seed certification agencies, and seed producers. Genetic purity may deteriorate due to natural mutation, outcrossing with off-types, mechanical mixtures, etc. Different methods are used in field and laboratory for maintaining the genetic purity of crop. Among them

Table 1. List of used germplasm for characterization at RPGRC, RARS, Ishurdi, Pabna during 2017-18.

Entry no.	Entry name	Entry no.	Entry name	Entry no.	Entry name
1	BD-6034	33	BD-6268	65	BD-6481
2	BD-6035	34	BD-6307	66	BD-6482
3	BD-6038	35	BD-6313	67	BD-6483
4	BD-6039	36	BD-6320	68	BD-6484
5	BD-6045	37	BD-6454	69	BD-6485
6	BD-6046	38	BD-6455	70	BD-6486
7	BD-6048	39	BD-6456	71	BD-6487
8	BD-6049	40	BD-6033	72	BD-6488
9	BD-6051	41	BD-6457	73	BD-6489
10	BD-6055	42	BD-6458	74	BD-6490
11	BD-6056	43	BD-6459	75	BD-6491
12	BD-6058	44	BD-6460	76	BD-6493
13	BD-6060	45	BD-6461	77	BD-6496
14	BD-6061	46	BD-6462	78	BD-6498
15	BD-6062	47	BD-6463	79	BD-6500
16	BD-6072	48	BD-6464	80	BD-6501
17	BD-6597	49	BD-6465	81	BD-6502
18	BD-6201	50	BD-6466	82	BD-6504
19	BD-6205	51	BD-6467	83	BD-6505
20	BD-6207	52	BD-6468	84	BD-6507
21	BD-6210	53	BD-6469	85	BD-6509
22	BD-6212	54	BD-6470	86	BD-6510
23	BD-6214	55	BD-6471	87	BD-6513
24	BD-6220	56	BD-6472	88	BD-6653
25	BD-6221	57	BD-6473	89	RC-110
26	BD-6232	58	BD-6474	90	AHM-74
27	BD-6235	59	BD-6475	Check varieties	
28	BD-6238	60	BD-6476	91.	BARI Chola-5
29	BD-6245	61	BD-6477	92.	BARI Chola-6
30	BD-6252	62	BD-6478	93.	BARI Chola-9
31	BD-6259	63	BD-6479		
32	BD-6265	64	BD-6480		

characterization through morphological traits have been used as a major component for identification of genotypes or cultivar. Identification of any cultivar is not possible based on a single trait a detailed morphological description of plants and seeds should be prepared.

Thirteen qualitative traits of 93 chickpea accessions were presented in Tables 4 and 7. The 93 accessions were divided into four different categories (no anthocyanin, low anthocyanin, high anthocyanin, highly purple color) based on plant pigmentation. Fifty seven accessions (61.29%) were found with low anthocyanin

Table 2. List of used descriptors for morphological assessment of 13 qualitative traits in chickpea accessions with recording time and using scale at RPGRC, RARS, Ishurdi, Pabna during 2017-18

Sl. No.	Qualitative characters	Data recording period	Using scale
1.	Plant pigmentation	Vegetative stage	1 -No-anthocyanin, stems and leaves pale green, 3-No-anthocyanin, stems and leaves green, 5-Low anthocyanin, stems and leaves partly light purple
2.	Plant hairiness		3-Lightly pubescent, 5-Pubescent, 7-Densely-pubescent
3.	Growth habit	Mid-pod filling stage	1-Erect, 2-Semi erect, 3-Semi-spreading, 4-Spreading, 5-Prostrate.
4.	No. of leaflet per leaf	Flowering stage	Average number of leaflets from randomly selected five plants (one leaf from each plant).
5.	Leaflet size	Flowering stage	Average number of leaflet size from randomly selected five plants (one leaflet size from each plant).
6.	Flower colour	Flowering stage	3-Dark pink, 4-Pink, 5-Light pink, 6-White
7.	No. of flowers and pods per peduncle	Flowering stage	1-Single pod per peduncle, 2-Twin pods (at least 10% of the peduncles bear two pods)
8.	Pod length	Podding stage	5-Medium, 7-Long
9.	Pod dehiscence	Podding stage	1- < 10% dehiscence
10.	Seed shape	After harvesting	1-Angular, rams head, 2-Irregular rounded, owl's head.
11.	Testa color	After harvesting	3-Rough, 5-Smooth, 7-Tuberculated
12.	Seed colour	After harvesting	2-Brown, 3-Light brown, 4-Dark brown, 5-Reddish brown, 6-Greyish brown, 11-Yellow, 12-Light yellow, 13-Yellow brown, 14-Orange-yellow, 15-Orange

Table 3. List of recorded quantitative characteristics with recording period and using scale/measuring procedure at RPGRC, RARS, Ishurdi, Pabna during 2017-18

Sl. No.	Quantitative characters	Data recording period	Using scale/Measurement procedure
1.	Days to 50% flowering	Flowering stage	Days from sowing to 50% flowering
2.	Days to maturity	Ripening stage	Days from sowing date to physiological maturity stage or just before harvesting of the pods
3.	Plant height	Maturity stage	Hight from ground level to the top of the plants
4.	Branches per plant	Ripening stage	Total branches of each plant, (average of five plants)
5.	No. of pods per plant	Harvesting stage	Average of five plants
6.	No. of seeds per pod	Harvesting stage	Average of five selective plants seeds
7.	100 seeds weight (g)	After threshing	Weight of 100 seeds from randomly selected five plants at 8 - 10% (air dry) seed moisture content
8.	Yield per plant	Before storing	Average yield from randomly selected five plants
9.	Yield per hectare	Before storing	Plot yield was converted in to the hectare
10.	Harvest Index	After threshing	Percentage yield ratio of economical yield and biological yield

Table 4. Frequency distribution of 13 qualitative traits assessed in 90 chickpea accessions along with three check varieties at RPGRC, PRC & RARS, Ishurdi, Pabna during 2017-18

