PERFORMANCE AND FARMERS PARTICIPATORY SELECTION OF COWPEA VARIETIES IN SOUTHERN ETHIOPIA †

[RENDIMIENTO Y SELECCIÓN PARTICIPATIVA DE VARIEDADES DE COWPEA POR LOS AGRICULTORES EN EL SUR DE ETIOPÍA]

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SUMMARY

Background. Farmers' participation in varietal selection process is important to collect the actual feedbacks on their performance in the field and hastens promotion and popularization of technologies. The study was conducted during 2016-2017 main cropping seasons in Gofa district of southern Ethiopia. **Objective.** To assess and select superior cowpea variety (ies) that meet needs of farmers and preferences through farmers' participation. **Methodology.** Data on agronomic traits were collected on plant and plot basis whereas at maturity and post harvest stages, farmers were requested to evaluate each variety. Eight cowpea varieties were laid out in a randomized complete block design (RCBD) with three replicates on the Gofa research station and additional unreplicated block at three nominated farmers' fields from each testing site. **Results.** Analysis of variance (ANOVA) showed the existence of significant differences ($p<0.05$) among the tested varieties for all the measured agronomic traits. Combined mean values showed that Brazil-3 (1.65 t ha^{-1}), Brazil-2 (1.62 t ha^{-1}), Kenketi (1.53 t ha^{-1}), and bole (1.52 t ha^{-1}) were high-yielding varieties with a yield advantage of 3.9 to 12.2 % more than the check variety white wonderer trailing. In case of farmers' evaluation using direct matrix and pair-wise ranking methods showed that Kenketi, Brazil-3, Brazil-2, and Bole were the most preferred varieties. The rank correlation analysis between varieties' ranked by farmers and the varieties' grain yield rank was positive across the tested villages. **Implication**. These results lead to identify the farmers' screening criteria needs to be incorporated into new varieties being developed which will contribute considerably to increased acceptance of improved cowpea varieties among smallholder farmers across the growing areas of southern Ethiopia.**Conclusion**. The results of this study have confirmed the need for researchers to incorporate farmers' preferred traits in cowpea improvement programmes. The study also identified cowpea varieties Brazil-3, Brazil-2, Kenketi and Bole as potential ones that can be recommended for further demonstration, popularization, and dissemination on farmers' fields to improve cowpea productivity in southern Ethiopia.
Keywords: Cowpea; direct matrix; pair-wise; participatory variety selection.

RESUMEN

Antecendents. La participación de los agricultores en el proceso de selección de variedades es importante para recopilar los comentarios reales sobre su desempeño en el campo y acelerar la promoción y popularización de tecnologías. El estudio se llevó a cabo durante las principales temporadas agrícolas 2016-2017 en el distrito de Gofa, en el sur de Etiopia. **Objetivo.** Evaluar y seleccionar variedades superiores de caupí que satisfagan las necesidades y preferencias de los agricultores a través de la participación de los agricultores. **Metodología.** Los datos sobre características agronómicas se recopilaron por planta y parcela, mientras que en las etapas de madurez y poscosecha, se solicitó a los agricultores que evaluaran cada variedad. Se dispusieron ocho variedades de caupí en un diseño de bloques completos al azar (RCBD) con tres réplicas en la estación de investigación de Gofa, y plantaciones en un bloque no repetido en tres campos de agricultores nominados de cada sitio de prueba. **Resultados.** El análisis de

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varianza (ANOVA) mostró la existencia de diferencias significativas ($p <0.05$) entre las variedades probadas para todos los rasgos agronómicos medidos. Los valores medios combinados mostraron que Brasil-3 (1.65 t ha-1), Brasil-2 (1.62 t ha-1), Kenketi (1.53 t ha-1) y bole (1.52 t ha-1) eran variedades de alto rendimiento. con una ventaja de rendimiento de 3.9 a 12.2% más que la variedad de control “white wonderer”. En el caso de la evaluación de los agricultores que utilizó matriz directa y métodos de clasificación por pares, se demostró que Kenketi, Brazil-3, Brazil-2 y Bole eran las variedades más preferidas. El análisis de correlación de rango entre las variedades clasificadas por los agricultores y el rango de rendimiento de grano de las variedades fue positivo en las aldeas examinadas. **Implicaciones.** Estos resultados llevan a identificar los criterios de selección de los agricultores que deben incorporarse en las nuevas variedades que se están desarrollando, lo que contribuirá considerablemente a una mayor aceptación de las variedades mejoradas de caupí entre los pequeños agricultores de las zonas de cultivo del sur de Etiopía. **Conclusión.** Los resultados de este estudio han confirmado la necesidad de que los investigadores incorporen las características preferidas de los agricultores en los programas de mejora del caupí. El estudio también identificó las variedades de caupí Brazil-3, Brazil-2, Kenketi y Bole como potenciales que pueden recomendarse para una mayor demostración, popularización y difusión en los campos de los agricultores para mejorar la productividad del caupí en el sur de Etiopía.
Palabras clave: Caupí; matriz directa; selección participativa; variedades.

INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) is a legume grown mainly in tropical and subtropical regions of the world for grains and vegetables and to a lesser extent as fodder crops (Oyewale and Bamaiyi,2013). Annually global cowpea production is estimated at 7,704,000 tons, of which more than 6.74 million tons (87.5%) are from Africa (FAO, 2018). It is also widely cultivated by poor farmers in developing countries with over 80% of its production coming from tropical Africa (Gbaguidi *et al*., 2015). According to Néya *et al*. (2015) up to 200 million people in tropical Africa use cowpea.

