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Screening of Long Cowpea [*Vigna unguiculata* (L.) Walp. ssp. *sesquipedialis*] Varieties in Autumn in Hunan and Comparison of Various Comprehensive Evaluation Methods

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Abstract [**Objectives**] The paper was to screen new varieties of long cowpea that are suitable for autumn cultivation in Hunan, as well as to develop a comprehensive evaluation method to assess their adaptability and performance. [**Methods**] A total of 48 long cowpea varieties were introduced, and a range of comprehensive evaluation methods was employed to assess these varieties through the collection and analysis of field data. [**Results**] The square Euclidean distance of 14 allowed for the classification of all varieties into eight distinct groups. Groups II, III, and V belong to the autumn dominant group within this region, while groups I and VIII belong to the intermediate group. Additionally, groups IV, VI, and VII belong to the autumn inferior group in this area. Through a comparative analysis of various comprehensive evaluation methods, it was determined that the common factor comprehensive evaluation, grey correlation method, and fuzzy evaluation method were appropriate for application in the selection of long cowpea varieties. Furthermore, the evaluation outcomes were largely consistent with the cluster pedigree diagram. [**Conclusions**] Through comprehensive index method, ten varieties demonstrating superior performance in autumn cultivation have been identified, including C20, C42, C29, C40, C3, C14, C18, C25, C15, and C47. The selected varieties exhibit several advantageous traits, such as a reduced growth duration, a lower position of initial flower nodes, a decreased number of branches, predominantly green young pods, elongated pod strips, thicker pod structures, an increased number of pods per plant, and higher overall yields. These characteristics render them particularly valuable for extensive cultivation.

Key words Long cowpea; Variety; Screening; Cluster analysis; Comprehensive evaluation method

1 Introduction

In research concerning the resource screening of cowpea [*Vigna unguiculata* (L.) Walp], the majority of studies employed a singular analytical approach to assess the adaptability of new varieties. Commonly utilized methods include principal component analysis and common factor analysis[1-4], fuzzy evaluation method[5], and comprehensive index method[6]. Some researchers opted to integrate multiple methods. For instance, Chen Chanyou *et al.*[7] utilized principal component cluster analysis in conjunction with the comprehensive index method to evaluate cowpea. Similarly, Huang Haitao *et al.*[8] and Huang Weikang *et al.*[9] employed principal component analysis alongside the fuzzy evaluation method to assess the cold tolerance of cowpea. Liu Qin *et al.*[10] combined principal component cluster analysis with the grey correlation method, while Chen Hailing *et al.*[11] utilized grey scale correlation analysis in tandem with the fuzzy evaluation method to evaluate and identify cowpea resources. Furthermore, the entropy weight-TOPSIS method has experienced a growing application within this domain[12]. The introduction and screening of resources is an ongoing process. In Hunan, the area designated for the autumn cultivation of cowpea is relatively limited, and the number of suitable varieties is even fewer. Furthermore, there has yet to be a report comparing the effectiveness of various evaluation methods employed in the screening of cowpea varieties. In this study, 48 varieties of long cowpeas were introduced to assess key agronomic traits, as well as to collect data on phenological periods and yield. Subsequently, cluster analysis was performed, and the resources were comprehensively evaluated using several methodologies, including common factor analysis, entropy weight-TOPSIS, grey correlation analysis, and fuzzy evaluation. This approach aimed to compare the effectiveness of these four methods in evaluating long cowpeas. The comprehensive index method was employed to synthesize the results of relevant evaluation techniques, leading to the selection of suitable varieties for autumn cultivation in this region. This approach offers valuable insights for seed selection, breeding, and variety replacement.

2 Materials and methods

2.1 Materials A total of 48 varieties of long cowpeas designated as C1 to C48 were selected for testing.

2.2 Experimental design A completely randomized design was employed, consisting of three replications across 144 plots, each measuring 12.6 m^2 and containing 46 plants. The method employed involved uniform hole tray sowing, with three seeds allocated per hole, followed by uniform transplanting. The seedlings were arranged in a single-ridge double-row pattern, with a plant

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spacing of 40 cm × 70 cm. Subsequently, consistent field management practices were implemented post-transplanting.

2.3 Index measurement The subsequent items were examined and recorded in accordance with the methodology outlined in the *Cowpea Germplasm Resource Description Specification and Data Standards*[13].

2.3.1 Critical stages. The critical developmental stages included the sowing stage, seedling transplantation stage, branching stage, first flowering date (defined as the first bloom), flowering stage (characterized by 50% of the plants having bloomed), young pod initiation stage (indicated by 50% of pods being set), and the maturity stage (when more than 70% of pods exhibit a ripe coloration). The growth duration was quantified as the time interval from sowing to the maturity stage.