Sl. No.	Descriptor	Descriptor status	Number of accessions	% of accessions	Accession
1	Plant pigmentation	2 = No- anthocyanin, stems and leaves pale green	02	2.15	BD 6493, RC-110
		3 = No anthocyanin, stem and leaves green	14	15.00	
		5 = Low anthocyanin, stems and leaves partly light purple	57	61.29	
		7 = High anthocyanin, stems and leaves predominantly light purple	19	20.43	
		9 = Highly purple	01	1	BD-6220
2	Plant hairiness	3 = Lightly pubescent	04	4.30	
		5 = Pubescence	46	49.46	
		7 = Densely-pubescent	43	46.24	
3	Growth habit	1 = Erect	01	01	RC-110
		2 = Semi-erect	40	43	
		3 = Semi-spreading	40	43	
		4 = Spreading	12	13	
		5 = Prostrate	0	0	
4	No. of leaflet per leaf	11-13 leaflets	93	100	
		over >13 leaflets			
5	Leaflet size	Small	93	100	
		Medium	-	-	
6	Flower colour	3 = Dark pink	22	23.66	
		4 = Pink	40	43.00	
		5 = Light pink	28	30.11	
		7 = White pink striped	03	03.23	
7	No. of flowers and pods per peduncle	1 = Single pod per peduncle	93	100	
		2 = Twin pods (at least 10% of the peduncles bear two pods)			
8	Pod length	3 = Short	01	1	BD-6061
		5 = Medium	68	73	
		7 = Long	24	26	
9	Pod dehiscence	1 = < 10% dehiscence	44	47.32	
		2 = < 10 dehiscence	49	52.68	
10	Seed shape	1 = Angular, rams head	59	63.44	
		2 = Irregular rounded, owl's head	31	33.33	
		3 = Pea shaped	03	03.23	
11	Seed texture	3 = Rough	16	17.20	
		5 = Smooth	36	38.71	
		7 = Tuberculated	41	44.09	
12	Seed colour	1 = Black	06	06.45	
		2 = Brown	12	12.90	
		3 = Light brown	06	6.45	
		4 = Dark brown	28	30.11	
		5 = Reddish brown	26	27.96	
		6 = Greyish brown	02	02.15	
		13 = Yellow brown	01	01.08	
		15 = Orange	01	01.08	
		18 = Green	01	01.08	
		21 = Black brown mosaic	10	10.75	
13	Absence/presence of minute black dots	Absent	69	74.19	
		Present	24	25.81	

(stems and leaves partly light purple), 19 (20.43%) accessions had high anthocyanin (stems and leaves partly light purple), 14 accessions (15%) had no anthocyanin, stems and leaves green and only two accessions (2.15%) were found with no anthocyanin (stems and leaves pale green). No anthocyanin plant pigmentation was further categorized into two groups: two accessions (BD 6493, RC-110) had no anthocyanin pigmentation with pale green stem and leaves, and 14 accessions (BD-6058, BD-6205, BA-6252, BD-6313, BD-6320, BD-6467, BD-6471, BD-6479, BD-6481, BD-6486, BD-6489, BD-6496, BD-6410, BD-6413) had no anthocyanin pigmentation with green stems and leaves. High anthocyanin plant pigmentation (stems and leaves predominantly light purple) was observed in 19 accessions (BD-6035, BD-6038, BD-6046, BD-6048, BD-6055, BD-6056, BD-6062, BD-6072, BD-6268, BD-6456, BD-6458, BD-6464, BD-6468, BD-6473, BD-6476, BD-6477, BD-6478, BD-6487, BD-6401) in which only one accession BD-6220 had highly purple plant pigmentation. Stem color variation was shown in Figure 1. Similarly, characterization of chickpea based on ten distinguished morphological qualitative features of 47 chickpea accessions were reported by Choudhury et al. (2014).

Pubescence was found in 46 accessions (49.46%), densely-pubescence in 43 accessions (46.24%), and only four accessions (4.30%) (BD-6469, BD-6482, BD-6488, and BD-6493) were lightly pubescence. Based on plant growth habit, the studied germplasm was characterized by four categories: erect, semi erect, semi-spreading, and spreading type. Forty one accessions (44%) were characterized as semi-erect and 40 accessions (43%) as semi-spreading, whereas only one accession (1%; RC-110) had erect type growth habit. Moreover, 11 accessions (12%) (BD-6035, BD-6046, BD-6056, BD-6060, BD-6062, BD-6238, BD-6462, BD-6475, BD-6480, and BD-6496) including one check variety (BARI Chola-5) had spreading type growth habit. No prostate type growth habit was observed in the studied germplasm. Morphological variability in plant growth habit was shown in Figure 3. All accessions had less than 13 leaflets per leaf, and all accessions had small sized leaflet. Except for BD-6235 (twin flower), all accessions had single flower. Based on flower color the accessions were categorized into four categories: light pink, pink, dark pink, and white pink strip (Figure 2). Among them 40 accessions (43%) had pink flowers, whereas 28 accessions (30.11%) had light pink flowers, 22 accessions (23.66%) had dark pink flowers, and only three accessions (3.23%; BD-6486, RC-110, and AHM-74) had white pink strip flower color. All accessions had only one pod per peduncle. In case of pod length, 68 accessions (73%) had medium pod length, 24 accessions (26%) were characterized as long sized pod, whereas only one accession (BD-6061) had short pod. More than 52% of accession were recorded as more than 10% pod dehiscence, whereas 48% had less than 10% of pod dehiscence. Three categories of seed shape were recorded: 59 accessions (63.44%) were characterized as angular (rams head), 31 accessions (33.33%) as irregular rounded (owl's head), and only three accessions (BD-6491, BD-6493 and check variety BARI Chola-6) were characterized as pea shaped (3.23%) seed (Figure 4). Seed texture was characterized based on three categories: 41 accessions (44.09%) were identified as tuberculated seed texture, 36 accessions (38.71%) had smooth texture, and 16 accessions (17.20%) had rough seed texture (Figure 5). Variations was also observed in case of seed color. Seeds with reddish brown color were in 28 accessions (30.11%), greyish brown color of seeds was in 26 accessions (27.96%), 12 accessions (12.90%) were with brown color of seeds, six accessions (6.45%) had black seed color, 6 accessions (6.45%) had light brown seeds, 10 accessions (10.75%) had black brown mosaic, two were with greyish brown seeds, and one accession each had yellow brown, orange and green seed color (Figure 6). Seeds of the tested accessions were also characterized based on the presence and absence of minute black dots on seed coat, and 69 accessions (74.19%) were without minute black dots, whereas 24 accessions (25.81%) had the presence of minute black dots on the seed surface. The individual characterization data based on the Descriptors of Chickpea (*Cicer arietinum* L.), IBPGR/ICRISAT/ICARDA (1993) was presented in the Table 7. Similarly, identification of chickpea genotypes based on distinguishable morphological characters were reported by Yadav and Shrivastava (2002) and Chowdhury et al. (2002).

