Appraisal of Cowpea Cropping Systems and Farmers' Perceptions of Production Constraints and Preferences in the Dry Savannah Areas of Nigeria

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ABSTRACT

Background

Low plant density and wide intra-plant spacing in traditional cowpea cropping systems are among factors responsible for low yield on farmers' fields. Sole cropping and improved intercropping systems have been advocated in the last few years, to increase yield in the northern guinea savannah of Nigeria. This study investigated the level of adoption of high yielding cowpea cropping systems including factors that influenced their use, and assessed farmers' perceived production constraints and preferences. A total of 420 farmers across 36 villages of northern Nigeria were interviewed, and data collected was analyzed using descriptive statistics to appraise farmers predominant cowpea cropping systems and factors that determine the use of sole vis-à-vis intercropping were identified with the aid binary logit regression. Furthermore, pairwise comparison ranking was deployed to understand farmers' view of cowpea production constraints and preferred traits.

Results

The results revealed that many farmers (42%) still grow cowpeas in the traditional intercropping and a good number (25%) cultivate the crop as a sole crop, while 23% had fields of cowpeas in sole and intercropping systems. Farmers reported the incidence of high insect pests, limited access to land, desire to have multiple benefits, and insurance in the event of crop failure as reasons for preference for mixed intercropping over sole planting. The pairwise comparison ranking of constraints and preferences revealed insect pests, *Striga*, drought and poor access to fertilizers as major constraints to increased production, while many farmers indicated high yield as the most preferred trait.

Conclusions

Findings from the study indicated a need for increased education and training of cowpea farmers on the importance of growing cowpeas in sole cropping and or improved intercropping systems. Genetic improvement efforts should focus on developing cowpea varieties that address farmers production constraints and reflect the diversity of consumers' preferences for the crop. Hence, breeding for resistance to insect pests and high yield is recommended as an important priority of cowpea breeding programmes in the region.

Keywords

Cowpea, Cropping systems, Sole cropping, Intercropping, Pairwise comparison, Northern Nigeria

Background

Legumes such as cowpea form a complementary balanced diet when combined with cereals, because of their high content of essential amino acids like lysine and tryptophan, micronutrients (Fe and Zn), macronutrients like Mg, Ca, and other important B-group vitamins (1). The compositional profiles of cowpeas can help in attaining the United Nations Sustainable

Development Goal (SDGs) of eradicating all forms of hunger and malnutrition and reducing child stunting.

Cowpea [*Vigna unguiculata* (L.) Walp.] is a vital grain legume widely cultivated in Sub-Saharan Africa (SSA) as food for humans and feed for livestock. The crop's grain is rich in proteins, micro- and macronutrients. In most areas of SSA, the yield on farmers' fields are below its genetic potential due to a series of stress factors, poor agronomic practices, and socio-economic constraints (2,3). Thus, innovative systems to increase productivity and yield of cowpea that would serve the needs of all stakeholders should be the main target of its cropping systems research in the major producing areas. The high-yielding cropping systems comprise sole cropping, one-row cereal with double rows cowpea strip planting, and the doubled-up system used in eastern Africa, where a second legume crop is planted as a succeeding crop of legume in the same field within a season (1,4,5).

Cowpea cropping systems here referred to the sequence of crops grown and managed together with cowpea in one field. Intercropping means growing more than one crop simultaneously or as a relay of one over the other in one field, while sole cropping means growing one crop type in the field in a season (6). There is a huge gap between realized and potential yield of cowpea due to several factors including sub-optimal agronomic practices such as wide intra-plant spacing, and very low cowpea density (1, 000 – 5, 000 plants/ha) in traditional intercropping compared to the recommended density of about (66, 666 plants/ha) in the solely planted fields (3,7). The wider within row spacing of cowpeas intercropped or relayed with cereals ranged from 40 – 100 cm, compared with 20 – 25 cm in sole cropping of the crop (4,5). There is a promise for increased grain yield in the northern guinea savannah of Nigeria, where most of the grain cowpeas in Nigeria are produced, if suitable agronomic practices and recommended planting patterns are used by

smallholder farmers (4,5). It is important to understand and document the current prevailing cowpea cropping systems in major producing areas of Nigeria, since the country is the world's largest consumer of the crop. The demand for grain cowpea in Nigeria is expected to increase tremendously due to the increasing population of the nation (8), thereby presenting a potential food crisis in the coming years especially as the traditional cropping systems are breaking down and cannot support the demand for food and fodder of the increasing population.