Cowpea seeds contain a mean of 23-25 % protein and 63.6 % carbohydrates (Akyaw *et al*., 2014). It is also a vital crop in the livelihoods of both humans and animals, where it serves as the closest source of animal protein, especially for those who cannot afford animal protein due to low income and large family size (Kwon-Ndung and Kwala, 2017). Therefore, it is considered very important to reduce the protein deficiencies in the human diets of malnutrition among children and resource-poor rural households, where it is considered the ‘meat of the poor’ (Owolabi *et al*., 2012). In addition, the capacity to adapt to different soil types and intercropping systems, their drought tolerance, and the ability to restore soil fertility through fixation of nitrogen (Néya *et al*., 2015; Pungulani *et al*., 2012), and erosion precaution make cowpea an important economic crop in many developing regions (Ewansiha and Tofa, 2016). Being a drought-tolerant and warm-weather crop it adapts well to the drier region of the tropics where other food legumes do not perform well (Bashir *et al*., 2018).

In Ethiopia, cowpea is grown in the drier areas of the Rift Valley and the dry highlands of Hararghe (east and west Haraghe zone, Oromiya region) usually intercropped with sorghum and in the Northeastern part of the country around Shewrobit, Kobo, north and south Wollo zone and Waghimira (Amahra region) areas, in southern and eastern Tigray zone, Ethio-Somali region, Afar region, Wolayita zone and Jinka zone (Kassaye *et al*., 2013). Also, it is cultivated in low rainfall areas of Southern Nations, Nationalities, and Peoples' Region (SNNPR) especially in Konso, Derashe, Humbo, Hammer Bako, Loka Abaya, Gofa, and Loma woredas (Tesema and Esthetayehu, 2003). In Ethiopia, although cowpea is grown in different regions (Oromiya, Amhara, Tigray, SNNPR, and Gambella) the area coverage hasn’t been recorded by the central statistics Authority. In the country, cowpea seeds are mostly used as a boiled grain or “nifiro” or converted to other food products like “Shiro”, and “Kollo" in the diet of the society in the growing areas (Tesfaye *et al*., 2018). Cowpea is produced in Ethiopia for a long time in lowlands by smallholder farmers without using any chemical inputs. In the drier areas of the country, cowpea is an excellent source of protein, feed, and income for farmers and plays an imperative role in restoring soil fertility (Fantaye *et al*., 2017; Tesfaye *et al*., 2018).

Regardless of its significance, the average national yield of cowpea in Ethiopia remains low with an average yield of the resource-poor farmers at about 0.4 t ha^{-1} (Beshir *et al*., 2019), whereas in research farms yields of 2.2–3.2 t ha^{-1} have been commonly recorded from improved varieties with proper crop management and protection practices (Ashinie *et al.*, 2020). Low yields were due to some factors, including the absence of improved high-yielding varieties, poor soil fertility, absence of suitable varieties to meet farmers needs, poor farmer participation, moisture stress, losses due to insect pests and diseases, and poor crop management practices (Fantaye *et al*., 2017).

In this respect, there is a potential for enhancing productivity and adoption of the crop through the application of measures that help to solve the constraints. To this end studies on farmers' participatory variety selection may play a fundamental role. The reasons behind the use of PVS are because researchers tend to focus on increasing productivity and their goals may differ from those of farmers, including market value, quality (cooking ability, taste, color, size), and household use (Kamara *et al*.,2010; Ndiso *et al*., 2016). In addition, the results from the conventional research systems take longer to reach farmers. Selection of farmer acceptable varieties with better adaptability through a participatory methodology is an essential approach to meet the actual needs of the farmers in south Ethiopia. Close cooperation between research scientists and farmers in the testing of varieties could enable the identification of crop genotypes preferred by farmers for large-scale production or targeted breeding (Horn *et al*., 2017). A participatory approach improves the adoption of improved technologies and farmers' knowledge and empowers traditional knowledge and innovations to be included in the research (Orawu *et al*., 2013). Farmer participation in the selection of crop varieties for low-income farmers is necessary to help ensure acceptance and eventual adoption (Hailemariam**,** 2016). Furthermore, Abady *et al*. (2017) reported that the process of adoption of new improved varieties tended to be lower in areas where farmers were less involved in the research process. In this sense, farmers' knowledge of the selection of suitable varieties for their lands, climate, and other social conditions should be considered in the varietal improvement programs.

Horn *et al*. (2017) on elite cowpea genotypes have shown that farmers involvement in research enable farmers to select new and promising varieties for their areas based on larger seed size, white grain color, high pod setting ability, insect pest tolerance, early maturity, longer pod size, drought tolerance, high biomass and pod yields. Therefore, participatory variety selection is considered to be a friendly approach to the identification and dissemination of new improved varieties with preferred traits to the societies (Thapa *et al*., 2009). It also enhances farmer's access to crop varieties, increases diversity, allows cost-effective varietal selection in targeted areas, and thus facilitates seed production and scaling-up at the community level (De Boef and Ogliari, 2008). Currently, 92.7% of farmers in the study areas mainly grow local landraces, whose seed they recycled for many seasons, while about 7.3 % grow both improved and local, often in addition to the local cultivars. To fill this gap, the execution of farmers' participatory varietal selection that has not been practiced on the crop would be useful in southern Ethiopia to come up with desirable cowpea genotypes that satisfy farmer's desires. Hence, the objectives of this research were to evaluate and select superior cowpea varieties that meet the requirements and choices of farmers using the farmers' participation and to identify selection criteria for cowpea variety improvement in the study area.

