



Comparative assessment of yield potentials of improved cowpea breeding lines using performance index and ranking methods

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Abstract

Identification of the best variety from a variety trial is often done using the least significant difference (LSD), Duncan's multiple range test (DMRT) and stability analysis methods. However, these methods are unable to discriminate among a smaller group of varieties which are not statistically significantly different from each other. Therefore, there is a need for another method which can further discriminate among these small groups of varieties. This study was undertaken to assess the efficacy of the performance index (PI) and rank total (RT) methods in identifying the best variety from a variety trial. Eighteen cowpea breeding lines including a local check were grown for two years in three environments representing the major cowpea growing zone of West Africa to assess their grain yield potential. The yield data were analyzed and variety means were compared using different methods. The PI revealed that IT98K-398-14 was the best with a PI index of 88% compared to 59% for IT98K-412-13 and IT98K-506-1 with 35%, and RT method showed IT98K-412-13 with RT of 34, IT98K-398-14 with RT of 35 and IT98K-506-1 with RT 42 as the most promising cowpea varieties while the stability analysis indicated IT98K-506-1 with a b value of 1.03 as the most stable variety in the test environments with a mean yield of 1491 kg ha⁻¹ which is above overall mean yield of 1340 kg ha⁻¹. The PI is a simple and easy approach to classify varieties especially when the number of varieties and test environments is large. The RT method is also an alternative approach devoid of much calculation and will therefore be a valuable tool for plant breeders especially when quick decisions are to be made on the selections of varieties. All three methods identified the same three varieties as the best varieties.

Key words: Cowpea breeding lines, performance index, ranking total, variety trial.

Introduction

Cowpea [*Vigna unguiculata* (L.) Walp.] originated in Africa and is an integral part of traditional cropping systems throughout the continent, particularly in the semi-arid regions of West Africa⁹. It provides a major source of protein in human diets, cash for the farmers and fodder for livestock. Cowpea is of major importance to the livelihood of millions of people in less developed countries of the tropics⁸.

Its production areas spread throughout the tropical world since it fits into diverse production systems, rain fed and irrigated systems and in areas with poor soils and limited rainfall. Cowpea can be grown on a wide variety of soils ranging from predominantly sandy to predominantly clay with little organic matter, and for acidic to basic soil (pH 4.5 to 9.0)⁷. The actual farm yields obtained in the West African sub-region are lower (0.025-0.100 t/ha), due to severe attacks from an extensive pest complex⁶ and lack of inputs. The International Institute of Tropical Agriculture (IITA) has world mandate for the development of improved cowpea varieties. IITA in collaboration with several national institutes has developed a number of varieties and distributes improved lines to 60 different countries⁸. A number of these countries have released some of these varieties while others have used some in breeding programs as sources of important genetic materials.

The major objective of any crop improvement program is the development of superior crop varieties and their release for

commercial production. The cowpea varieties developed by IITA are normally tested in diverse environments before they are distributed to national programs for further testing and release to farmers as new varieties for mass cultivation. These tests are conducted primarily to ascertain the genetic potentials of the improved varieties for important traits, especially yield, and secondly, to identify which variety is best adapted to which environment. Usually, the identification of a better performing variety with respect to a particular trait is based on the assessment of differences among the variety means for the trait under investigation and their statistical significance using LSD and DMRT as well as the use of regression models to determine the yield superiority and its stability^{1,3,5}.

Significance tests are used to distinguish the performance of varieties. In the process, the variety means are usually arranged in a descending order i.e. from the highest to the lowest. Any pair of means that do not differ significantly between themselves are either assigned the same letter of the alphabet or underscored by the same line. Conversely, significantly different means are assigned different alphabets or underscored by different lines. Although, this is a universally established procedure, it tends to be cumbersome especially if the number of varieties increases, thereby making visual discrimination difficult². The aim of this study was to compare an alternative and simple method called the performance index (PI) approach² and rank total (RT) with

other methods in assessing the grain potential of new improved cowpea varieties.