Cowpeas are grown by most smallholder farmers in the traditional systems as a mixed intercrop or relayed after cereals leading to low plant stands, shading effects by the companion crops, and competition between crops with negative consequences on the productivity of the crop. This has been a widespread practice by smallholder farmers in the northern regions of Nigeria known for its substantial cowpea production (4,9). Understanding farmers' knowledge of production technologies and cropping systems is critical to increasing the level of crop productivity and adoption of new farming technologies (10).

In the northern guinea savannah areas of Nigeria, where there are significant outreach efforts by organizations like the International Institute of Tropical Agriculture (IITA) and the Institute for Agricultural Research of Ahmadu Bello University Zaria (IAR/ABU), improved agronomic practices such as sole cropping and improved cereal - cowpea systems for increased productivity have been developed and advocated. However, the level of adoption of these systems is not well documented. Also, farmers and consumers have a varied preference for cowpea's seed size and coat colour in major consuming areas (11,12). Recent studies have indicated that the relatively low level of adoption of improved cowpea varieties among smallholders in Nigeria (13,14) includes the non-availability of farmers and market preferred traits such as seed size, and colour among others. Hence, assessing farmers' understanding of constraints, trait preferences, as well

as their farming systems, is essential for the wide adoption of new production technologies including newly developed varieties (15). Farmers' participatory assessment approach such as participatory rural appraisal, focus group discussion, and semi-structured can be used to identify and document farmers' practices, perceived production constraints, and preferred traits (10,15,16). Appraising and documenting this information will serve as baseline data and support setting priorities for farming system research, development programmes and provide feedback to the scientists and policymakers in Nigeria and as well as for areas with similar agro-ecologies in the savannah regions. Therefore, the main objective of this research was to investigate the impact of several efforts by the research institutions in developing and disseminating improved agronomic practices to scale up the productivity of cowpeas in the major producing areas of Nigeria on current cropping systems. Specific objectives were to document the prevailing cowpea cropping systems, understand factors influencing the use of the systems, and assess farmers' perceived production constraints and preferences.

Materials and methods

Description of the study areas and sampling procedure

This study was conducted in three states in the northern guinea savannah of Nigeria across 36 communities (Figure 1, Supplementary Figure 1). The chosen areas are among major cowpea producing areas in Nigeria and have been the primary focus of outreach efforts by the IITA (Kano-station) and the IAR/ABU Zaria for the past few decades (17–19).

Participants for the study were determined through a two-step sampling procedure. First, the major cowpea growing areas were identified from literature (20) which lead to the selection of Kano, Katsina and Kaduna States for the survey. Second, a total of 420 cowpea farmers across the study communities were selected with the assistance of extension personnel familiar with the selected

communities. It is a well-established fact that, field extension agents are mostly more familiar with farmers in study sites and are often more helpful during farmers participatory activities (10).

At each survey site, all interviews were conducted in person and in the "*Hausa"* language from January through March 2017. The design of this study was reviewed and approved by the Legumes and Oilseeds Research Review Committee of the Institute for Agricultural Research (IAR) Zaria as an internal interview process. Also, the informed consent of interviewees was always obtained verbally before conducting the interviews and focus group discussions, as well as the option to participate or withdraw from the conduct of the study, was orally given to the participants.

123

124 **Fig. 1** Map of study sites across three Nigerian States (Map produced with ArcGIS 10.4)

125 **Data collection and analysis**

126 Primary data were sourced through semi-structured questionnaires designed and administered by

127 the research team. Data were collected from a total of 420 cowpea farmers drawn randomly from

three villages per local government area (LGA) across 12 LGA, giving a total of 36 villages for the study. Data collected include socio-economic attributes, years of experience in cowpea production, cowpea cropping systems, use of phosphate fertilizers, attendance of field-days, and contacts with extension workers. Information obtained on farming systems through the questionnaire surveys was verified through focus group discussions (FGD) with key informants and personal observation during the surveys. The FGD centred around cowpea production constraints and preferences using the pairwise comparison chart to rank information. Identified production constraints and preferences at each community were arranged in a matrix of rows and columns on a whiteboard and were ranked in a pairwise manner to identify the most important constraints or preference of the farmers, such that when two constraints or preference were ranked, the most important receives 1 and the less important of the two gets 0 (21–23).