MATERIALS AND METHODS

Description of the study area

The experiments were conducted at a research station and in three farmers' fields, each in Boreda, Suka, and Zuluze kebeles in Gofa district during the main cropping seasons of 2016 and 2017. Gofa is located at the coordinates of 6º 19'-20'N latitude and 36º 55'E longitude and has an elevation of 1317 meters above sea level (m.a.s.l). The soil is mostly sandy loam. The amount of rainfall received during the 2016 growing season was 487 mm with an average temperature of 22.04°C. In 2017, 692.8 mm of rainfall was obtained with an average temperature of 21.8°C (NMA,2018)**.** Long-term (15 years) rainfall of 500 mm was received over four months (July, August, September, and October) with a mean temperature of 21.9°C. During the crop growth period, the precipitation pattern was different from that of the long-term average; considering the total amount of precipitation during the whole crop growth period; it was less than the long-term average in 2016 while greater than that of the long-term average in 2017. Average relative humidity varied from 45.9 % to 66.7 % during the crop growth period (NMA,2018).

Treatments, Experimental Design and Agronomic Management

Four improved cowpea varieties obtained from the Melkasa Agricultural research center and four introduced varieties selected from the 2015 adaptation trial were further evaluated using participatory variety selection. Eight cowpea varieties including standard check variety were used in our investigation. Each of the varieties seeds were initially sourced from Melkasa Agricultural Research Center. The varieties are listed in Table 1 below and, 'white wonderer trailing' was considered as a standard check.

The varieties were sown in the mid to end of July 2016 and 2017 main cropping seasons and the trial was conducted using the grand mother-mother method. The experiments were laid out in a randomized complete block design (RCBD) with three replicates in the grand-mother trial on the Gofa research station while mother trials consisted of plantings in an unreplicated block at three nominated farmers' fields from each testing site (a total of nine farmers). Three host farmers at each testing site planted one replication each as a mother trial. On station, trial was planned and accomplished by the researcher while on-farm trails were designed by a researcher and managed jointly by the researcher and farmers. The grandmother trial was used to produce the researcher's data while the mother trials were used for participatory varietal selection and to value farmers' preferences during evaluation. Each experimental plot had an area of 7.2 m^2 with four rows of 3 m length spaced at 60 cm between rows and 20 cm between plants. Fertilizer at the rate of 100 kg/ha of Di-ammonium phosphate (DAP) was applied during sowing. At Gofa trial station, the sowing dates were July 14, 2016, and July 19, 2017, respectively. At farmers' fields, planting was done from 13 to 15 July 2016 and 18 to 20 July in 2017. Hand weeding was made two times over the growing season to put the trial plots free of weeds.

Table 1. Description of tested cowpea varieties.

No	Variety	Year of release	Maintainer
1	Brazil-1	Introduced	MARC/EIAR
2	Bole	2005	MARC/EIAR
3	kenketi	2012	MARC/EIAR
4	Brazil-2	Introduced	MARC/EIAR
5	Brazil-3	Introduced	MARC/EIAR
6	BEB	1976	MARC/EIAR
7	Brazil-4	Introduced	MARC/EIAR
8	White wonderer trailing (SC)	1976	MARC/EIAR

MARC-Melkasa Agricultural Research Center; SC-standard check; EIAR-Ethiopian Institute of Agricultural Research.

Data collection

Agronomic data collected

Researchers collected vital data from grandmother trials on economically significant traits. These traits include days to 50% flowering, plant height, number of pods per plant, pod length, days to maturity, 100 seed weight, grain yield, and above ground biomass yield. Data were collected from the central two rows, leaving border rows. Data on plant height, number of pods per plant, and pod length were collected from five arbitrarily chosen plants from each plot and the average value was considered per plant basis. Whereas data on days to 50% flowering, days to maturity, 100 seed weight, grain yield, and above-ground biomass yield were recorded on a plot basis. The grain yield per plot was adjusted to storage moisture content (10%) determined using a digital Grain Moisture Meter (DRAMINSKI, POLAND). Data on insect (aphids) reactions were also recorded. Obopile (2006) explained that aphids damage was recorded and rated on a 1-9 scale, where: 1=resistant, 3= moderate resistant, 5= moderate susceptibility, 7= susceptible, 9=very/high susceptibility. In addition, grain yield data from the mother trials were collected.

Farmers' participatory varietal selection

For the farmers' assessment; the researcher together with the agricultural development workers selected farmers and farms for the study. The varieties selection process with farmers were done at maturity and threshing stages by 92 farmers (72 men and 20 women) selected with the help of the development agent in the kebele for field evaluation. Besides, field evaluation, the sensory panel which consisted of 40 (16 men and 24 women) panelists was performed in one of the host farmers' homes where the evaluation was carried out. The criteria preferred by farmers were grain yield, earliness, aphid resistance, drought tolerance, seed color, seed size, pod number, pod length, short cooking ability, good taste, above-ground biomass yield, and growth habit and were used to determine the best cowpea varieties.

PVS was performed using direct matrix and pair-wise ranking methods on tested cowpea varieties at maturity and threshing stages of cowpea. Direct matrix tables were prepared to evaluate tested cowpea varieties compared to traits reported by the farmers. Data were collected from studies involving eight varieties, in which each variety was equated with the other varieties for identified traits for varieties acceptability at a score of 1-5. A score of 1–5 was used to assess these characters, and genotypes were involved in all sites with the definition as follows: 5 = not preferred/poor, 4 = less preferred/below average, 3 = moderately preferred/Average, 2 = highly preferred/good, and 1 = very good. Farmers were asked to rate visually the wanted traits by assigning between one and five seeds. Farmers as a group (10 to 15) received 5 seeds and were asked to place 1, 2, 3, 4, or 5 seeds to score a given trait and variety. The seeds were counted and the smallest total count was ranked first. All the characters were determined by visual observation in the field except for taste and time of cooking. During threshing, 1kg seed sample of all the varieties was boiled in dishes before the organoleptic test. At cooking, the water was boiled in the dish first before the cowpea were put. The time taken from when the cowpeas were placed in the boiling water to the time they were ready to eat was recorded. Farmers were later allowed to taste all the varieties and rank them by taste. A sensory panel consisting of 40 panelists, was conducted at one of the host farmer's homes, where an evaluation was performed (Ndiso *et al*., 2016). The languages used in sensory testing were Amaharic and Gofigna (local language). The panelists had been screened for their understanding with the cowpea dish and their ability to determine differences among cowpea boiled grain from different cowpea varieties. Sensory attributes evaluated were short cooking ability and taste. Based on the selection criteria, they were asked to give the rank score of the varieties tested. At maturity and threshing, farmers were requested to evaluate each variety, using the same scoring method. To determine the scoring value of a variety against agronomic traits, the value of each site was summed and averaged. Finally, the overall performances of each of the varieties were determined. Then the values were arranged from the smallest to the largest; the smallest average value ranked first and vice versa. Furthermore, pairwise comparison was done, in which every variety was equated with the other genotypes for identified traits.