Materials and Methods

The materials used in this study consisted of 17 advanced cowpea breeding lines developed at the IITA, Kano Station, and a local check, Danila. The entries were evaluated in 2000 and 2001 at three locations: Minjibir (Lat. 12°11'N; Log. 8°37'E), Samaru (Lat. 11°11'N; Log. 7°38'E) and Toumnia (Lat. 13°58'N; Log. 9°01'E) representing the three major cowpea growing zones. Samaru is in the northern Guinea savanna zone of Nigeria, where rain starts in April, reaches its peak in July/August and ends in October with long-term average of 1014 mm. Minjibir is in the Sudan savanna zone of Nigeria, where the rain typically starts in May, reaches its peak in August and ends in October with long-term average of about 800 mm. Toumnia is in the Sahel savanna zone of Niger Republic where rain starts in June and ends in September with long-term average of about 350 mm.

The experimental design used was a randomized complete block design (RCBD) with 3 replications. Each plot consisted of 4 ridges, 4 m long spaced at 0.75 m apart in each location. The between plant spacing was 0.2 m and 3 seeds were sown, which were later thinned down to 2 plants per hill at 2 weeks after sowing (WAS). Compound fertilizer (NPK 15:15:15) was broadcasted at the rate of 100 kg ha⁻¹ at land preparation. The plots were kept weed-free by hoe weeding at 3, 6 and 9 WAS. Insect pests were controlled by Sherpa Plus (250 ml cypermethrin + 30 g/l dimethoate) at the rate of 1 litre in 200 litres of water using a knapsack sprayer at the pre-flowering, flowering and podding stages of the crop. At maturity which is when about 90% of the pods have dried, pods from the 2 central rows were harvested and sun-dried. The dried pods were later manually threshed and the resulting seed weighed and recorded as seed per plot. The values were extrapolated to per hectare basis and analysis of variance performed based on the procedure described by Steel and Torrie¹⁰.

To compute the cultivar PI, the mean values of grain yield for the varieties were arranged in descending order of magnitude

based on year, location and year*location. The LSD value obtained from the analysis of variance for each year, location and year*location were subtracted from the first mean. The result obtained was compared to the remaining variety means. The number of variety means that were less than this value indicated the number of varieties that were significantly inferior to the first variety mean. This number was designated as 'm'. The procedure was repeated thereafter for the second and subsequent variety means. Eventually, a series of 'm' values is obtained for each year, location and year*location. The individual 'm' values were used to calculate the cultivar performance index (P) as defined by Fasoulas²:

$$P = \frac{m}{n-1} \times 100$$

where m = the number of significantly inferior varieties, n = number of varieties tested.

In computing the RT, the grain yields of the varieties in each of the 6 environments were ranked from 1 to 18 and summed to get a cumulative total with the best variety giving the lowest value. The number of times each variety took positions 1 to 3 was also tabulated. The overall mean and the DMRT for each variety were determined. The variety means were regressed against location means and the regression values (b) were given for each of the varieties to indicate their stability.

Results and Discussion

The performance of the varieties tested in 2000 is presented in Table 1. At Minjibir, IT97K-556-4 with a performance index of 71 was the highest yielding line. The PI indicated that the variety significantly out yielded 71% of all other varieties tested in this location. It was also observed that 3 lines (IT97K-312-13, IT97K-398-14 and IT97K-837-8) all had a PI of 24; indicating that their yields were not significantly different from each other, but each one of them was significantly higher yielding than 24% of all other lines tested in this location. At Samaru, IT97K-398-14 was the best performing line out yielding significantly 59% of the lines tested. Two sets of 3 breeding lines each had performance indices of 35 and 41, respectively. This indicated that there was no significant difference among the 3 lines with the same index value, but each out yielded 35 and 41% of the test lines respectively. IT98K-205-8 was the best performing line at Toumnia having the highest PI score of 76 for the year. Three lines recorded an index score of 47; showing that their performances were not significantly different but each one of them significantly out yielded 47% of the rest varieties in this location. Overall, almost half of the breeding lines tested including the local check had PI of zero at Minjibir and Samaru in 2000. This revealed the inability of any of these lines to out yield significantly even one line at these locations. At Toumnia, however, only 5 of the tested varieties excluding the local check failed to out yield significantly even a single variety.