We used a binomial logistic regression in SPSS to predict whether the "cowpea cropping system by farmers" can be predicted based on age category, education, experience on cowpea production, contact with extension workers, field-day attendance, gender, household size, marital and use of phosphate fertilizer (Table 1). The system of growing cowpea was modelled as a dependent variable with a binary choice: the value was 1, if the farmer grew cowpea as a sole crop; otherwise, the value was 0, thereby making the farmers' decision two mutually exclusive events, such that when a farmer chose the option of growing the crop as a sole crop, the other option by default was not chosen (16).

Data collected from questionnaires and FGD sessions were coded, entered in spreadsheets, and analyzed using the SPSS version20. Results were summarized and presented using descriptive statistics, logit regression and the pairwise comparison ranks were visually displayed as bar charts with the aid of R software (R Core Team). As an exploratory study aimed at stimulating interest

and further investigations, this paper leaned heavily on descriptive statistics to report the predominant system in use by farmers for growing cowpea. The main aim of the binary logit analysis was to describe if growing cowpea as sole or intercrop was influenced by the explanatory variables stated in Table 1. Empirically, the model for estimating the determinants of the probability of farmers growing cowpea sole crop is as follows;

$$\ln\left[\frac{P_x}{1-P_x}\right] = \beta_o + \sum \beta i \; Xi$$

where P_x is the probability of an event occurring (value of 1 if the farmer grows cowpea as a sole crop; otherwise, the value is 0), β_o is a constant term, and βi is a coefficient associated with the independent variable Xi.

Table 1 List and description of variables used in the binary logit regression model

Variable	Description	Variable type	Units
Dependent variable			
Cowpea cropping system	Farmer's system of growing cowpea in the field	Dummy	1 = sole, 0 = intercrop
Independent variable			
Age	Farmer's age category	Years	Continuous
Education	Farmer's formal education	Levels	Continuous
Experience-cowpea	Experience in cowpea cultivation	Years	Continuous
Extension-contacts	Access to cowpea production information from extension agents	Dummy	1 = yes, 0 = no
Fertilizers	Use of phosphate fertilizers	Dummy	1= yes, 0 = no
Field-days	Attendance of cowpea field-days	Dummy	1 = yes, 0 = no

Gender	Farmer's gender	Dummy	1 = male, 0 = female
Household-size	Size of farmer's household	Persons	Continuous
Status	Farmer's marital status	Dummy	1 = married, 0 = single

Results and discussion

Appraisal of the socio-economic characteristics of the respondents

Most of the respondents across the 12 local government areas (LGA) surveyed were male (Table 2). The preponderance of male cowpea farmers across the three states is due to the cultural and religious norms of the communities since many women in these areas are not involved in physical farm operations. Women in northern Nigerian societies are mainly involved in post-harvest operations like threshing and winnowing (24). There was, however, a significant number of female cowpea growers in a few of the areas like Kajuru (41%), Makarfi (37%), Bunkure (29%) and Tsanyawa (29%). This is probably due to their contact with extension workers (Table 2). Our report validates findings of Iya and Kwaghe (25) in north-eastern Nigeria and Akpalu et al. (26) in northern Ghana and, that men were more involved in cowpea farming and women were involved in post-harvest operations. The practice of having more men involved in cowpea field operations in northern Nigeria is in contrast to reports from Southern and West African countries like Burkina Faso and Zambia, where women are the main growers of the crop (27).

The average household size of the surveyed areas was 14 persons, indicating most of the cowpea farmers had relatively large households. The size of households varies widely from 8 persons in Kajuru to 18 persons in Birnin_Gwari and Giwa areas (Table 2). Large household size is important, as it provides easy access to labour for field operations from members of the family. Attendance