2.3.2 Agronomic traits. The initial flower node and the number of branches per plant were documented. Descriptive classifications were assigned for flower color (white = 1, purple = 2), stem color (green = 1, purple = 2), young pod color (white = 1, light green = 2, green = 3, dark green = 4, red = 5, purplish-red = 6, mottled = 7), and pod surface morphology (slightly flat = 1, slightly convex = 2, convex = 3).

2.3.3 Yield traits. A total of ten long cowpeas were randomly selected from each treatment and replication to assess pod length, pod thickness, and tender pod weight, with the mean values subsequently recorded. Furthermore, three plants were randomly chosen from each treatment for the evaluation of pod number and yield per plant.

2.4 Statistical analysis WPS Office software was utilized for various analytical processes, including data collation, fuzzy comprehensive evaluation, grey correlation method comprehensive evaluation, entropy weight-TOPSIS comprehensive evaluation, and comprehensive index method comprehensive evaluation. The procedures for the fuzzy comprehensive evaluation and grey correlation method comprehensive evaluation were based on the methodologies outlined by Chen Hailing *et al.*[11]. The entropy weight-TOPSIS comprehensive evaluation followed the operational steps established by Geng Zhiguang *et al.*[12], while the comprehensive index method comprehensive evaluation was conducted in accordance with the guidelines provided by Chen Chanyou *et al.*[7]. Duncan's significant difference analysis, cluster analysis, and comprehensive evaluation of common factors were conducted utilizing SPSS version 19.0. In the cluster analysis, systematic clustering was employed, with square Euclidean distance as the measure of cluster distance, and the intergroup linkage method was applied for clustering. The comprehensive evaluation based on common factors adhered to the procedural steps established by Jiang Wan *et al.*[14].

3 Results and analysis

3.1 Comparison of key phenological periods As illustrated in Fig. 1, all varieties were sown on July 27. Following uniform transplanting on August 3, seven varieties reached the branching stage by August 19, marking the earliest occurrence. In contrast, the C26 variety was the last to attain the branching stage, achieving this milestone on August 30, which represents a delay of 11 d compared to the earliest varieties. In relation to the first flowering date and flowering stage, a total of 16 varieties exhibited the earliest first flowering date of August 30. Among these, varieties C20, C30, C34, C38, C42, and C45 demonstrated the earliest flowering on August 31. Conversely, the latest variety, C2, first flowered on September 9 and reached the flowering stage on September 12, resulting in a difference of 10 and 12 d, respectively, from the earliest varieties. In relation to maturity and growth duration, C8 and C33 exhibited the shortest periods, commencing on September 12 and lasting for 47 d. In contrast, C9 had the longest duration, beginning on September 24 and extending for 59 d, resulting in a difference of 12 d.