Table 1. Performance of cowpea varieties based on mean grain yield (kg ha⁻¹), the number of significantly inferior varieties (m) and performance index (PI), in 2000.

Location Variety	Minjibir			Samaru			Toumnia		
	Mean yield	m	PI	Mean yield	m	PI	Mean yield	m	PI
IT97K-556-4	2804	12	71	1321	0	0	432	0	0
IT98K-277-1	2384	5	29	1045	0	0	531	2	12
IT98K-412-13	2331	4	24	1831	7	41	236	0	0
IT97K-398-14	2318	4	24	2302	10	59	716	3	18
IT97K-837-8	2279	4	24	786	0	0	723	4	24
IT98K-506-1	2241	3	18	1777	7	41	814	6	35
IT97K-608-14	2187	2	12	1243	0	0	778	5	29
IT98K-628	2112	1	6	867	0	0	845	7	41
IT98K-321-7	2077	1	6	1687	5	29	465	0	0
IT97K-1101-5	1950	0	0	1094	0	0	867	8	47
IT98K-131-2	1902	0	0	905	0	0	324	0	0
Danila	1877	0	0	788	0	0	580	2	12
IT98K-422-2-1	1840	0	0	1758	6	35	512	1	6
IT98K-1137-3	1778	0	0	1779	7	41	222	0	0
IT97K-1034-94	1658	0	0	1723	6	35	958	8	47
IT98K-205-8	1587	0	0	741	0	0	1119	13	76
IT97K-1034-92	1526	0	0	1345	0	0	816	7	41
IT97K-819-118	1448	0	0	1757	6	35	976	8	47

It was noted that the best performing line at Minjibir (IT97K-556-4) had zero PI values at Samaru and Toumnia. Incidentally, the highest yielding and best performing breeding line at Toumnia (IT98K-398-14) scored an index value of zero at Minjibir and Samaru indicating a variety by location interaction.

The lines performance trend in 2001 was different from the year 2000 (Table 2). At Minjibir, IT98K-321-7 was the best performing line with an index score of 53; significantly out yielding 53% of all other varieties. Two varieties (IT98K-412-13 and IT98K-422-2-1) had the same PI values (24); indicating no significant differences between them but out yielded others by 24%. IT98K-412-13 was the best breeding line at Samaru with a PI of 65. IT98K-131-2 and IT97K-819-118 were at par with index scores of 24 each in this location. The most superior performing line at Toumnia in 2001 was IT97K-398-14, which significantly out yielded 65% of all breeding lines tested in this location. Three pairs of different lines and another group of three lines were at par with each other within each group. Generally, the number of varieties with non-significant PI values (0) in 2001 was observed to be higher than those in 2000 with many of them maintaining their positions in both years and locations as well.

The differential responses of these lines in the different years and locations revealed the presence of genotype x environment interactions. The presence of this genotype x environment interactions necessitates the need to develop location-specific cowpea varieties. This is important because cowpea varietal requirements for plant- and seed-type, maturity and consumer needs are extremely diverse from region to region ⁷. Several methods have been applied to study the genotype x environment interactions and further estimate stability parameters and to recommend environmentally specific varieties of many crops ^{1,3,4,11}. The cultivar PI is an alternative and simple approach in this regard.