of field-days on cowpea production was low to none in most of the areas surveyed. Cowpea farmers in Bunkure had the highest attendance and participation in cowpea field-days while most farmers in Birnin_Gwari, Dandume, Danja, Kaita and Makarfi areas reported no attendance of field-days on cowpea production practices. This shows that these farmers have limited exposure and awareness of improved cowpea technologies such as enhanced cropping systems that could increase their yield. Also, a relatively large number of cowpea farmers (44%) reported no contact with extension personnel, 33% had one to five contacts whereas around 23% of the farmers had more than five contacts with extension personnel (Table 2). Contact with extension workers helps in educating and guiding farmers on improved cowpea technologies and practices. Earlier reports have indicated low farmers to Extension ratio (1:10, 000) in Nigeria (28,29) compared to the recommendation of 1:800 - 1, 000 Extension to Farmers' ratio by the World Bank. Agricultural inputs use and advisory services are important for providing guides to smallholder farmers on crop management practices (30). These findings underscore the need to increase training and educational programmes targeting cowpea farmers to achieve increased productivity in the region and ensure a sustainable food system. We noted also that, most of the farmers who reported attendance of cowpea field-days were those that participated in the USAID-supported cowpea upscaling projects at Matazu, Minjibir, and Albasu areas (31).

Half of the farmers interviewed (50%) had more than ten years of experience in cowpea cultivation, 27% had up to 20 years of experience, while approximately 2% have been growing cowpeas for up to 40 years (Figure 2). This means that these farmers are used to the traditional cowpea production practices such as the use of local varieties (landraces), intercropping with staple cereals, and late season planting of the crop after the rains are well established.

Table 2 Socioeconomic characteristics of cowpea farmers across the surveyed areas in northern Nigeria in 2017

	Albasu	Birnin	Bunkure	Dandume	Danja	Giwa	Kaita	Kajuru	Makarfi	Matazu	Minjibir	Tsanyawa	Mean
Gender (%)													
Male	92	86	71	100	100	88	100	59	63	91	100	71	**85**
Female	8	14	29	0	0	12	0	41	37	9	0	29	**15**
Household size	15	18	10	16	13	18	14	8	10	15	10	15	**14**
Field-days attendance	2	0	4	0	0	2	0	1	0	3	2	3	**1**
Contact with extension agent (%)													
None	29	60	29	76	72	60	50	29	37	17	54	24	**44**
Less than 5 times	37	31	40	17	17	29	23	63	43	29	9	53	**33**
More than 5 times	34	9	31	7	11	12	27	7	20	54	37	24	**23**