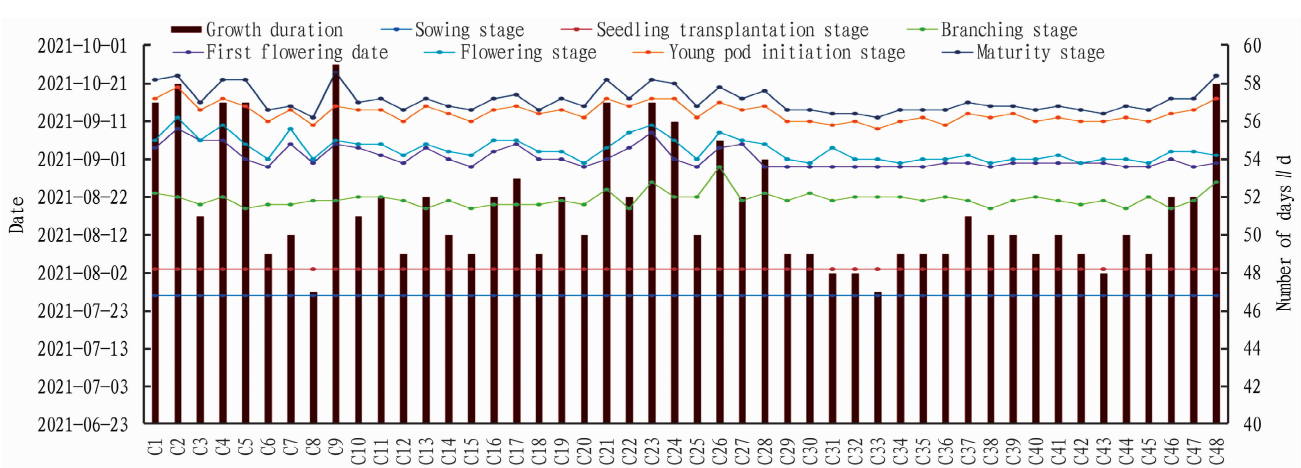

Fig. 1 Duration of key phenological periods

3.2 Comparison of agronomic traits and yield As illustrated in Table 1, the predominant majority of the varieties exhibited purple flowers accompanied by green stems and young pods that were either green or dark green, characterized by slightly convex pod surfaces. Regarding the initial flower nodes, nodes 1 to 9 were observed, with the majority of the varieties flowering at node 4, while a smaller subset flowered at node 1. The analysis of branch quantity per plant revealed a maximum of three branches per plant, a minimum of one branch per plant, with the majority of varieties exhibiting between one to two branches per plant. In regard to yield traits, the majority of the evaluated varieties exhibited the following characteristics, with a 95% confidence interval: number of pods (13.5 – 15.7 pods/plant), pod length (68.8 – 73.2 cm), pod thickness (9.2 – 9.6 mm), weight per pod (27.1 – 31.1 g), and yield per plant (379 – 418.5 g).

Table 1 Statistics on agronomic and yield traits of 48 long cowpea varieties

Quantitative trait	Mean	Standard deviation	95% Confidence interval		Minimum value	Maximum value
			Lower limit	Upper limit		
Flower color	2	0	2	2	1	2
Stem color	1	0	1	1	1	2
Green pod	3	1	3	4	1	7
Pod surface	2	1	2	2	1	3
Initial flower node	4	2	3	4	1	9
Number of branches per plant	1.5	0.5	1.4	1.7	1	3
Pod length//cm	71.0	7.5	68.8	73.2	54.3	90.3
Pod thickness//mm	9.4	0.7	9.2	9.6	8.3	10.8
Weight per pod//g	29.1	6.8	27.1	31.1	13.9	45.9
Number of pods per plant	14.6	3.8	13.5	15.7	6.7	22.3
Yield per plant//g	398.7	68.0	379.0	418.5	297.5	596.2

3.3 Cluster analysis As illustrated in Fig. 2, the 48 varieties exhibited significant differences, and all varieties can be classified into eight categories based on a square Euclidean distance of 14. The group I comprised C22, C27, C16, C17, C3, C7, and C10, which were characterized as white cowpeas exhibiting moderate growth duration concentrated around 50 to 52 d. These varieties generally displayed a higher position of initial flower nodes and flatter pod surfaces; however, there were significant variations in pod length and yield per plant. Group II comprised the following varieties: C29, C42, C33, C44, C34, C25, C28, C46, C47, and C31. These varieties exhibited a pod length exceeding 70 cm and a pod thickness greater than 9.7 mm, categorizing them within the long-pod, strong-pod type. Group III comprised the following varieties: C18, C38, C20, C15, C40, C36, C45, C39, C30, C12, C43, C8, and C13. This group exhibited a relatively short growth duration of approximately 49 d, a high number of pods per plant, and superior yield characteristics. These varieties were classified as early-maturing and high-yielding, making them particularly suitable for autumn cultivation in Hunan. Group IV comprised C5, C24, C21, C48, C26, C35, C37, C19, C32, C6, and C2. This group exhibited an extended growth duration, a low number of pods, and an average yield, while the remaining traits were characterized as intermediate. Group V exclusively comprised C14, characterized by white flowers, a greater number of pods per plant, and a higher overall yield. In contrast, Group VI was solely represented by C41, which exhibited white flowers, shorter pod lengths averaging 56.7 cm, a light single plant weight of 13.9 g, and a lower yield. Group VII comprised C4, C23, and C9, all of which exhibited a relatively extended growth duration ranging from 57 to 59 d, and were classified as mottled cowpeas. In contrast, Group VIII included C1 and C11, both of which were identified as red cowpeas characterized by a slightly flatter pod surface and a greater number of branches, while the remaining traits were found to be intermediate. Clustering is an unsupervised classification technique that organizes various varieties into distinct class clusters based on their features[15]. This method possesses a degree of objectivity and can serve as a reference for comparing comprehensive evaluation methods.