The combined cowpea variety performance tested across years, locations and year x location is presented in Table 3. Across the 2 years, IT97K-556-4 was the best performing line at Minjibir with a PI score of 47. Two lines (IT98K-412-13 and IT98K-1137-3) were the most superior where each of them out yielded the rest by 71% at Samaru. IT97K-398-14 stood as the best variety at Toumnia. Considering the PI across the 3 locations, it was revealed that IT97K-398-14 was the best line in the year 2000, while in 2001 IT98K-412-13 was the top in performance. Considering the variety performance combined over years and locations, IT97K-398-14 and IT98K-412-13 were the most promising lines. In particular, IT98K-398-14 was evidently more promising as it had encouraging performance across the years, locations as well as in the combined. The value of the PI approach in the rating of varieties across environments lies in its simplicity and ease of computation as well as interpretation especially when the number of varieties and test locations is large.

Table 2. Performance of cowpea varieties based on mean grain yield (kg ha⁻¹), the number of significantly inferior varieties (m) and performance index (PI), 2001.

Variety	Minjibir			Samaru			Toumnia		
	Mean yield	m	PI	Mean yield	m	PI	Mean	m	PI
IT97K-556-4	1439	0	0	1023	0	0	1401	1	6
IT98K-277-1	1284	0	0	1192	0	0	1379	1	6
IT98K-412-13	1767	4	24	1798	11	65	1551	3	18
IT97K-398-14	1630	1	6	903	0	0	2173	11	65
IT97K-837-8	1253	0	0	1073	0	0	1426	2	12
IT98K-506-1	1630	1	6	1314	1	6	1172	0	0
IT97K-608-14	1762	3	18	755	0	0	1665	4	24
IT98K-628	1340	0	0	1078	0	0	728	0	0
IT98K-321-7	2007	9	53	1369	2	12	804	0	0
IT97K-1101-5	1104	0	0	782	0	0	1234	0	0
IT98K-131-2	1368	0	0	1412	4	24	1959	7	41
Danila	1432	0	0	802	0	0	1909	7	41
IT98K-422-2-1	1803	4	24	723	0	0	874	0	0
IT98K-1137-3	1512	0	0	1762	10	59	1233	0	0
IT97K-1034-94	1121	0	0	882	0	0	1567	3	18
IT98K-205-8	1017	0	0	1277	0	0	1019	0	0
IT97K-1034-92	1156	0	0	937	0	0	1625	3	18
IT97K-819-118	1216	0	0	1419	4	24	1674	4	24

Using the RT method, similar results were obtained (Table 4). IT98K-412-13 and IT97K-398-14 with a cumulative total ranking of 34 and 35, respectively and mean ranking of 6 were the best varieties across locations in the two years. Their mean grain yields of 1586 and 1674 kg ha⁻¹, respectively were also the highest yields. IT98K-506-1 with cumulative ranking of 42 and mean of 7 was the third best overall line. IT98K-412-13 had the highest grain yield in 1 of the 6 environments and was second in 1 and third in 2 other environments. IT97K-398-14 was the highest yielder in 2 environments while IT98K-506-1, though in the ranking was the third best line, did not take position 1-3 in any environment. The b values reflected the variations of the varieties from the regression. IT98K-412-13 and IT97K-398-14, though with high mean grain yields, had b values of 1.44 and 1.33 indicating favourable response to better environments but their performances in other environments were poor. However, IT98K-506-1 with b value of 1.03 was a more stable variety than IT98K-412-13 and IT97K-398-14 and with a mean grain yield

Table 3. Rating of different cowpea varieties based on performance index (PI).