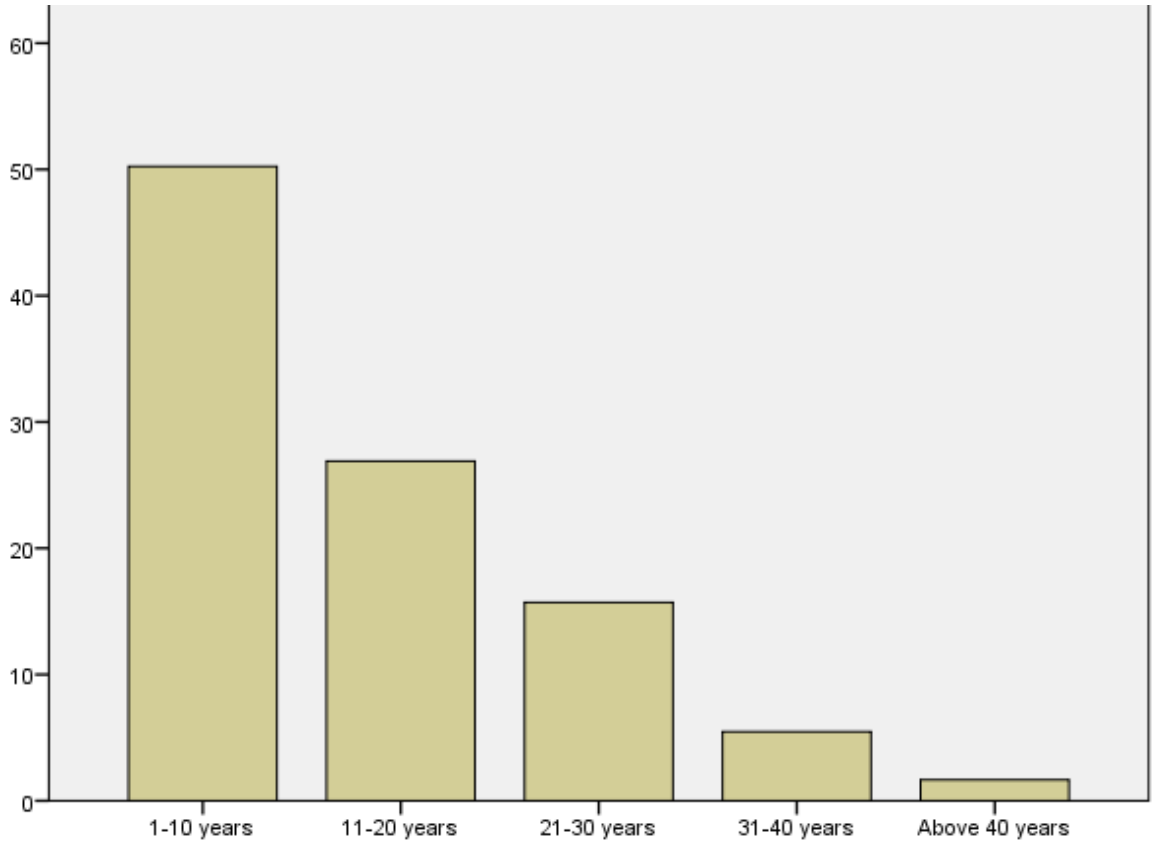

Fig. 2 Farmers' experience in cowpea production across three States of northern guinea savannah of Nigeria in 2017. The X-axis represents the year of experience while the Y-axis is the percent of farmers

Predominant cowpea cropping systems in the guinea savannah areas of Nigeria

The prevailing cowpea cropping systems varied among farmers across the study areas. Intercropping of cowpea with major cereals like maize, sorghum, and pearl millet was the most popular system among the respondents. On average, 42% of respondents use intercropping (Table 3; Supplementary Figure 1). Our findings validate earlier reports in northern Namibia (Horn *et al.*, 2014), northern Ghana (26), and Yobe state in Nigeria (3,7), where intercropping of cowpea with cereals was the main planting systems among smallholder farmers. Despite the huge benefits associated with sole cropping of cowpeas including higher yields, only about 25% of the respondents reported cultivation of cowpea as a sole crop and this was mostly among farmers at

Kajuru, Bunkure, Minjibir, Albasu, and *Tsanyawa* areas. Relay cropping, where cowpea is planted as a secondary crop after harvest of major crops like maize was reported in a few areas (9%) (Table 3; Supplementary Figure 1). The traditional systems of intercropping cowpea with cereals are associated with low grain and fodder yield due to low plant population, shading of cowpeas by the cereal crops, little or minimal fertilization for cowpea and poor level of pest management (3,7). A region-wide survey of West and Central Africa countries including; Nigeria, Niger Republic, Republic of Benin, Togo, Cameroon, and Burkina Faso have been reported in Mortimore *et al.* (33), that indicated diversity in cowpea cropping systems, where over 15 types of intercropping systems were found.

In-depth discussions with farmers during the FGD revealed that sole cropping in these areas was associated with farmers with formal education, contact with extension workers, and participation in intervention programmes like USAID-supported cowpea upscaling, and IITA's varietal demonstrations. Farmers growing cowpeas as a relay crop do plant early maturing varieties of maize and followed by local cowpea cultivars, which are often late maturing. Several reasons were given by farmers for preferring cowpea in intercrop or as a relay with cereals. These include the need to maximize the use of limited land, benefits from residual fertilization of maize fields, ease of management, and post-harvest drying (Table 4). In most intercropped fields, separate application of fertilizer is usually not provided for cowpea and late-maturing cowpea varieties were commonly used (Table 4). Some farmers plant their cowpeas late, such that they mature when most of the cereal crops have been harvested by the time cowpeas would be ready for harvesting, thereby making more labour available. Similar findings have been reported, that popularity of cowpea as intercropping among farmers is due to the culture of the farming communities, multiple

benefits derived from the practice, and the high cost of pest control associated with sole fields of cowpea (6,33,34).