Data Analysis

Agronomic data were collected and exposed to statistical analysis using the SAS computer program, version 9.0 (SAS, 2002). The homogeneity of the individual variances was verified using the Bartlett test (1937) before the combined analysis. Then the combined analysis of variance over the years was done by the SAS statistical package. Mean separation was conducted using the Least Significance Difference (LSD) at the 0.05 probability level. To identify and decide on farmers' selection criteria on each of the cowpea varieties procedures such as pairwise ranking and direct matrix were applied. The degree of the correlation coefficient in farmer's trait preferences scores and data taken by the researchers (actual grain yield after measuring) were tested by using Spearman's correlation coefficient (Steel and Torrie, 1980) by the formula:

$$Rs = 1 - \left(\frac{6\Sigma d2}{n3 - n}\right)$$

where, Rs,= correlation coefficient , *d* = difference in the ranks assigned to the same individual or phenomenon and *n* = number of individuals or phenomena ranked.

RESULTS AND DISCUSSION

Cowpea varieties performance in the study sites

Analysis of variance revealed that there was a highly significant (P<0.01) to significant a (P<0.05) differences among the tested cowpea varieties for all characters in the case of researchers managed field at Gofa research station (Tables 2 and 3). Scientists evaluated varieties based on yield and other agronomic characteristics. The varieties showed a distinct statistical differences in all collected agronomic traits. Similar to this study, Fantaye *et al*. (2017) showed that there was significant variation among cowpea varieties for all traits. Another study by Solomon and Kibrom (2014) demonstrated that most traits showed significant variation among cowpea genotypes. Nevertheless, he reported, the findings of this study were not the same in the case of pods per plant and plant height.

Table 2 shows the researcher's assessment of the mean value of different agronomic traits. The average data showed that cowpea varieties differed significantly for all agronomic traits. The results of this study showed that the number of days to 50% flowering and the number of days to maturity of cowpea varieties varied significantly. Days to 50 % flowering, the earliest variety was BEB (45.3 days) while the late-flowering variety was Brazil-4 (52.8 days). Brazil-4 required 52.8 days for 50% flowering being statistically most late followed by Brazil-2 (52.3 days) and Brazil-3 (52.2 days). The lowest days to 50% flowering was found in BEB which was statistically similar with Kenketi and Bole. The difference in days to 50% flowering between the cowpea varieties tested could be due to varietal difference. For days to maturity, the earliest maturing varieties in terms of maturity time were kenketi (79 days), Bole (80 days), and BEB (81 days). Kenketi took 79 days to mature, and which is 17 days earlier than Brazil-2. Brazil-2 variety takes relatively long period (95.8 days) to mature than other varieties and its maturity time was higher than 80 days mentioned by Singh *et al.*, (2007) and Dugje *et al.*, (2009) for cowpea varieties. The attribute of maturity time denotes the number of days it takes for a variety to complete its growth cycle from sowing to full maturity ready for harvest in dry form. Experience from the PVS activities shows that farmers have often revealed a preference for earliness in cowpeas for various reasons. In drought-stressed environments, short growth cycles enable cowpea varieties to grow with minimum rainfall and allowing rapid food access to food insecure families. After harvesting cowpea, they can plant a second crop in the same cropping season. Similar results supporting the current findings were reported by Kamai *et al*. (2014). In Namibia and other arid and semi-arid regions of sub-Saharan Africa, farmers prefer short cycle duration cowpea varieties (Abadassi, 2015; Horn *et al*., 2015). The maximum plant height was recorded in Brazil-3 (123.4cm) and was statistically identical to Brazil-4 (116.7 cm), Brazil-2 (111.4 cm), and Brazil-1 (103.2 cm). The shortest plant height (82.8 cm) was found from the kenketi, but at par with bole (84.6 cm).

A similar research result was also reported previously (Fantaye *et al*., 2017; Solomon and Kibrom, 2014) that the authors perceived variations in plant height among the cowpea varieties. The pod length of Brazil-3, Brazil-2 and Brazil-4 was 19, 17.8 and 17.2 cm respectively. Pod length was found to be highly significant with a maximum in the variety Brazil-3 (19.0 cm), which was statistically at par with Brazil-2 (17.8 cm) and a minimum in variety Bole (12.4 cm). The pod length of cowpea varieties was ranged from 12.4 to 19.0 cm (Table 2). The variation observed between varieties for the measured pod length was supported by Tesfaye *et al*., (2018) and Yama *et al*.,(2006) who tested different cowpea genotypes and found a significant variation in pod length.

There were significant differences among cowpea varieties tested for above-ground biomass yield ($P<0.01$) (Table 2). The highest above-ground biomass yield (5.662 t ha^{-1}) was gotten from Brazil-2 which was statistically identical with Brazil-4, Brazil-3, and white wonderer trailing but numerically higher than standard check variety (Table 2). Biomass is an vital trait as cowpea straw has high protein concentrates for animal feeds. With this reason Brazil-2,Brazil-4 and Brazil-3 can take the advantages over the other varieties. The lowest above-ground biomass yield (3.49 t ha^{-1}) was achieved from BEB. These findings on the cowpea genotypes were also reported by Solomon and Kibrom (2014), identifying different above-ground biomass yields in different cowpea genotypes.