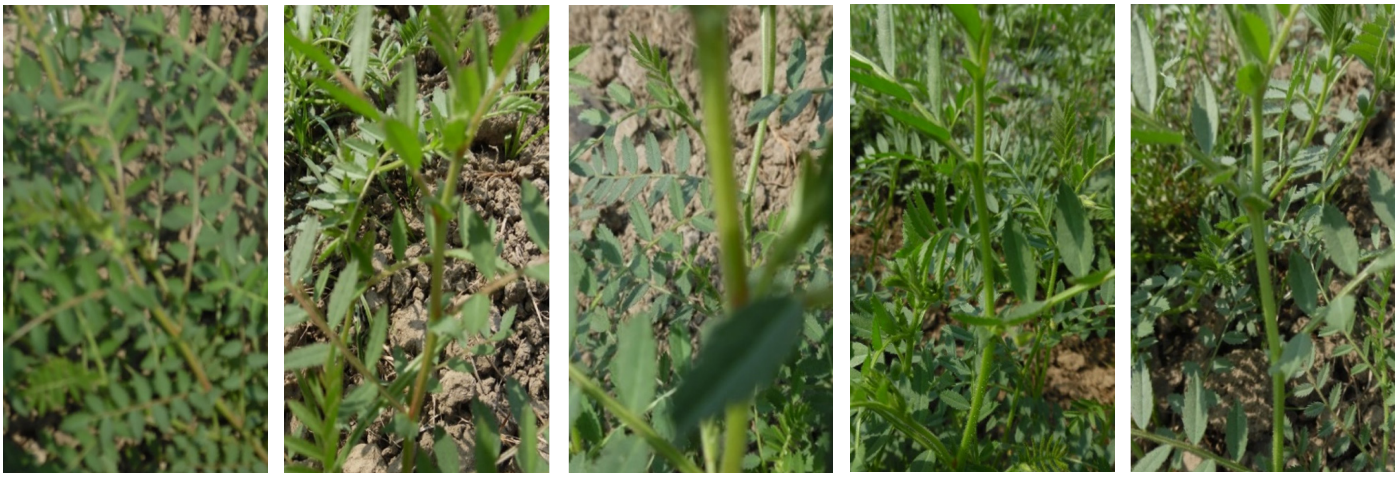

Figure 1. Morphological variation in stem color (Plant pigmentation: A - Highly purple, B - High anthocyanin, stems and leaves predominantly light purple, C - Low anthocyanin, stems and leaves partly light purple, D - No anthocyanin, stem and leaves green, E - No anthocyanin, stem and pale leaves green)

A. Erect B. Semi C. Semi Spreading D. Spreading

Figure 2. Morphological variation in plant growth habit (A, B, C, D)

A. White pink B. Light pink C. Pink D. Dark pink

Figure 3. Morphological variation in flower color

A. Angular shape B. Owl's head shape C. Pea shape

Figure 4. Morphological variation in seed shape

A. Rough B. Smooth C. Tuberculated

Figure 5. Morphological variation in seed

a. Black b. Brown c. Light brown d. Reddish brown e. Greyish brown

f. Dark brown g. Yellow brown h. Orange color i. Yellow mosaic color j. Green color

Figure 6. Morphological variation in seed color (a, b, c, d, e, f, g, h, i & j)

Quantitative characteristics

Twelve quantitative traits of 93 chickpea accessions along with three check varieties (BARI Chola-5, BARI Chola-6 and BARI Chola-9) are presented in the Tables 5 and 6. From the twelve quantitative traits, highest co-efficients of variation (CV) were observed for harvest index (0.50%), straw yield plant^{-1} (0.43%), grain yield plant^{-1} (0.42%), and pods plant^{-1} (0.36%) indicating the maximum variability among these traits. Significant variations were observed among germplasm pertaining all quantitative traits. The days to 50% flowering were recorded from 52nd to 66th days after sowing and days to maturity were recorded from 108th to 117th days. Twentyfive accessions flowered earlier than the check varieties; also 32 accessions matured earlier compared to the check varieties. The accession BD-6475 matured within 117 days, which was comparatively delayed to all check varieties, and other accessions but the accession BD-6473 matured earlier with the moderate yield performance 120.43 g plant^{-1} and 1946 kg ha^{-1}. The experiment was sown at delay condition that's why days to maturity were earlier in case of all accessions including the three check varieties. In regard to plant canopy height, 10 accessions were taller than the check varieties, but 56 accessions were the dwarf type genotypes compared to three check varieties (BARI Chola-5, BARI Chola-6 and BARI Chola-9). The accession AHM-74 was the shortest genotype with 35.56 cm canopy height, whereas the tallest genotype was RC-110 with 74 cm canopy height. Plant canopy width range was 48 - 86 cm. Twelve accessions were recorded with wider canopy compared to the all check varieties.

Table 5. Range, mean, standard deviation and CV (%) of 90 chickpea accessions along with three check variety

Characteristics	Range	Maximm	Minimum	Mean	SD	CV%
Days to 50% flowering	14.00	66.00	52.00	58.48	2.90	0.05
Days to maturity	9.00	117.00	108.00	112.25	2.73	0.02
Plant canopy height (cm)	38.33	74.00	35.67	47.91	5.61	0.12
Branches per plant	3.00	5.00	2.00	3.06	0.71	0.23
Canopy wide (cm)	38.00	86.00	48.00	61.92	6.52	0.11
Pods per plant	202.80	232.80	30.00	80.70	29.05	0.36
Seeds per pod	2.00	3.00	1.00	2.02	0.28	0.14
100 seeds weight (g)	14.90	23.00	8.10	13.62	4.20	0.31
Yield per plant (g)	156.57	176.13	19.56	67.93	28.77	0.42
Straw yield per plant	185.07	206.17	21.10	81.22	34.82	0.43
Harvest Index	337.68	365.02	34.10	94.25	47.07	0.50
Grain yield (kg ha^{-1})	2994.00	3523.00	529.00	1510.23	456.02	0.30

Table 6. Mean performance of yield and yield contributing characters of 93 accessions of chickpea including three check varieties at RPGRC, RARS, Ishurdi, Pabna during 2017-2018.