Improved intercropping of cowpeas in a ratio of 2 rows of cereals with four densely populated rows of cowpea (2 cereal rows: 4 cowpea rows), that provides higher productivity with relatively smaller need for inputs like fertilizers and insecticides, has been developed and deployed in some areas of northern guinea savanna of Nigeria by the IITA in the early 2000s (4,5). The improved cereal-cowpea system eliminates most of the problems associated with the traditional inter or relay cropping, as it provides higher plant density for both cereal and cowpea, reduced shading effects associated with traditional intercropping, gives increased productivity of both crops (cereal and cowpea), and increased income for farmers. Also, the system (2 rows cereal: 4 rows cowpea) permits the production of the cowpeas twice within the growing season by using early and medium varieties in the cereal-cowpea mixed intercropping. We observed that farmers do not largely adopt the use of this improved cowpea intercropping in most of the studied areas. Despite the obvious advantages and demonstrated successes of the 2 cereal: 4 cowpea rows intercropping and subsequent large-scale dissemination of this technology in the early 2000s in the northern guinea savannah region of Nigeria. The smallholder cowpea farmers have largely abandoned the practice and most of them plant cowpea in the traditional systems. This underscores the need for continuous and intensive extension programmes to advocate and promote the use of yield-enhancing technologies.

The intercropping of legumes with cereals has also led to the underrepresentation of legumes statistics, resulting in low investment in research and development by donor agencies since attention is always on sole crop fields (1), this calls for the need to scale up production of legumes like cowpeas with innovative high-yielding cropping systems such as 2: 4 cereal-cowpea

combination mentioned earlier. Overall, farmers across most of the locations indicated an interest in continuing intercropping of cowpea (Table 4). The sole cropping of cowpea might provide high yield, resulting from increased plant population but, unfortunately, the adoption has been very low in major growing areas in Nigeria due to its incompatibility with farmers' existing practices and needs, since most of the smallholder farmers are interested in multiple benefits from their investment and are focused on producing enough food for family consumption and surplus for the market (1).

Table 3 Percentage of farmers reporting different cowpea cropping systems across study sites in three the northern Nigerian States

Cropping Systems	Albasu	Birnin Gwari	Bunkure	Dandume	Danja	Giwa	Kaita	Kajuru	Makarfi	Matazu	Minjibir	Tsanyawa	Mean
Sole cowpea	42	17	51	0	0	19	3	71	10	9	51	26	**25**
Mixed cropping	50	17	14	90	61	50	57	27	43	46	31	24	**42**
Relay cropping	0	54	3	0	14	19	0	0	7	3	0	9	**9**
Sole & Mixed farms	8	11	31	10	25	12	40	2	40	43	17	41	**23**

*Total number of farmers across States (N) = 420

Table 4 Summary of farmers' view on different cowpea cropping systems during the focus group discussion sessions across three States in the northern guinea savannah of Nigeria in 2017

Location*	Comments on cowpea cropping systems	
	Sole	**Intercropping**
Albasu	Common here due to project demonstrations	Used for a late-maturing variety
Birnin_Gwari	It is associated with high insect problems. Often not used due to limited access to land.	This system provides insurance against crop failure and weather conditions
Bunkure	Good for market-oriented growers, since it gives higher yield and returns.	Provides more food for families. Cowpea benefits from maize's residual fertilizers
Dandume	No adequate land for sole cropping	Intercropping is more preferred
Danja	Few farmers here plant cowpea in sole cropping. Phosphate fertilizers like SSP are not used by many due to non-availability. Fertilizers, in addition, lead to high vegetative growth of cowpea	Intercropping is the most prominent among farmers here due to the ease of management of the system
Giwa	It yields more but demands a lot of attention	It is easier to manage and provides other benefits
Kaita	It is difficult to manage due to need to spray a lot of insecticides, and where there is no means, the field gets destroyed by insects	Planted with sorghum, millet, or groundnut on some farms. Intercropping guarantee dual benefits
Kajuru	This is more suitable and often used for early maturing varieties.	It is popularly for late maturing varieties, thereby do not require much pest controls
Makarfi	Not too popular here	Cowpea is grown mainly here with groundnut, sesame, and maize.
Matazu	Needs phosphate-based fertilizers such as SSP.	Planted with millet, maize, and groundnut.
Minjibir	It is high yielding and requires a lot of resources such as insecticides to manage.	Requires less investment and grains become mature during the harmattan season, making it easier to manage.
Tsanyawa	Good for early maturing varieties, gives more yield for sale and consumption. It needs more fertilizers than intercropping.	Late maturing is planted, more popular due to limited land. Improved varieties do not grow well in intercrop while farmers prefer intercrop

* Locations are names of local government areas across Kaduna, Kano, and Katsina States, all in northern Nigeria