As shown in Table 2, the performance of the tested varieties differed significantly ($P<0.05$) to highly significant ($P<0.01$) for yield and yield components of cowpea. Bole produced highest number of pods per plant having a value of 30.0 which had statistically similar with varieties Brazil-3 (27.6), kenketi (26.9) and white wonderer trailing (26.5), while least by Brazil-4 (19.0). These findings are in agreement with that of Bhattarai *et al*., (2017), who also reported significant genetic differences for this parameter among cowpea varieties.

The variation in 100 seed weight was highly significantly affected due to various cowpea varieties (Table 2). The highest 100 seed weight (20.48 g) was found in Brazil-2, which was statistically at par with Brazil-3 (20.22 g), Brazil-1(19.96g), and Brazil-4 (19.9g), and the lowest (10.35 g) from check variety white wonderer trailing followed by kenketi (13.98 g). These results are similar to those of other researchers who have reported that cowpea genotypes were significantly affected by 100 seed weight (Kamara *et al*.2018). Equally to the other traits aphids resistance varieties are more

Table 2. Mean agronomic traits of grand-mother experiment of cowpea varieties at Gofa, 2016 and 2017(n=1).

Varieties	FD	MD	HSW	PPP	PH	BY(t)	PL(cm)	AP
Brazil-1	52.2a	94.7a	19.9a	21.9cd	103.2abc	4.08bc	16.6bc	8.01a
Brazil-2	52.3a	95.8a	20.5a	24.9bc	111.4ab	5.662a	17.8ab	5.0d
Brazil-3	52.2a	95.3a	20.2a	27.6ab	123.4a	5.661a	19.0a	5.2cd
Brazil-4	52.8a	95.3a	19.8a	19.9d	116.7ab	5.61a	17.2b	5.3cd
Bolle	50.2b	80.2c	15.5b	30.0a	84.6d	4.28bc	12.4f	5.2cd
BEB	45.3c	80.8c	20.0a	22.7cd	93.4dc	3.49c	15.2de	7.0b
Kenketi	46.5c	79.3c	13.9c	26.9ab	82.8d	4.35bc	14.2e	5.5c
WWT	52.0a	89.5b	10.4d	26.6ab	98.2bcd	4.84ab	15.8cd	5.2cd
Mean	50.4	88.9	17.5	25.1	101.7	4.7	16.0	5.8
CV (%)	2.3	1.6	6.3	11.6	18.7	16.7	6.8	10.4
LSD (5 %)	1.4	1.7	1.3	3.5	22.5	1.0	1.3	0.49

Means with the same letter within the same column are not significantly different, at 5% probability level, LSD=Least significant differences, n=number of grandmother or mother trials,CV= coefficient of Variation, WWT=white wonderer trailing (StandardCheck), FD=Days to 50% flowering, MD=Days to maturity, HSW=hundred seed weight, PPP=pods per plant, PH=Plant height, BY= above ground biomass yield and PL=pod length. AP=Aphid score.

Table 3. Grain yield (t ha^{-1}) from grandmother (n=1) and mother trials (n=9).

Variety	Grandmother	Mother	Mean	Rank	% increase over standard check
Brazil-1	1.08d	1.07d	**1.07c**	**8**	**-**
Brazil-2	1.63ab	1.61ab	1.62a	2	10.2
Brazil-3	1.66a	1.64a	1.65a	1	12.2
Brazil-4	1.42c	1.44bc	1.43b	6	-
Bole	1.48bc	1.58abc	1.529ab	4	3.9
BEB	1.09d	1.06d	1.08c	7	-
Kenketi	1.61ab	1.45abc	1.533ab	3	4.3
WWT	1.54abc	1.39c	1.47b	5	-
Mean	1.44	1.40	1.41		
CV (%)	8.9	11.3	10.7		
LSD (5%)	0.152	0.105	0.086		

Means with the same alphabet are not significantly different, at 5% probability level , CV= coefficient of Variation, n=number of grandmother or mother trials, WWT=white wonderer trailing (Standard Check), % of standard check =yield advantage over the combined mean.

advantageous for cowpea improvement. The infestations of the aphids varied among cowpea varieties (Table 2). The infestation of aphids was relatively lower for 6 varieties (75 %) showed moderately suceptible reaction, while very susceptible for Brazil-1. These might be occurred due to genetic variation of the varieties. The results verified the findings of Souleymane et al (2013) and Gonné et al. (2013). Identification of cultivars with high grain combine with aphids' resistance allows use of cowpea as a potential alternative to help control aphids infestation.

The grain yield of the cowpea crop is the combined effect of various yields attributing components. In the grandmother trial, the grain yield was ranged from the lowest yield of variety Brazil-1 (1.08 t ha^{-1}) to the highest yield of variety Brazil-3 (1.66 t ha^{-1}), while in the mother trial it ranged from 1.06 to 1.64 t ha^{-1} for BEB and Brazil-3, respectively (Table 3). The varieties Brazil-3, Brazil-2, Kenketi, and Bole had the highest similar yields in both trials with a significant difference from the rest of the varieties (Table 3). The variety Brazil-3 was better in both trials comparing to others, and the average yield of the grandmother and mother trials showed that varieties Brazil-3, Brazil-2, Bole, and Kenketi had 1st,2nd,3rd, and 4th ranks, respectively (Table 3). The maximum combined mean grain yield was recorded in Brazil-3 (1.65 t ha^{-1}) and it was statistically similar to that of Brazil-2 , Kenketi , and Bole but increased the grain yields numerically by an average of 3.9 to 12.2% yield advantage over standard check variety white wonderer trailing (Table 3). The highest grain yield in Brazil-3 varieties was attributed to higher pods/plant, plant height, pod length, and 100 seed weight. The variation in yield of different cowpea varieties was attributed to the cumulative effects of the different yield components. Similar findings were reported by Manggoel *et al*. (2012) and Nwosu *et al*. (2013). Our results are in line with those of Ndiso *et al.* (2016), who evaluated different improved cowpea varieties and reported that mean grain yield varied from 0.48 to 3.3 t ha^{-1} .