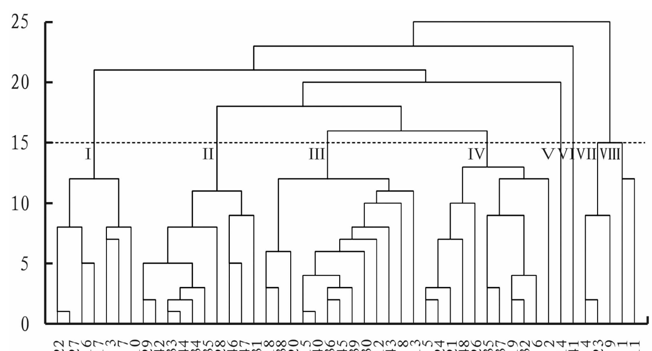

Fig. 2 Cluster pedigree diagram of 48 long cowpea varieties

3.4 Evaluation of common factor method As illustrated in Table 2, the variety C42 achieved a score of 1.525 4, securing the first rank. The remaining varieties that ranked within the top ten, in descending order, were C29, C20, C47, C25, C33, C38, C18, C15, and C28. In addition, C23 received a score of –1.083 6, placing it in the 48th position. The varieties ranked from 39th to 47th were C26, C4, C16, C43, C27, C48, C21, C22, and C41. A comparison of the cluster pedigree diagram revealed that the top ten varieties were predominantly located within groups II and III. In contrast, the bottom ten varieties were primarily distributed across groups I, III, IV, VI, and VII. While the overall results exhibited a degree of consistency, notable discrepancies existed, particularly the overlap observed between the top ten and bottom ten varieties within group III.

Table 2 Scores of the common factor method

No.	F	Rank	No.	F	Rank	No.	F	Rank	No.	F	Rank
C1	-0.258 3	32	C13	-0.309 4	34	C25	0.774 0	5	C37	0.034 7	18
C2	-0.366 5	35	C14	0.514 0	12	C26	-0.552 8	39	C38	0.697 9	7
C3	0.051 5	17	C15	0.614 9	9	C27	-0.667 5	43	C39	-0.060 2	24
C4	-0.575 0	40	C16	-0.605 1	41	C28	0.544 6	10	C40	0.474 4	13
C5	-0.296 4	33	C17	-0.544 1	38	C29	1.314 2	2	C41	-1.047 1	47
C6	0.343 9	15	C18	0.655 8	8	C30	0.024 9	19	C42	1.525 4	1
C7	-0.108 3	27	C19	-0.093 0	25	C31	-0.038 1	22	C43	-0.632 4	42
C8	-0.014 1	20	C20	1.234 2	3	C32	-0.133 5	28	C44	0.376 1	14
C9	-0.467 3	36	C21	-0.818 4	45	C33	0.730 6	6	C45	-0.034 2	21
C10	-0.153 1	29	C22	-0.910 8	46	C34	0.522 3	11	C46	0.216 6	16
C11	-0.097 4	26	C23	-1.083 6	48	C35	-0.168 8	30	C47	0.917 9	4
C12	-0.504 4	37	C24	-0.247 5	31	C36	-0.060 2	23	C48	-0.720 4	44

3.5 Evaluation of entropy weight -TOPSIS method As illustrated in Table 3, the proximity to the ideal solution, represented by a value of 1, indicated that C3 achieved a C_i value of 0.973 11, making it the closest to the ideal solution and consequently ranked first. In contrast, C28 recorded a C_i value of 0.070 28, positioning it as the furthest from the ideal solution and ranked 48th. A comparison of the cluster pedigree diagram indicated that the top ten varieties were predominantly located within groups I, III, IV, and VIII. In contrast, the bottom ten varieties were primarily found in groups II and IV. Notably, there was no overlap between the groups of the top ten varieties and those of the bottom ten varieties.

Table 3 Scores of the entropy weight-TOPSIS method

No.	C_i	Rank	No.	C_i	Rank	No.	C_i	Rank	No.	C_i	Rank
C1	0.870 69	10	C13	0.946 62	5	C25	0.128 04	41	C37	0.513 28	13
C2	0.510 87	19	C14	0.493 53	37	C26	0.143 89	39	C38	0.499 73	35
C3	0.973 11	1	C15	0.512 65	17	C27	0.502 42	30	C39	0.512 79	15
C4	0.501 58	31	C16	0.510 84	20	C28	0.070 28	48	C40	0.512 66	16
C5	0.503 90	29	C17	0.510 22	21	C29	0.106 62	45	C41	0.513 53	12
C6	0.106 59	46	C18	0.497 63	36	C30	0.501 53	32	C42	0.109 66	44
C7	0.935 49	7	C19	0.500 41	33	C31	0.511 76	18	C43	0.512 89	14
C8	0.922 89	8	C20	0.506 35	27	C32	0.499 82	34	C44	0.139 01	40
C9	0.486 53	38	C21	0.507 75	25	C33	0.126 41	42	C45	0.513 76	11
C10	0.940 92	6	C22	0.506 68	26	C34	0.125 43	43	C46	0.504 73	28
C11	0.901 23	9	C23	0.509 25	22	C35	0.966 53	3	C47	0.106 15	47
C12	0.969 43	2	C24	0.508 36	23	C36	0.508 15	24	C48	0.952 24	4