Determinants for sole and intercropping of cowpea by farmers across study areas

The binary logit was performed to ascertain the influence of nine explanatory variables in Table 1 on the likelihood of cowpea farmers growing the crop as a sole crop or in intercropping. The results showed four independent variables had significant influence on farmers' use of sole or intercropping of cowpea, age category ($p = 0.010$), use of phosphate-based fertilizers ($p = 0.003$), attendance of field-days ($p = 0.033$), and gender or sex ($p = 0.000$) to have contributed significantly to the model prediction (Table 5). The model explained about 16% (Nagelkerke R^2) of the variance in the cropping systems and correctly classified 63.1% of the cases. The use and adoption of technologies and recommendations are dependent on farmers' awareness and advocacy (35). In this study, the logit model was used to understand how explanatory variables influencing the cultivation of cowpea as sole crop by smallholder farmers. Studies demonstrating the use of binary logistics regression models have been used previously to estimate factors influencing use phosphate fertilizers on cowpea fields (16), farmers' knowledge of pea weevils (35), and the decision to use pesticides in vegetable crops (36).

Table 5 Binary logit outputs on variables influencing the use of cowpea cropping system

Variable (see Table 1)	B	SE	Wald	Sig.	Exp(B)
Constant	2.982**	1.006	8.790	0.003	19.731
Age	-0.292*	0.113	6.671	0.010	0.747
Education	0.274	0.232	1.405	0.236	1.316
Experience-cowpea	0.036	0.121	0.090	0.764	1.037
Extension-Contacts	0.203	0.153	1.762	0.184	1.225
Fertilizer use	-0.893**	0.298	9.011	0.003	0.409
Field-days	0.387*	0.181	4.546	0.033	1.472
Gender	-1.507***	0.342	19.446	0.000	0.222
Household-size	0.003	0.013	0.069	0.793	1.003
Status	0.054	0.546	0.010	0.921	1.056

*P < 0.05; **P < 0.01; N = 420; B = coefficient for the constant (or the "intercept"), SE = standard error around the coefficient for the constant, Wald = Wald chi-square test, Sig. = statistical significance of the test, and Exp (B) = exponentiation of the B coefficient, which is an odds ratio

Assessment of cowpea farmers production constraints and preferences

Farmer's description of constraints and preferences varied from one location to another. Major constraints identified by cowpea farmers were pooled with the aid of pairwise ranking across the study areas. These were; insect pests, aphid infestation, pod sucking bugs, limited access to improved seeds, *Striga, Maruca* pod borer, drought, adulterated chemicals, and fluctuation in market prices in that order of importance. (Figures 3 & 4; Supplementary Table 2). It is interesting to note that, farmers in some areas specifically mentioned aphids, *Maruca*, pod sucking bugs, termites, and weevils in storage as their constraints rather than mentioned them as insect pests (Figure 3, Supplementary Figure 2). The factors identified as constraints to production of cowpea in northern Nigeria are similar to cowpea farmers' perception in northern Namibia (Horn et al., 2014; Horn and Shimelis, 2020), and in an intra-household impact study of dual-purpose cowpea among women in northern Nigeria (37).

Understanding farmers' constraints to increased productivity is valuable for breeding programmes in the region target development and deployment of improved varieties with increased yield and income of farmers (10,38). Improved varieties that addressed farmers' constrainst will record large scale adoption.

In the current study, farmers identified and listed different traits as their preferred traits. Across all locations, farmers ranked high grain yield as the most preferred trait desired in a cowpea variety (Figures 5 & 6; Supplementary Figure 3; Supplementary Table 3). This corroborates findings on cowpea preferences of farmers in Mozambique (39). Other preferences varied between the study areas, such as the appealing look of grains termed as "good market value" and large-seeded grains were ranked the second and third most important preferred traits in most of the locations. Consumers and cowpea value chain stakeholders in Nigeria, Ghana, and Mali have indicated similar preferences (12).

Other qualities identified as preferred traits in most of the locations were resistance to pests, early maturity, and good fodder quality. Reasons given for early maturity is that they provide quick food and money to take care of other crops in the field, while those with good fodder types provide feed for their livestock. Interestingly, small-seeded grains were mentioned as an important characteristic in two areas, this was preferred by local food vendors for making cowpea paste called "*moi-moi"*, while large-seeded types were preferred by those interested in using cowpea for direct consumption in local dishes such as boiled rice combined with cowpea meal (Supplementary Figure 3, Supplementary Table 3). Increasing productivity of cowpeas is needed to avoid food crises in high consuming countries, especially as the World population is expected to reach over 9 billion in the next few decades (40).