Farmers preferred traits and selection criteria

Farmers at all sites have the same experience in cowpea production and cowpea has used as major food and to some extent as cash crops. The farmers who were involved and evaluated the genotypes were selected to be representatives of the area that had long experience in growing cowpea. Farmers first identified 12 criteria of cowpea varieties that influence their choice of varieties to cultivate and then ranked and scored (Table 4). Twelve different traits such as earliness to maturity, aphid's tolerance, drought tolerance, short cooking ability, seed color, taste, pod length, pod number, seed size, growth habit, grain, and above-ground biomass yield were used when evaluating cowpea varieties for selection. The rating was based on a scale of 1 to 5, 1 is being very good and 5 being poor. In Boreda, the important criteria were in order of importance: high yield, early maturity, aphid resistance, drought tolerance, taste, pod length, cooking ability, seed color, pod number, seed size, growth habit, and lastly biomass yield. Farmers at the Suka site followed a similar trend except for a slight variation in priority in Zuluze and on station sites. Important criteria used by Zuluze farmers were early maturity, high yield, resistance to aphids, resistance to drought, pod length, good taste, number of pods, seed size, and seed color. Analysis across the sites showed high yield, early maturity, aphid resistance, drought tolerance, short cooking ability, seed color, good taste, pod length, pod number, and seed size were ranked as ten top criteria. Only a few traits were inconsistently ranked across all sites. For instance, the taste and length of the pods are more preferred by farmers in Boreda, ranked fourth, as compared to farmers from near station sites where it was ranked eighth. Likewise, the short cooking ability was important in Suka and station sites and were ranked fourth, as compared to Zuluze site where it was ranked tenth. Spearman's rank correlations (rs=0.57-0.93) showed that farmers' trait preferences were strong, positive, and significant (Table 4) indicating that the ranking order was roughly consistent among the four sites. Overall, the criteria for selecting a good cowpea variety were essentially the same across the four tested sites; suggesting that similar selection criteria can be applied for the cowpea improvement programs (Table 4). This implied that the farmers' variety selection criteria reveal the degree of importance given to different varieties as well as the choice of traits. This shows that grain yield is not the only selection criterion farmers use, but rather on the combination of agronomic and qualitative traits as farmers' interests. Thus, the result confirmed the importance of farmers' knowledge to complement the researcher's perception in the selection of cowpea varieties for a specific area. Similar observations were made by Ndiso *et al*., (2016) who reported that grain yield, drought tolerance, early maturity, ease of harvesting, leafiness, seed color, taste, and cooking duration as main criteria, and high grain yield was in the first place because all the farmers who participated in the evaluation used cowpea mostly for grain production. Previous studies by (Abadassi, 2015; Horn *et al.*, 2015) working on cowpea reported similar findings of farmers using a combination of traits when evaluating new genotypes.

Farmers' varieties selection based on direct matrix ranking

Based on the selection criteria of farmers', a comparison was conducted among the tested cowpea varieties. Cowpea varieties were identified for their morphological performance and ranked as indicated in Table 5. At Gofa station farmers (Table 5) varietal assessment showed that variety Kenketi was ranked highest (2.10), followed by Brazil-3 and Brazil-2 with values of 2.33 and 2.72, respectively. Similarly, in Boreda site farmers' evaluation of the varieties showed that their preferred varieties are Brazil-3, Brazil-2, and kenketi with values of 2.28 and 2.33 each, respectively. The farmers' evaluation of the varieties on the Suka site also showed that their preferred varieties were Kenketi, Brazil-3, and Brazil-2 with values of 2.19, 2.24, and 2.46, respectively. On the other hand, in the Zuluze locality, the varietal evaluation of farmers showed

Table 4. Direct matrix rank and scores of traits of cowpea variety across four sites in Gofa.

Sites	**Boreda**		**Suka**		**Zuluze**		**Station**		**FR**	
Trait	score	rank	score	rank	score	Rank	score	rank	MS	rank
Grain yield	1	1	1	1	2	2	1	1	1.3	1
Aphid resistance	2.7	3	2.7	3	2.3	3	2.7	4	2.6	3
Earliness	2	2	2	2	1	1	2	2	1.8	2
Drought tolerance	3	4	3	4	2.7	4	2.3	3	2.8	4
Pod length	3	4	4	7	3	5	4	10	3.5	7
Growth habit	4.3	10	4.3	9	4.7	11	4	10	4.3	11
Biomass yield	4.7	11	5	12	5	12	3.9	8	4.7	12
Seed color	3.3	7	3.3	6	4	8	3	6	3.4	6
Seed size	4	9	4.7	10	4	8	3.7	7	4.1	10
Pod number	3.7	8	4.7	10	3.7	7	3.9	8	4.0	9
Good taste	3	4	4	7	3	5	4	10	3.5	7
Short cooking ability	3.1	6	3	4	4.3	10	2.7	4	3.3	5
Rank correlation (rs)		0.89*[1]	0.93*[2]	0.61*[3]	0.76*[4]	0.78*[5]	0.57*[6]			
Total participants	35		32		30		35		132	

Preference ranking score is based on a scale 1 to 5: 1 = Very good, 2 = Good, 3 = Average, 4 = below average and 5 = Poor/low priority; participants (M=88; F=44);1 Spearman's rank correlation coefficient (rs) between boreda and suka farmers' preference ranking; 2 rs between boreda and Zuluze farmers' preference ranking; 3 rs between boreda and near station farmers' preference ranking;4 rs between suka and zuluze farmers' preference ranking; 5 rs between suka and near station farmers preference ranking; 6 rs between Zuluze and near station farmers preference ranking; R=Rank, mscore=mean score, FR=farmers overall rank.