Variety	Across 2 years (P _y)			Across 3 locations (P _l)		Across 2 years & 3 locations (P _{yl})
	Minjibir	Samaru	Toumnia	2000	2001	
IT97K-556-4	47	0	0	18	0	12
IT97K-398-14	29	41	65	88	29	88
IT98K-412-13	29	71	0	18	53	59
IT97K-608-14	29	0	24	12	12	6
IT98K-321-7	29	35	0	12	12	12
IT98K-506-1	24	35	6	41	0	35
IT98K-277-1	24	0	0	0	0	0
IT98K-422-2-1	18	0	0	6	0	0
IT97K-837-8	6	0	12	0	0	0
IT97K-1034-94	0	6	29	12	0	0
IT97K-819-118	0	41	41	12	12	18
IT98K-628	0	0	0	0	0	0
IT97K-1101-5	0	0	12	0	0	0
IT98K-131-2	0	0	24	0	35	0
Danila	0	0	29	0	6	0
IT98K-1137-3	0	71	0	0	24	6
IT98K-205-8	0	0	12	0	0	0
IT97K-1034-92	0	0	24	0	0	0

Table 4. Performance of advanced cowpea genotypes based on rank total, DMRT and regression.

S/No.	Variety	2000			2001			Total	Mean
		Minjibir	Samaru	Toumnia	Minjibir	Samaru	Toumnia		
1	IT98K-412-13	3	2	17	3	1	8	34	6
2	IT97K-398-14	4	1	10	6	13	1	35	6
3	IT98K-506-1	6	4	7	5	6	14	42	7
4	IT97K-819-118	18	6	2	14	3	4	47	8
5	IT97K-608-14	7	11	8	4	17	5	52	9
6	IT98K-321-7	9	8	14	1	5	17	54	9
7	IT97K-556-4	1	10	15	8	11	10	55	9
8	IT98K-1137-3	14	3	18	7	2	13	57	10
9	IT98K-131-2	11	14	16	10	4	2	57	10
10	IT98K-277-1	2	13	12	12	8	11	58	10
11	IT97K-1034-94	15	7	3	16	14	7	62	10
12	IT97K-837-8	5	17	9	13	10	9	63	11
13	IT97K-1034-92	17	9	6	15	12	6	65	11
14	Danila	12	16	11	9	15	3	66	11
15	IT98K-628	8	15	5	11	9	18	66	11
16	IT98K-422-2-1	13	5	13	2	18	16	67	11
17	IT97K-1101-5	10	12	4	17	16	12	71	12
18	IT98K-205-8	16	18	1	18	7	15	75	13

Table 4 cont.

S/No.	Variety	Position			Mean yield	b
		1st	2nd	3rd		
1	IT98K-412-13	1	1	2	1586ab	1.44
2	IT97K-398-14	2	0	0	1674a	1.33
3	IT98K-506-1	0	0	0	1491abc	1.03
4	IT97K-819-118	0	1	1	1415abc	0.34
5	IT97K-608-14	0	0	0	1397abc	1.16
6	IT98K-321-7	1	0	0	1401abc	1.16
7	IT97K-556-4	1	0	0	1403abc	1.73
8	IT98K-1137-3	0	1	1	1381abc	1.02
9	IT98K-131-2	0	1	0	1312abc	1.11
10	IT98K-277-1	0	1	0	1302abc	1.31
11	IT97K-1034-94	0	0	1	1318abc	0.59
12	IT97K-837-8	0	0	0	1257bc	1.12
13	IT97K-1034-92	0	0	0	1234bc	0.58
14	Danila	0	0	0	1231bc	1.04
15	IT98K-628	0	0	0	1162c	0.87
16	IT98K-422-2-1	0	1	0	1252bc	1.08
17	IT97K-1101-5	0	0	0	1172c	0.83
18	IT98K-205-8	1	0	0	1127c	0.26
				Mean	1340	1

(1491 kg ha⁻¹) above the overall mean (1340 kg ha⁻¹). Therefore, this line can be recommended for any of the environments.

The ranking method is also an alternative approach devoid of much calculation. It was noticed that the conclusions from all the methods compared, were similar at least in identifying the top 3 breeding lines (IT98K-412-13, IT97K-398-14 and IT98K-506-1). The ranking method will therefore be a valuable tool for plant breeders especially when quick decisions are to be made on the performances of varieties for selections.

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