Acc. No.	Days to 50% flowering	Days to maturity	Plant canopy height (cm)	Plant canopy width (cm)	Number of branches plant^{-1}	Number of pods per plant	Number of seeds per pod	100 seed weight (g)	Grain yield per plant	Straw yield per plant	Harvest Index	Seed yield (kg ha^{-1})
BD-6034	60	112	43.67	59.67	2	61	2	9	63.34	42.28	149.81	807
BD-6035	59	116	47.67	60.00	2	85	3	8.1	36.47	67.80	53.79	1370
BD-6038	58	111	47.67	58.33	2	93	2	8.9	68.77	88.43	77.76	1708
BD-6039	58	114	44.00	62.00	3	94	2	8.9	63.47	76.73	82.71	1697
BD-6045	60	109	45.33	57.67	3	89	2	9.4	54.10	46.87	115.43	1231
BD-6046	60	114	46.00	56.33	4	104	2	9.4	71.00	55.07	128.93	1291
BD-6048	60	112	41.67	60.00	4	97	2	8.6	54.40	82.00	66.34	1454
BD-6049	58	110	50.00	58.67	2	91	2	10.7	86.90	168.80	51.48	1349
BD-6051	61	109	39.00	48.67	3	125	2	9.5	119.40	71.77	166.37	1310
BD-6055	60	110	51.33	62.33	4	75	2	12.4	52.23	39.37	132.68	805
BD-6056	66	111	39.67	59.67	5	135	2	10.1	60.52	33.08	182.95	568
BD-6058	59	110	38.33	52.67	3	96	2	10.1	124.70	87.23	142.95	1722
BD-6060	58	109	42.33	61.33	3	125	2	12.3	134.67	87.70	153.55	1121
BD-6061	55	109	46.00	57.33	3	72	2	8.5	39.60	66.93	59.17	1355
BD-6062	61	116	38.67	55.67	4	102	2	9.8	75.80	84.10	90.13	1068
BD-6072	60	113	49.67	61.33	3	56	2	8.3	53.80	116.57	46.15	897
BD-6597	59	109	40.67	51.67	3	91	3	10.8	136.23	96.60	141.03	1636
BD-6201	59	114	50.33	63.33	3	103	2	11.2	54.17	72.83	74.38	1954

Acc. No.	Days to 50% flowering	Days to maturity	Plant canopy height (cm)	Plant canopy width (cm)	Number of branches plant^{-1}	Number of pods per plant	Number of seeds per pod	100 seed weight (g)	Grain yield per plant	Straw yield per plant	Harvest Index	Seed yield (kg ha^{-1})
BD-6205	58	115	55.00	69.67	3	68	3	13.6	50.34	86.64	58.10	1379
BD-6207	55	108	52.67	67.00	3	77	3	12.2	64.88	68.06	95.33	1455
BD-6210	61	114	46.67	59.67	3	96	2	9.5	65.07	98.33	66.17	856
BD-6212	58	108	45.67	54.00	4	52	2	11.1	79.97	133.50	59.90	1955
BD-6214	66	108	45.00	52.67	3	129	2	8.6	109.87	137.37	79.98	1200
BD-6220	58	109	42.33	55.00	3	104	2	9.7	89.10	156.47	56.95	1576
BD-6221	58	109	42.67	54.33	3	92	2	11.8	103.67	206.17	50.28	2008
BD-6232	58	114	44.33	52.33	3	89	2	11.6	68.00	53.57	126.94	1751
BD-6235	63	113	58.33	70.33	4	75	2	12.9	176.13	141.67	124.33	1080
BD-6238	61	112	48.00	68.00	2	83	3	11.2	61.44	33.44	183.73	848
BD-6245	58	114	58.67	74.33	3	66	2	10.6	35.87	105.20	34.10	1469
BD-6252	59	117	49.67	64.67	4	104	2	10.9	82.08	83.44	98.37	1427
BD-6259	58	112	47.67	57.00	3	105	2	15.9	82.37	119.83	68.73	1250
BD-6265	55	114	42.00	58.00	3	106	2	14.1	36.24	59.08	61.34	1192
BD-6268	57	114	42.67	60.33	3	83	2	11.7	73.90	82.40	89.68	1675
BD-6307	61	116	45.00	56.33	4	103	2	15.7	80.70	123.37	65.41	1268
BD-6313	55	109	51.33	64.33	3	107	2	11.1	74.33	35.05	212.07	1743
BD-6320	55	117	51.67	60.33	3	81	2	12.1	52.22	38.00	137.42	2227
BD-6454	59	108	47.33	59.33	3	94	2	10.4	46.04	80.57	57.15	1769
BD-6455	55	116	45.00	55.00	4	70	2	11.7	62.77	84.33	74.43	1895
BD-6456	58	109	45.67	60.00	3	77	2	10.4	45.80	63.80	71.79	1391
BD-6457	58	117	53.00	65.33	3	58	2	12.4	57.94	74.08	78.21	1262
BD-6458	61	116	45.00	56.67	4	67	2	11.3	34.48	43.08	80.04	966
BD-6459	55	115	43.33	59.67	2	95	2	9.9	55.90	111.80	50.00	1680
BD-6460	60	112	51.33	71.33	3	88	2	10.8	139.93	120.03	116.58	1778
BD-6461	64	110	46.67	54.67	3	107	2	9.4	105.43	105.47	99.97	1390
BD-6462	59	112	41.33	62.33	3	90	2	10.4	85.43	96.93	88.14	1434
BD-6463	53	109	44.00	58.00	3	79	2	9.4	52.23	108.43	48.17	1161
BD-6464	58	117	49.67	69.00	4	112	2	12.2	66.12	77.08	85.78	991
BD-6465	55	112	42.33	52.67	3	68	2	11.2	45.20	56.53	79.95	1989
BD-6466	57	112	45.00	48.67	3	79	2	13	129.87	86.43	150.25	1566
BD-6467	61	111	38.33	51.33	3	93	2	9.9	99.07	69.83	141.86	1687
BD-6468	59	114	53.33	59.00	3	71	2	10	69.87	136.90	51.03	1422
BD-6469	59	110	47.00	61.33	3	56	2	11.6	26.14	68.14	38.36	1436
BD-6470	59	109	40.00	50.67	4	117	2	10.7	123.30	105.07	117.35	1607
BD-6471	57	112	47.67	54.00	3	72	2	11.8	42.53	124.33	34.21	1695
BD-6472	65	114	36.00	48.00	3	119	2	11	79.80	108.87	73.30	1288
BD-6473	59	108	40.33	56.00	4	127	2	9.5	105.50	120.43	87.60	1946
BD-6474	58	114	53.33	71.33	3	81	2	12.6	77.02	21.10	365.02	1204