3.6 Evaluation of grey correlation method To obtain the desired result, we should calculate the inverse of the number of growth duration and subsequently multiply this value by 100. Additionally, the inverse of the initial flower node, the number of branches per plant, and the pod surface area should be determined. Finally, the average of these five calculated values should be taken into account to construct the "reference variety" based on the average value obtained. The parameters utilized in this analysis included: growth duration R(2.13 d), initial flower node (1st node), number of branches per plant (1), pod surface area (1), pod length (90.3 cm), pod thickness (10.8 mm), weight per pod (45.9 g), number of pods (22.3), and yield per plant (596.2 g). The weights assigned to each parameter were as follows: 0.08 for growth duration, initial flower node, number of branches per plant, and pod surface area; 0.1 for pod length, pod thickness, weight per pod, and number of pods; and 0.28 for yield per plant. These calculations culminated in the results presented in Table 4. As illustrated in Table 4, the weighted correlation degree for C20 was 0.814 50, positioning it in the first rank, while the correlation degree for C9 was 0.530 78, placing it in the 48th rank. In comparison to the cluster pedigree diagram, the top ten varieties, as ranked by the grey correlation method comprehensive evaluation, were predominantly located within groups I, II, III, and V. Conversely, the bottom ten varieties were primarily found in groups I, IV, and VII. Notably, the intersection between the top ten and bottom ten varieties occurred within group I.

3.7 Evaluation of fuzzy evaluation method As illustrated in Table 5, the weighted fuzzy evaluation indicated that C20 achieved a score of 0.789 32, securing the first rank, whereas C9 obtained a score of 0.250 46, placing it in the 48th position. In comparison to the cluster pedigree diagram, the top ten varieties were predominantly grouped within groups I, II, III, and V. Conversely, the bottom ten varieties were primarily located in groups I, II, IV, and VII. Notably, both the top ten and bottom ten varieties intersected within groups I and II.

Table 4 Scores of grey correlation method

No.	Weighted correlation degree	Rank	No.	Weighted correlation degree	Rank	No.	Weighted correlation degree	Rank	No.	Weighted correlation degree	Rank
C1	0.631 66	22	C13	0.634 76	20	C25	0.686 17	8	C37	0.627 83	27
C2	0.608 51	29	C14	0.694 34	5	C26	0.570 80	40	C38	0.641 58	16
C3	0.719 69	2	C15	0.677 82	12	C27	0.569 43	41	C39	0.636 02	18
C4	0.541 86	47	C16	0.633 41	21	C28	0.577 90	38	C40	0.687 73	6
C5	0.573 89	39	C17	0.593 86	35	C29	0.687 49	7	C41	0.613 93	28
C6	0.582 22	37	C18	0.680 74	10	C30	0.606 15	32	C42	0.709 40	4
C7	0.628 94	25	C19	0.554 66	45	C31	0.608 09	30	C43	0.635 90	19
C8	0.671 44	13	C20	0.814 50	1	C32	0.555 88	44	C44	0.631 11	23
C9	0.530 78	48	C21	0.555 99	43	C33	0.637 50	17	C45	0.679 94	11
C10	0.710 84	3	C22	0.567 28	42	C34	0.601 82	33	C46	0.587 40	36
C11	0.607 63	31	C23	0.551 38	46	C35	0.630 13	24	C47	0.644 49	15
C12	0.681 91	9	C24	0.650 44	14	C36	0.601 00	34	C48	0.628 92	26

Table 5 Scores of the fuzzy evaluation method

No.	Weighted fuzzy evaluation	Rank	No.	Weighted fuzzy evaluation	Rank	No.	Weighted fuzzy evaluation	Rank	No.	Weighted fuzzy evaluation	Rank
C1	0.433 17	31	C13	0.478 50	24	C25	0.571 29	13	C37	0.494 26	21
C2	0.417 76	33	C14	0.611 98	8	C26	0.294 27	46	C38	0.590 68	11
C3	0.643 51	4	C15	0.639 02	6	C27	0.373 00	39	C39	0.536 60	16
C4	0.308 41	45	C16	0.476 48	25	C28	0.366 41	40	C40	0.665 01	2
C5	0.409 25	34	C17	0.406 70	35	C29	0.643 04	5	C41	0.400 06	37
C6	0.406 64	36	C18	0.636 21	7	C30	0.497 20	19	C42	0.658 06	3
C7	0.476 06	26	C19	0.366 14	41	C31	0.451 39	29	C43	0.468 95	27
C8	0.577 63	12	C20	0.789 32	1	C32	0.362 46	42	C44	0.508 98	18
C9	0.250 46	48	C21	0.336 07	44	C33	0.545 25	15	C45	0.594 16	10
C10	0.611 89	9	C22	0.345 34	43	C34	0.449 74	30	C46	0.455 54	28
C11	0.423 09	32	C23	0.273 46	47	C35	0.496 55	20	C47	0.557 25	14
C12	0.515 47	17	C24	0.491 47	23	C36	0.493 93	22	C48	0.396 40	38