Table 5. Farmers average score (1-5) and rank for combined traits per variety.

Sites	**Boreda**		**Suka**		**Zuluze**		**Gofa station**		**FDW**		**RR**	
Varieties	score	R	score	R	score	R	score	R	score	R	GY(t)	R
Brazil-1	3.08	6	3.07	7	3.94	8	2.9	5	3.25	7	1.07	8
Brazil-2	2.33	2	2.46	3	2.44	3	2.72	3	2.49	3	1.62	2
Brazil-3	2.28	1	2.24	2	2.18	1	2.33	2	2.26	1	1.65	1
Brazil-4	2.76	5	2.76	5	2.76	5	3.4	7	2.92	5	1.41	6
Bole	2.48	4	2.49	4	2.58	4	2.88	4	2.61	4	1.53	4
BEB	3.41	8	3.13	8	3.13	6	3.43	8	3.28	8	1.08	7
Kenketi	2.33	2	2.19	1	2.4	2	2.1	1	2.26	1	1.53	3
W/W/T	3.23	7	3.04	6	3.23	7	2.95	6	3.11	6	1.47	5

R=Rank, FDM=Farmers direct matrix Rank, RR=Researchers rank (grain yield)

Table 6. Farmers' rating of cowpea varieties at maturity and threshing stages across sites.

Trait	Brazil-1	Brazil-2	Brazil-3	Brazil-4	Bole	BEB	Kenketi	WWT
Grain yield	4.58	1.68	1.50	3.50	2.55	4.75	1.75	3.75
Aphid resistance	3.63	2.95	2.58	3.80	3.75	4.65	2.65	2.68
Earliness	4.65	4.60	4.75	4.93	1.95	2.40	1.00	4.53
Drought tolerance	3.33	2.00	3.20	3.80	2.00	3.00	1.93	3.38
Pod length	2.35	2.05	1.00	1.60	3.30	3.13	2.15	2.15
Growth habit	4.00	3.43	4.03	4.30	1.70	2.73	1.45	4.20
Biomass yield	3.08	2.00	1.00	1.83	4.00	3.80	3.15	2.25
Seed colour	2.75	3.00	3.55	3.38	1.13	3.38	3.05	1.80
Seed size	2.38	1.68	1.00	1.18	2.25	1.23	2.90	3.68
Pod number	3.58	2.60	2.00	3.18	1.00	4.53	2.55	2.93
Good taste	1.86	1.65	1.20	1.48	4.00	2.15	1.85	2.60
Short cook ability	2.83	2.23	1.33	2.08	3.63	3.58	2.75	3.40
Mean	3.25	2.49	2.26	2.92	2.60	3.28	2.26	3.11
Farmers rank	7	3	1	5	4	8	1	6
TC (minutes)	53	51	50	52	71	63	56	62

*Overall Scores: (1 – 5) Scales; 1 = Very good, 2 = Good, 3 = Average, 4 = below average and 5 = Poor and TC=Time of cooking.

Brazil-3 (2. 18) is the preferred variety, followed by Kenketi and Brazil-2 with values of 2.40 and 2.44, respectively. Across the selection criteria, based on farmers' direct matrix ranking for the varieties showed Keneketi and Brazil-3 with equal scores (2.26) and ranked first, followed by Brazil-2 (2.49) and Bole (2.6) (Tables 5 and 6). On the other hand, sensory evaluation (taste) showed that the variety Brazil-3 (1.2 score), Brazil-4 (1.48 score), Brazil-2 (1.65 score), Brazil-1 (1.86 score), and kenektii (1.85 score) have very good to good tastes and can therefore be consumed more than other tested varieties and standard check variety (see Table 6). The standard check variety white wonderer trailing had average palatability in taste with a mean score of almost 3. In addition to taste, the cooking time of cowpea samples was between 50 and 71 minutes. The cooking time for each variety revealed that the variety Brazil-3 (50 minutes), Brazil-2 (51 minutes), Brazil-4 (52 minutes), and Brazil-1 (53 minutes), while Bole had the longest cooking time (71 minutes). Most of the test varieties were highly rated by the farmers (Tables 5 and 6). Overall, the farmers' responded positively to the improved varieties, they have evaluated. Table 5 showed that the rank of the researchers did not match with the rank of the farmers for the keneketi and Brazil-2 varieties, which were ranked 1st and 3rd by a farmer while 2nd and 3rd by the researcher. The farmers' selection criteria were slightly different from those of researchers in that the earlier included traits such as good taste, seed size, short cooking ability, and seed color. Current investigation confirms the observation by Horn *et al*. (2017) and Abadassi (2015) that farmers' perception about cowpea varieties is not always the same as researchers' and if given the opportunity, farmers can express their preferences differently.

Table 7. Farmers pairwise ranking of cowpea varieties studied at Gofa in 2016 and 2017.