Acc. No.	Days to 50% flowering	Days to maturity	Plant canopy height (cm)	Plant canopy width (cm)	Number of branches plant^{-1}	Number of pods per plant	Number of seeds per pod	100 seed weight (g)	Grain yield per plant	Straw yield per plant	Harvest Index	Seed yield (kg ha^{-1})
BD-6475	58	117	48.00	61.33	4	88	1	11.6	47.00	68.00	69.12	1727
BD-6476	61	114	43.67	62.67	4	68	2	11.8	62.02	80.28	77.25	1449
BD-6477	58	116	49.00	61.67	3	51	2	10.7	36.28	32.50	111.63	1214
BD-6478	61	112	45.33	54.00	3	88	2	9.70	77.33	109.70	70.50	1339
BD-6479	58	112	50.67	67.33	4	159	2	11.3	73.43	40.07	183.28	1141
BD-6480	57	109	49.33	58.00	3	69	2	9.7	90.23	103.50	87.18	2467
BD-6481	55	113	55.00	70.33	4	86	2	10.40	51.56	57.12	90.27	1859
BD-6482	54	109	51.00	62.00	3	106	2	14.2	73.93	71.17	103.89	1742
BD-6483	55	109	43.67	52.33	2	47	2	13.20	49.97	102.90	48.56	1644
BD-6484	59	116	47.00	66.00	3	84	2	14.9	108.20	174.00	62.18	1196
BD-6485	62	110	42.33	54.33	4	150	2	12.5	68.16	72.14	94.48	529
BD-6486	55	112	45.00	59.33	2	65	2	13.4	48.52	98.00	49.51	974
BD-6487	61	112	44.00	53.33	3	123	2	10.9	54.87	86.37	63.53	1255
BD-6488	55	113	45.33	53.33	3	72	2	16.00	109.30	106.93	102.21	1465
BD-6489	59	112	48.67	64.33	3	72	2	9.7	84.34	72.02	117.11	1387
BD-6490	60	114	54.33	69.00	4	61	2	8.1	52.42	38.04	137.80	1161
BD-6491	54	108	50.33	61.00	3	74	2	11.9	71.17	73.13	97.32	1880
BD-6493	59	109	37.00	59.00	2	96	2	12.2	71.77	50.23	142.87	704
BD-6496	55	111	53.33	67.00	4	134	2	14.8	62.80	121.73	51.59	1295
BD-6498	57	112	54.67	72.00	2	85	2	13.7	66.73	90.33	73.87	1671
BD-6500	65	108	50.00	66.00	2	53	2	11.4	35.23	68.37	51.54	3523
BD-6501	60	113	46.33	64.33	4	83	2	14.2	36.10	49.53	72.88	1191
BD-6502	55	114	48.67	63.00	4	86	2	9.3	30.56	67.34	45.38	1168
BD-6504	66	114	45.00	59.00	3	52	2	13.00	33.72	73.12	46.12	1186
BD-6505	55	109	44.33	58.67	3	123	1	16.4	119.67	105.27	113.68	1666
BD-6507	55	113	51.67	70.33	3	62	2	13.2	29.87	40.00	74.67	1289
BD-6509	59	113	51.67	60.67	4	71	2	19.8	62.14	124.14	50.06	1083
BD-6510	55	111	49.00	62.00	4	111	2	13.3	57.07	47.17	120.99	1482
BD-6513	58	109	42.33	58.00	3	73	3	12.4	102.23	157.07	65.09	1605
BD-6653	62	111	54.33	70.67	3	102	2	10.4	70.80	45.07	157.10	1313
RC-110	58	112	74.00	86.00	3	77	2	22.8	89.43	147.17	60.77	1977
AHM-74	60	109	35.67	58.33	5	233	2	9.2	80.30	63.16	127.14	1023
BARI Chola-5	58	114	49.69	65.17	3	65	2	14.76	54.41	59.52	103	1646
BARI Chola-6	58	113	48.92	63.78	3	54	2	19.98	55.5	85.61	68.84	1445
BARI Chola-9	59	112	52.39	68.28	2	54	2	21.72	65.91	66.53	109	1960
CV	0.05	0.02	0.12	0.11	0.23	0.36	0.14	0.31	0.42	0.43	0.50	0.30

The accession RC-110 had wider canopy (86 cm) with the better yield performance (1977 kg ha^{-1}). The minimum canopy width (48 cm) was recorded for the accession BD-6475. Twenty five accessions produced more branches than the check varieties. Five branches per plant had the accession AHM-74 with the medium yield performance. Almost all accessions produced higher pods plant per compared to the check varieties, and the highest 233 pods per plant was recorded for accession AHM-74 with better harvest index (127.14) compared to all check varieties. Most of the accession contained two seeds per pod except BD-6035, BD-6597, BD-6205, BD-6207 and BD-6238 that had three seeds per pod. The seeds of all the accessions were smaller compared to the check varieties except the accession RC-110 that was bold seeded and the 100 seeds weight was 22.8 g. The 100 seeds weight range was 8.10 to 22.80 g. A total of 46 accessions produced the higher yield per plant compared to all check varieties, and the yield per plant range was 19.56 to 176.13 g plant^{-1}. The maximum grain yield 176.13g plant^{-1} was recorded for accession BD-6235 and the minimum 19.56 g plant^{-1} for accession BD-6164. The straw yield per plant range was from 21.10 to 206.17 g, and the minimum straw yield of 21.10 g plant^{-1} was recorded from the accession BD-6474. Maximum harvest index 365.02 was recorded for accession BD 6474, and the minimum harvest index was 27.34 for the accession BD 6245. The individual data of each accession is shown in Table 7.