3.8 Comprehensive evaluation of comprehensive index method The findings from the comprehensive evaluation utilizing the entropy weight-TOPSIS method exhibited inconsistencies with the superior and inferior groups delineated in the cluster pedigree diagram. In contrast, the results obtained from the common factor method, grey correlation method, and fuzzy subordinate function were largely congruent. These consistent results may serve as a foundation for the comprehensive evaluation of cowpea variety resources. Utilizing the comprehensive index method, a composite score was generated based on the rankings of three varieties (Table 6). The top ten ranked varieties, in order, were C20, C42, C29, C40, C3, C14, C18, C25, C15, and C47. These ten varieties exhibited several advantageous characteristics, including shorter growth duration, lower position of initial flower nodes, fewer branching, predominantly green young pods, elongated and thicker pods, a higher number of pods per plant, and increased yields. They were primarily clustered within groups II, III, and V of the pedigree diagram, with a minor representation in group I. Furthermore, these varieties demonstrated superior performance during the autumn cultivation in Hunan Province, indicating their potential for promotion. The varieties ranked from 39th to 48th, in order, were C19, C41, C32, C27, C6, C22, C4, C9, C21, and C23. The majority of these ten varieties exhibited a higher position of initial flower nodes, shorter pod lengths, a reduced number of pods, and lower yields. They were predominantly categorized within groups IV, VI, and VII, with a limited number found in group I. Further observation of their performance during autumn cultivation in Hunan is warranted.

Table 6 Comprehensive evaluation of long cowpea varieties

No.	Grey correlation method	Fuzzy evaluation method	Common factor method	Comprehensive index	Rank	No.	Grey correlation method	Fuzzy evaluation method	Common factor method	Comprehensive index	Rank
C1	27	18	17	20.67	29	C25	41	36	44	40.33	8
C2	20	16	14	16.67	35	C26	9	3	10	7.33	43
C3	47	45	32	41.33	5	C27	8	10	6	8.00	42

(To be continued)

(Continued)

No.	Grey correlation method	Fuzzy evaluation method	Common factor method	Comprehensive index	Rank	No.	Grey correlation method	Fuzzy evaluation method	Common factor method	Comprehensive index	Rank
C4	2	4	9	5.00	45	C28	11	9	39	19.67	32
C5	10	15	16	13.67	36	C29	42	44	47	44.33	3
C6	12	13	34	19.67	31	C30	17	30	30	25.67	21
C7	24	23	22	23.00	24	C31	19	20	27	22.00	28
C8	36	37	29	34.00	15	C32	5	7	21	11.00	41
C9	1	1	13	5.00	46	C33	32	34	43	36.33	12
C10	46	40	20	35.33	13	C34	16	19	38	24.33	22
C11	18	17	23	19.33	34	C35	25	29	19	24.33	23
C12	40	32	12	28.00	18	C36	15	27	26	22.67	26
C13	29	25	15	23.00	25	C37	22	28	31	27.00	19
C14	44	41	37	40.67	6	C38	33	38	42	37.67	11
C15	37	43	40	40.00	9	C39	31	33	25	29.67	17
C16	28	24	8	20.00	30	C40	43	47	36	42.00	4
C17	14	14	11	13.00	37	C41	21	12	2	11.67	40
C18	39	42	41	40.67	7	C42	45	46	48	46.33	2
C19	4	8	24	12.00	39	C43	30	22	7	19.67	33
C20	48	48	46	47.33	1	C44	26	31	35	30.67	16
C21	6	5	4	5.00	47	C45	38	39	28	35.00	14
C22	7	6	3	5.33	44	C46	13	21	33	22.33	27
C23	3	2	1	2.00	48	C47	34	35	45	38.00	10
C24	35	26	18	26.33	20	C48	23	11	5	13.00	38

4 Discussion and conclusions

The majority of the varieties evaluated in this trial exhibited the following characteristics, with a 95% confidence interval: growth duration (51 – 52 d), green stems, purple initial flowers located below the fourth node, branches (1.4 – 1.7 branches/plant), green young pods, slightly convex or slightly flat pod surface, pods (13.5 – 15.7 pods/plant), pod length (68.8 – 73.2 cm), pod thickness (9.2 – 9.6 mm), weight per pod (27.1 – 31.1 g), yield per plant (around 379 – 418 g). In comparison to spring cowpea cultivated in Hunan Province[1], the growth duration was reduced by more than 10 d. Additionally, the position of the initial flower node was lower, the number of branches decreased by approximately one, and both pod length and weight per pod increased. However, the total number of pods was diminished, resulting in a lower yield per plant compared to that observed in spring. In comparison to autumn cowpea cultivated in Hubei[16], the growth duration exhibited similarities; however, the position of the initial flower node was positioned lower, and the yield was marginally reduced. The growth duration was delayed by approximately 5 d in comparison to autumn cowpea in Turpan, Xinjiang[17], while it was advanced by approximately 10 d relative to autumn cowpea in Guizhou[18]. This variation may be attributed to the differences in light hours and temperature during the autumn season in Hunan[19].