Sites	Boreda		Suka		Zuluze		Gofa station		FPW		FDM	RR
Varieties	score	R	score	R	score	R	score	R	score	R	R	R
Brazil-1	1	7	1	7	0	8	0	8	2	7	7	8
Brazil-2	5	3	5	3	5	3	5	3	20	3	3	2
Brazil-3	6	2	7	1	6	1	6	2	25	1	1	1
Brazil-4	2	6	4	4	4	4	3	5	13	5	5	6
Bole	4	4	3	5	4	4	4	4	15	4	4	4
BEB	0	8	0	8	1	7	1	7	2	7	8	7
Kenketi	7	1	6	2	6	1	7	1	26	2	1	3
WWT	3	5	2	6	2	6	2	6	9	6	6	5
Rank correlation(rs)								0.95*[a]	0.91*[b]	0.98[c]		

Pairwise preference ranking low score= high rank and least preferred; High score=low rank and most preferred; FPW= =all farmers pairwise preference rank; FDM= all farmers direct matrix preference rank, RR=Researchers rank; a Spearman rank correlation coefficient (r) between all farmers using the pairwise method and crop harvest results (grain yield); b rs rank correlation coefficient (rs) between all farmers preference using direct matrix method and researchers measured grain yield; c spearman's rank correlation coefficient (rs) between two ranking methods; WWT =white wonderer trailing (standard check).

Farmers' varieties selection based on pairwise ranking

Farmer Preferences

Using pair wise ranking method, farmers' selection criteria were prioritized to identify the most important attributes desired by farmers. The results of farmer preference and selection of varieties according to the pair-wise ranking method are presented in Table 7. At Boreda site, varieties that were highly preferred and selected by farmers by the pair-wise ranking method were Kenketi, Brazil-3, Brazil-2, and Bole (Table 7). Brazil-1 and BEB varieties were the least productive (Table 3) and least preferred by farmers. Pair-wise variety rankings for Gofa show similar patterns: Kenketi, Brazil-3, Brazil-2, and Bole were the most preferred varieties. However, there was variation with regards to preferences for individual sites. The Kenektii variety was co-ranked with Brazil-3 as the first most preferred varieties in Zuluze while Brazil-3 was the most preferred variety in Suka, followed by Kenketi and Brazil-2 (Table 7). New varieties Brazil-3, Kenektii, Brazil-2, and Bole were consistently among the top four preferred varieties that affirm their potential (Table 7). Whereas Brazil-1 and BEB had an equal score and ranked last by farmers. There was a high correlation between the general impression as observed by farmers using direct matrix and pairwise ranking methods and the researchers' determined yield (rs = 0.93** and rs=0.95**; n = 132). A high correlation between the pairwise and direct matrix ranking (rs=0.98**) indicates their overlapping. Therefore, it is possible to use either of them as a method of cowpea varietal preferences.

The overall ranking of performance and farmers' preferences of cowpea varieties

The performance ranking is based on the mean grain yield of the variety while preference ranking is the average rank of the variety based on selection criteria using direct matrix and pair-wise ranking methods. Overall ranking, used to identify the final best variety based on the average rankings of performance and preferences (Tables 4 and 6). In the Gofa district, the overall rating identified four cowpea varieties based on the farmers' most preferred traits. Farmers classify them into two categories, in the first choice category, farmers preferred cowpea varieties for their early maturing (79-80 days), erect growth habit (suitable for intercropping as well as mono-cropping) and comparable grain yield. Furthermore, cowpea varieties, Brazil-3 and Brazil-2 were the second farmers' choice category because of their desirable traits including high grain yield, high above-ground biomass yield, large seed size, pod length, delicious taste, and short cooking ability. Whereas the Brazil-1 and BEB varieties as the least preferred varieties by farmers.The different maturation classes are targeted to different seasons, where the shortest-maturing varieties promoted in season receiving the least rainfall, late-maturing varieties could be suitable for mono-cropping to be promoted in season receiving the long rainfall. So, farmers can cultivate these four varieties besides standard check variety with certain yield advantages and quality traits.

In addition to yield, other priority traits considered include days to maturity, aphids resistance, drought tolerance, pod number, pod length, and growth habit as well as culinary characteristics such as taste, cooking time, seed color, and seed size. In this study, the cooking time of tested cowpea varieties varied between 50 to 71 minutes when the dish was used as a cooking device (Table 6). Less than one hour of cooking time was considered fast cooking, and more than one hour to be slow cooking. Faster cooking cowpea varieties reduces the time taken to prepare cowpea relish and would also offer the potential to save the cost of fuelwood and time women spend in collecting firewood. Nkongolo *et al*.(2009) reported that using the averages cooking duration, the six genotypes tested were classified into the two cooking ability categories i.e genotypes cooked under two hours (71- 98 minutes) were fast cooking while slow cooking took more than two hours (138-174 minutes). This is in agreement with Nadis *et al*. (2016) who reported that the success of any newly introduced variety will depend not only on its production characteristics but also on its acceptability by consumers in terms of both sensory and usage traits. Hence, there is a need to breed improved cowpea cultivars for agronomic as well as culinary traits. It is critical, therefore, that farmers' traits preferences, and desirable varieties are recognized and integrated into their improvement programs.

CONCLUSION

This experiment incorporated the knowledge of researchers and farmers to select potentially high-yielding cowpea varieties with farmers' traits preferences. In our study, the selection criteria for farmers were relatively similar and were early maturity, aphids resistance, drought tolerance, grain yield, long pod length, good taste, short cooking time, seed color, large pod number, and seed size. Results of the PVS study showed that Brazil-3, Brazil-2, Kenketi, and Bole consistently produced higher yields in both grandmother and mother trials and got higher scores in the overall preferences of farmers. Farmers preferred Kenketi and Bole for earliness coupled with high yield potential and up right growth habit as the first choice category of farmers*'*. In addition, two new varieties namely Brazil-3 and Brazil-2 gave the highest *g*rain yields, good taste, short cooking ability, and long pod length as the second choice category of farmers'. To increase cowpea production and yield four selected cowpea varieties could be the best option to encourage the farmers to improve cowpea production in southern Ethiopia. The farmers prefer cowpea traits that were somewhat different from those of the researchers in that farmers considered traits such as seed colour, taste, and cooking time. Therefore, farmers' preferences could be used by researchers to develop varieties that may be preffered by consumers and farmers in southern Ethiopia or incorporated during the cowpea improvement programs.

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