Table 7. List of assessed qualitative morphological traits of 90 chickpea accessions and three check varieties at RPGRC, RARS, Ishurdi, Pabna during 2017-2018

Sl. No.	Accessions	Growth habit	Number of branches per leaf	Plant pigmentation	Plant hairiness	Number of leaflets per leaf	Leaflets size	No. of flowers and pods	Flower color	Pod length	Pod dehiscence	Seed shape	Seed texture	Seed color	Absence/presence of minute black dots
1	BD-6034	3	2	5	7	5	2	1	5	5	2	1	3	21	+
2	BD-6035	4	2	7	7	4	2	1	5	5	2	1	7	3	0
3	BD-6038	2	2	7	5	5	2	1	5	5	2	1	7	5	0
4	BD-6039	2	3	5	7	5	2	1	3	5	1	2	5	2	0
5	BD-6045	3	3	5	7	5	2	1	4	5	2	1	7	6	0
6	BD-6046	4	4	7	7	5	2	1	3	5	1	1	3	2	0
7	BD-6048	3	4	7	7	5	2	1	3	7	2	1	3	5	+
8	BD-6049	3	2	5	7	5	2	1	4	5	2	1	7	21	0
9	BD-6051	2	3	5	7	5	2	1	3	5	1	1	7	4	0
10	BD-6055	3	4	7	7	5	2	1	3	5	2	1	3	3	0
11	BD-6056	4	5	7	5	3	2	1	4	5	1	1	7	2	0
12	BD-6058	3	3	3	7	5	2	1	3	5	2	1	7	4	0
13	BD-6060	4	3	5	5	5	2	1	4	7	1	1	5	4	0
14	BD-6061	3	3	5	7	4	2	1	5	3	1	1	5	4	+
15	BD-6062	4	4	7	5	4	2	1	4	7	1	1	3	4	0
16	BD-6072	2	3	7	5	5	2	1	5	5	2	1	3	5	0
17	BD-6597	2	3	5	7	5	2	1	5	5	1	2	5	5	0
18	BD-6201	2	3	5	7	4	2	1	3	5	2	1	7	4	0
19	BD-6205	3	3	3	7	5	2	1	4	7	2	1	7	21	+
20	BD-6207	2	3	5	5	5	2	1	5	7	1	2	5	21	+
21	BD-6210	2	3	5	5	5	2	1	3	5	2	1	3	4	0
22	BD-6212	3	4	5	5	5	2	1	4	5	2	1	7	4	0
23	BD-6214	3	3	5	7	5	2	1	3	5	1	1	7	2	0
24	BD-6220	3	3	9	5	5	2	1	3	5	1	1	7	4	+
25	BD-6221	2	3	5	5	5	2	1	3	5	2	1	7	2	0
26	BD-6232	3	3	5	7	5	2	1	4	5	2	2	5	4	0
27	BD-6235	2	4	5	5	5	2	2	4	5	2	1	7	4	0

Sl. No.	Accessions	Growth habit	Number of branches per leaf	Plant pigmentation	Plant hairiness	Number of leaflets per leaf	Leaflets size	No. of flowers and pods	Flower color	Pod length	Pod dehiscence	Seed shape	Seed texture	Seed color	Absence/presence of minute black dots
28	BD-6238	4	2	5	7	5	2	1	4	5	1	1	3	4	0
29	BD-6245	2	3	5	7	4	2	1	3	5	1	1	7	1	0
30	BD-6252	2	4	3	7	5	2	1	4	5	1	2	5	5	0
31	BD-6259	2	3	5	7	5	2	1	5	7	2	1	3	21	+
32	BD-6265	3	3	5	5	5	2	1	5	5	2	2	5	5	+
33	BD-6268	3	2	7	7	5	2	1	4	5	1	1	7	4	0
34	BD-6307	3	4	5	7	5	2	1	5	5	1	2	5	2	0
35	BD-6313	2	3	3	7	4	2	1	4	5	1	1	7	4	0
36	BD-6320	2	3	3	5	4	2	1	3	5	2	1	7	5	+
37	BD-6454	2	3	5	5	4	2	1	5	5	1	1	7	2	0
38	BD-6455	2	4	5	5	4	2	1	4	7	2	2	5	4	0
39	BD-6456	3	3	7	5	5	2	1	4	7	2	1	7	5	0
40	BD-6457	2	3	5	5	5	2	1	4	5	2	1	3	21	0
41	BD-6458	3	4	7	5	5	2	1	4	5	2	1	7	5	0
42	BD-6459	3	2	5	7	5	2	1	4	5	1	1	7	5	+
43	BD-6460	2	3	5	7	5	2	1	4	5	2	1	7	4	0
44	BD-6461	2	3	5	5	5	2	1	4	5	1	1	7	4	0
45	BD-6462	4	3	5	7	5	2	1	5	7	2	1	7	3	0
46	BD-6463	2	3	5	7	5	2	1	5	5	1	1	3	4	0
47	BD-6464	2	4	7	5	5	2	1	3	7	1	1	7	5	0
48	BD-6465	2	3	5	7	5	2	1	3	5	2	1	7	5	0
49	BD-6466	2	4	5	7	5	2	1	4	5	1	1	7	5	0
50	BD-6467	2	3	3	5	5	2	1	4	7	1	2	5	2	0
51	BD-6468	2	3	7	5	5	2	1	4	5	2	2	5	4	0
52	BD-6469	2	3	5	3	4	2	1	4	5	1	1	7	4	0
53	BD-6470	2	3	5	5	5	2	1	5	5	1	1	7	5	0
54	BD-6471	3	4	3	5	5	2	1	4	5	1	2	5	5	0
55	BD-6472	3	3	5	5	5	2	1	5	5	1	1	7	2	0
56	BD-6473	3	3	7	5	5	2	1	5	7	1	2	5	4	0
57	BD-6474	3	4	5	5	5	2	1	5	5	1	1	5	21	0
58	BD-6475	4	3	5	5	5	2	1	5	7	2	2	5	4	0
59	BD-6476	3	4	7	7	5	2	1	4	7	2	1	7	5	0
60	BD-6477	3	4	7	7	5	2	1	4	7	2	1	3	5	+
61	BD-6478	2	3	7	5	5	2	1	3	5	2	1	7	5	0
62	BD-6479	3	3	3	7	5	2	1	3	5	2	1	5	5	0
63	BD-6480	4	4	5	5	5	2	1	5	7	2	2	5	4	0
64	BD-6481	2	3	3	5	5	2	1	3	5	1	1	7	5	0
65	BD-6482	2	4	5	3	5	2	1	4	5	2	2	5	4	0
66	BD-6483	2	3	5	5	5	2	1	3	5	1	1	5	5	0