Cluster analysis is an efficient method for classifying and categorizing complex and diverse varieties based on their characteristics, serving as a valuable tool for understanding the differences and relationships among these varieties[20]. According to the cluster pedigree diagram, all varieties can be categorized into eight distinct groups. Group I comprises white cowpea, while group II is characterized by long-pod and strong-pod types. Group III includes varieties that exhibit early maturity and high yield potential. Group IV is noted for its longer growth duration and a lower number of pods. Group V represents high-yielding varieties, whereas group VI encompasses low-yielding types. Group VII is identified as mottled cowpea, and group VIII consists of red cowpea. An analysis of the performance of each group during the autumn season in the region reveals that groups II, III, and V are classified as dominant groups. In contrast, groups I and VIII are categorized as intermediate groups, while groups IV, VI, and VII are identified as inferior groups during this period.

The common factor comprehensive evaluation, entropy weight-TOPSIS method, grey correlation method, and fuzzy evaluation method are among the frequently employed techniques for assessing the adaptability of varieties (or classes)[21]. The comprehensive evaluation results obtained through the entropy weight-TOPSIS method exhibit a lack of consistency with the superior and inferior groups as depicted in the cluster pedigree diagram. This discrepancy arises from the fundamental principle of the entropy weight-TOPSIS method, which posits that a greater degree of dispersion corresponds to a higher weight[22]. In this study, the significant degree of dispersion observed in growth duration, the first flower node, the number of branches per plant, and pod surface, contrasted with the minimal degree of dispersion in pod length, pod thickness, weight per pod, number of pods, and yield per plant. This disparity contributed to the distortion of varietal scores. Furthermore, it is widely acknowledged in the literature that cowpea yield and its components should be weighted higher than other indicators[10-11,23]. The common factor method, grey correlation method, and fuzzy subordinate function are relatively more appropriate for the comprehensive evaluation of cowpea. The results obtained from these three evaluation methods are largely consistent with one another, aligning with findings from other researchers who have compared these evaluation techniques[11,24]. Consequently, all three methods can serve as a foundation for the comprehensive assessment of cowpea variety resources.

Through a comparative analysis of several comprehensive evaluation methods, it was determined that the common factor comprehensive evaluation, grey correlation method, and fuzzy evaluation method were all appropriate for application in the screening of cowpea varieties. The evaluation outcomes were found to be largely consistent with the results obtained from the cluster pedigree diagram. Building upon these three evaluation methods and utilizing the comprehensive index method, a total of ten varieties, C20, C42, C29, C40, C3, C14, C18, C25, C15, and C47, were identified as exhibiting superior performance in autumn cultivation. The ten varieties under consideration exhibit several advantageous characteristics, including reduced growth duration, a lower position of initial flower nodes, a decreased number of branches, predominantly green young pods, elongated pod strips, thicker pod structures, an increased number of pods per plant, and higher overall yields. These attributes render them particularly valuable for widespread cultivation. In contrast, the remaining varieties require further observation to assess their potential.

References

[1] ZHANG ZW, SUN XC, ZHAN YH, *et al.* Agronomic characters of cowpea germplasm resources: Correlation, principal component and cluster analysis[J]. Chinese Agricultural Science Bulletin, 2017, 33(36): 63-71. (in Chinese).

[2] ODESEYE, AO, IJAGBONE I, ALADELE S, *et al.* Characteristics and molecular identification of differentially expressed genes in some cowpea [*Vigna unguiculata* (L.) Walp.] accessions[J]. Journal of Agriculture and Food Research, 2022, 10(92): 100426.

[3] KUMARI G, SHANMUGAVADIVEL PS, LAVANYA GR, *et al.* Association mapping for important agronomic traits in wild and cultivated *Vigna* species using cross-species and cross-genera simple sequence repeat markers[J]. Frontiers in Genetics, 2022, 3(13): 1000440.

[4] PADHI SR, BARTWAL A, JOHN R, *et al.* Evaluation and multivariate analysis of cowpea [*Vigna unguiculata* (L.) Walp] germplasm for selected nutrients—mining for nutri-dense accessions[J]. Frontiers in Sustainable Food Systems, 2022. DOI: 10.3389/fsufs.2022.888041.