Sl. No.	Accessions	Growth habit	Number of branches per leaf	Plant pigmentation	Plant hairiness	Number of leaflets per leaf	Leaflets size	No. of flowers and pods	Flower color	Pod length	Pod dehiscence	Seed shape	Seed texture	Seed color	Absence/presence of minute black dots
67	BD-6484	3	2	5	5	5	2	1	3	5	1	1	7	1	+
68	BD-6485	3	3	5	5	4	2	1	5	5	1	2	5	4	+
69	BD-6486	3	4	3	5	5	2	1	7	5	2	1	3	5	0
70	BD-6487	3	2	7	5	5	2	1	5	5	1	2	3	1	+
71	BD-6488	3	3	5	3	4	2	1	4	7	2	1	7	18	0
72	BD-6489	3	3	3	5	5	2	1	5	5	1	2	7	4	+
73	BD-6490	2	3	5	7	5	2	1	4	5	2	1	3	21	+
74	BD-6491	2	4	5	7	5	2	1	4	5	2	3	5	4	0
75	BD-6493	2	3	1	3	5	2	1	4	5	2	3	5	5	0
76	BD-6496	4	2	3	7	5	2	1	4	5	1	2	5	5	0
77	BD-6498	3	4	5	7	5	2	1	5	5	1	2	5	2	0
78	BD-6400	3	2	5	5	5	2	1	5	7	2	2	5	1	+
79	BD-6401	3	2	7	5	5	2	1	5	5	2	2	7	3	0
80	BD-6402	3	4	5	5	5	2	1	4	7	2	2	5	21	+
81	BD-6404	3	4	5	7	5	2	1	4	5	2	2	7	1	+
82	BD-6405	3	3	5	5	5	2	1	4	5	2	2	5	1	+
83	BD-6407	2	3	5	7	5	2	1	3	5	1	2	5	5	0
84	BD-6409	2	3	5	7	4	2	1	5	5	2	1	7	3	0
85	BD-6410	2	4	3	5	4	2	1	4	7	1	2	5	4	+
86	BD-6413	3	4	3	5	5	2	1	5	5	2	2	5	21	+
87	BD-6653	3	3	5	5	5	2	1	3	5	1	1	5	13	+
88	BD-6033	2	3	5	7	5	2	1	4	5	1	1	3	3	0
89	RC-110	1	3	1	5	4	2	1	7	7	1	2	5	15	0
90	AHM-74	4	5	5	5	4	2	1	7	7	1	1	7	5	0
	BARI Chickpea-5	4	3	5	7	5	2	1	5		2	2	5	5	0
	BARI Chickpea-6	3	3	5	7	5	2	1	4		2	3	5	2	+
	BARI Chickpea-9	4	2	5	7	4	2	1	4		2	2	5	6	0

Cluster Analysis

A total of 93 genotypes grouped in to eight clusters (Table 8). Cluster I consisted of six genotypes that were characterized as dwarf type, medium canopy width, grain yield with maximum pods per plant, and second highest harvest index (Table 9). Cluster II consisted of eight genotypes characterized by maximum maturity period, moderate plant height, canopy width, hundred seed weight, grain, straw yield and harvest index. Cluster III was comprised 18 and Cluster V 19 genotypes that were characterized medium for all of studied agronomic traits. Cluster IV contained only one genotype (BD-6504) characterized by maximum flowering period, the tallest plants with maximum grain yield (kg ha^{-1}) and with medium canopy width. Cluster VI contained 23 genotypes that were characterized with medium for all studied traits except maximum straw yield with good harvest index. Cluster VII was comprised of five genotypes that were the tallest with highest canopy width, branches, pods, grain yield and harvest index. Cluster VIII contained 12 genotypes characterized by medium for all of the studied agronomic traits. Similar results were reported by Malik et al. (2014) and Ghafoor et al. (2003) for chickpea. For improving the grain yield the genotypes in Cluster IV and Cluster VIII would be crossed with genotypes in Cluster I and Cluster VII. Cluster I and Cluster VII consisted genotypes with maximum grain yield and harvest index, while cluster IV and Cluster VIII included genotypes with not apropriate yield and other yield contributing traits. These findings are supported by research of Sharifi et al. (2018) concerning chickpea. Cluster analysis of chickpea was also reported by Talebiand and Rokhzadi (2013) and Farshadfar and Farshadfar (2008).

Table 8. Distribution of 93 genotypes in eight clusters

Cluster	No. of entry	Entry no.	Entry name
Cluser I	06	4, 13.14, 31, 72, 79	BD-6039, BD-6060, BD-6061, BD-6259, BD-6487, BD-6500
Cluster II	08	18, 19, 24, 44, 50, 73, 88, 93	BD-6201, BD-6205, BD-6220, BD-6460, BD-6466, BD-6489, BD-6653, BARI Chola-9
Cluster III	19	8, 9, 12, 26, 34, 35, 37, 43, 49, 64, 71, 74, 81, 83, 84, 85, 87, 91	BD-6049, BD-6051, BD-6058, BD-6232, BD-6307, BD-6313, BD-6454, BD-6459, BD-6465, BD-6475, BD-6480, BD-6487, BD-6490, BD-6502, BD-6505, BD-6509, BD-6513, BARI Chola-5
Cluster IV	01	82	BD-6504
Cluster V	19	2, 5, 10, 11, 17, 22, 23, 32, 33, 42, 47, 48, 55, 56, 63, 65, 75, 76, 89	BD-6035, BD-6045, BD-6055, BD-6056, BD-6597, BD-6212, BD-6214, BD-6265, BD-6268, BD-6458, BD-6463, BD-6464, BD-6471, BD-6472, BD-6479, BD-6481, BD-6489, BD-6493, RC-110
Cluster VI	23	1, 6, 7, 15, 20, 27, 19, 36, 38, 40, 45, 46, 52, 53, 54, 57, 58, 62, 69, 70, 80, 86, 90	BD-6034, BD-6046, BD-6048, BD-6062, BD-6207, BD-6235, BD-6245, BD-6320, BD-6455, BD-6033, BD-6461, BD-6462, BD-6468, BD-6469, BD-6470, BD-6473, BD-6474, BD-6478, BD-6485, BD-6486, BD-6501, BD-6510 AHM-74
Cluster VII	05	16, 30, 61, 66, 77	BD-6072, BD-6252, BD-6477, BD-6482 BD-6496
Cluster VIII	12	8, 21, 25, 28, 39, 41, 51, 60, 67, 68, 78, 92	BD-6049, BD-6210, BD-6221, BD-6238, BD-6456, BD-6457, BD-6467, BD-6476, BD-6483, BD-6484, BD-6498, BARI Chola-6

Table 9. Mean value of eight clusters of 93 chickpea genotypes for 11 agronomic traits

Cluster	DF	DM	PH	BPP	CW	PPP	SPP	HSW	GY	SY	HI
Cluser I	61	111	43.7	3	60.5	100	2	11.2	62.9	45.1	147.8
Cluster II	60	114	45.3	4	60.1	100	2	11.7	60.8	88.1	74.4
Cluster III	59	113	46.4	3	59.6	94	2	11.9	63.5	83.9	82.7
Cluster IV	65	108	50.0	2	66.0	53	2	11.4	35.2	68.4	51.5
Cluster V	58	112	48.2	3	61.5	80	2	11.3	64.7	89.6	74.9
Cluster VI	58	111	45.4	3	58.4	89	2	11.7	82.8	90.4	99.5
Cluster VII	59	112	51.8	4	67.9	100	2	11.4	102.7	65.7	192.8
Cluster VIII	57	112	49.9	3	61.6	79	2	12.9	72.6	96.6	84

DF = days to flowering (days), DM = days to maturity (days), PH = plant height (cm), BPP = braches per plant, CW = canopy width (cm), PPP = pods per plant, SPP = seeds per pod, HSW = hundred seeds weight (g), GY = grain yield/plant (g), SY = straw yield per plant (g), and HI = harvest index.

Correlation study

Correlation among the 10 quantitative traits are presented in the Table 10. Significant positive correlation was observed between plant height and canopy width (0.79), followed by straw yield and grain yield (0.47), hundred seed weight and canopy width (0.44), branches per plant and pods per plant (0.42), and pods per plant and grain yield (0.39). Positive and significant correlation was also observed among days to 50% flowering, branches per plant, seeds per pod, and grain yield. Maximum and significant negative correlation was observed between pods per plant and hundred seed weight, and the plant height and pods per plant. However, negative and significant correlation was observed among the days to maturity, plant height, canopy width, and seeds per pod with grain yield, and days to maturity and grain yield and branches per plant with hundred seed weight. Similar was observed by Sharifi et al.(2018) who reported for chickpea that seed yield, pods per plant, canopy width, harvest index and biological yield had positive correlation. These results were also supported by the finding of Kumar et al. (2003) who observed the significant positive correlation between seed yield and pods per plant, plant height and branches per plant.

Table 10. Estimation of correlation co-efficient among ten quantitative traits with grain yield

	DF	DM	PH	BPP	CW	PPP	SPP	HSW	SY	GY
DF	1	0.03	-0.04**	0.12**	-0.06**	0.11**	0.07	-0.12**	0.08**	0.17**
DM		1	0.16**	0.15**	0.25**	-0.2**	-0.05	0.12**	-0.13**	-0.26**
PH			1	-0.09**	0.79**	-0.36**	-0.04	0.41**	-0.04**	-0.09**
BPP				1	-0.1**	0.42**	-0.16	-0.26**	-0.03**	0.12**
CW					1	-0.3**	-0.03	0.44**	-0.2**	-0.21**
PPP						1	-0.02	-0.47**	0.08**	0.39**
SPP							1	-0.16**	0.06**	0.05**
HSW								1	-0.03**	-0.09**
SY									1	0.47**
GY										1

DF = Days to flower, DM = Days to maturity, PH = Plant height, BPP = Braches per plant, CW = Canopy width, PP = Pods per plant, SPP = Seeds per pod, HSW = Hundred seeds weight, SY = Straw yield, and GY = Grain yield

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Conclusion

Qualitative characteristics were studied for identifiction of the germplasm of chickpea. Significant variations were observed in qualitative characteristics. Among the thirteen studied qualitative characteristics plant pigmentation, growth habit, flower color, seed color, seed shape, and seed texture showed the maximum variability. However, the quantitative characters, such as number of pods per plant, grain yield per plant (g), 100-seed weight (g), harvest index, and plant canopy height (cm) showed the maximum variability among 12 yield and yield contributing characteristics of 93 chickpea accessions including three varieties. Cluster analysis was done for identifying the genotypes with desired traits that would be used by chickpea breeders for future genetic improvement of chickpea. Cluster analysis classified the chickpea genotypes into eight different clusters that would be used for hybridization among the clusters for increasing heterosis in derived popuulation. Correlation study was carried out for estimation of the relationships among the studied morphological traits in existing genotypes of chickpea. Significant and positive correlation was observed among the straw yield, pods per plant, days to 50% flowering, branches per plant, and seeds per pod with grain yield, whereas negative significant correlation with grain yield was recorded for of days to maturity, plant height, canopy width, and hundred seed weight. The chickpea accessions BD-6051, BD-6058, BD-6557, BD-6214, BD-6221, BD-6235, BD-6460, BD-6461, BD-6470, BD-6471, BD-6472, BD-6473, BD-6478, BD-6480, BD-6481, 6483, BD-6484, BD-6488, BD-6491, BD-6500, BD-6505, and BD-6513 were found promising with better yield potential and harvest index compared to three check varieties and other chickpea accessions. These accessions could be used in future breeding program for improvement of chickpea varieties. Exploration of desired genetic traits of a germplasm and their incorporation in existing varieties might solve major challenges of feeding 200 million people of Bangladesh. The genetic potential of germplasm to grow in extreme habitats and harsh environment are considered to be useful to address the challenge for the development of climate smart crop.

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