[5] ZHANG HM, XU WJ, CHEN HT, *et al.* Identification of salt tolerance of yardlong bean germplasm accessions[J]. Acta Agriculturae Boreali-Sinica, 2021, 36(S1): 39-52. (in Chinese).

[6] CHEN Q, ZHANG ZM, GUO YY, *et al.* Character evaluation and variety screening of different *Vigna sesquipedalis* varieties in coastal areas of Guangxi[J]. Seed, 2020, 39(12): 146-150, 9. (in Chinese).

[7] CHEN CY, HU JP, LIU W, *et al.* Estimates of genetic parameters for fresh pod quality characters in asparagus bean [*Vigna unguiculata* (L.) ssp. *sesquipedalis* Verd.][J]. Journal of Jianghan University: Natural Science Edition, 2007(3): 64-68. (in Chinese).

[8] HUANG HT, HU J, XU DM, *et al.* Comprehensive identification and evaluation of cowpea cold tolerance at adult stage based on principal component analysis and fuzzy evaluation[J]. Southwest China Journal of Agricultural Sciences, 2018, 31(12): 2537-2547. (in Chinese).

[9] HUANG WK, FU QW, GUO JY, *et al.* Cold tolerance comprehensive evaluation of 25 long-podded cowpea cultivars at germination stage[J]. Journal of Changjiang Vegetables, 2023(6): 40-45. (in Chinese).

[10] LIU Q, HUANG WK, FU QW, *et al.* Study on 99 long podded cowpea germplasm resources and correlation analysis of their resistance to fusarium wilt[J]. Seed, 2022, 41(4): 70-80, 85. (in Chinese).

[11] CHEN HL, GUO YZ, HUANG Q, *et al.* Comparison of two comprehensive evaluation methods for introduced asparagus bean varieties[J]. Southeast Horticulture, 2021, 9(1): 34-40. (in Chinese).

[12] GENG ZG, CAO H, ZHANG JX, *et al.* Evaluation of comprehensive production performance of different alfalfa varieties based on entropy weight method TOPSIS[J]. Feed Research, 2024, 47(1): 114-119. (in Chinese).

[13] WANG PZ, LI XX. Specification for the description of cowpea germplasm resources and data standards [S]. Beijing: China Agricultural Press, 2006. (in Chinese).

[14] JIANG W, ZHANG ZW, HUANG L, *et al.* Evaluation and screening of different dwarf cowpea (*Vigna sinensis* Endb) varieties in autumn in Hunan province[J]. China Cucurbits and Vegetables, 2024, 37(5): 142-150. (in Chinese).

[15] SUN JG, LIU J, ZHAO LY. Clustering algorithms research[J]. Journal of Software, 2008(1): 48-61. (in Chinese).

[16] YAN L, GE CJ, XU LR. Adaptability of 3 cowpea varieties planted in autumn[J]. Chinese Journal of Tropical Agriculture, 2014, 34(2): 18-20, 26. (in Chinese).

[17] LIU ZG. Comparison of cowpea in facility in autumn delayed[J]. Journal of Anhui Agricultural Sciences, 2015, 43(20): 66-67, 70. (in Chinese).

[18] WANG TW, WEN LH, XIE WX, *et al.* A comparison test of autumn cowpea in Bijie city[J]. Seed, 2005(11): 78-80. (in Chinese).

[19] ZHANG ZW. Practical techniques for efficient cowpea cultivation [M]. Beijing: China Agricultural Publishing House, 2020: 9-10. (in Chinese).

[20] SRIDHAR V, SRIRAM A, RAO SS, *et al.* Evaluation of greengram (*Vigna radiata* L.) germplasm for seed yield and yield related traits through cluster analysis[J]. International Journal of Environment and Climate Change, 2022: 3563-3574.

[21] ZHANG YJ. A comparative study of systematic evaluation methods [D]. Nanjing: Hohai University, 2005. (in Chinese).

[22] CHUNHO C. A hybrid multi-criteria decision-making approach based on ANP-Entropy TOPSIS for building materials supplier selection[J]. Entropy, 2021, 23(12): 1597.

[23] FU QW, HUANG WK, CHEN JJ, *et al.* Comprehensive evaluation of 37 long-podded cowpea germplasm resources based on grey relational analysis and principal component and cluster analysis[J]. Guangdong Agricultural Sciences, 2022, 49(2): 24-36. (in Chinese).

[24] PANG JP, CHEN YL, LIU P, *et al.* A comparative study on priority design of beam of vertical grinding machine: Based on fuzzy comprehensive evaluation method, TOPSIS and grey correlation method[J]. Chinese Journal of Engineering Design, 2013, 20(2): 89-96. (in Chinese).