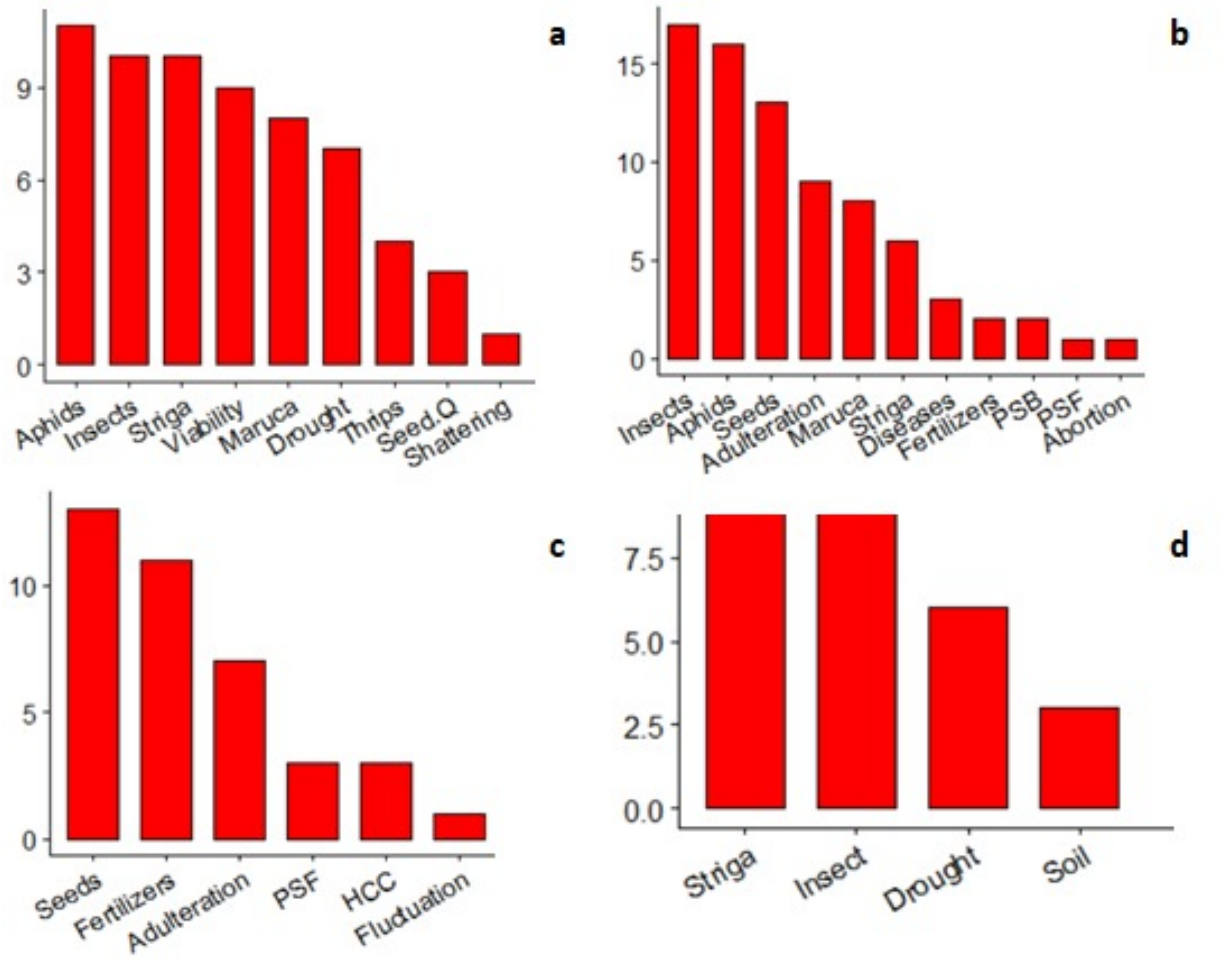

Fig. 3 Farmers' perception of cowpea production constraints using pair-wise comparison ranking in focus group discussions in the Kano State, Nigeria in 2017. The X-axis represents perceived production constraints identified by farmers whereas the Y-axis is the ranking of the constraints by farmers (A) Albasu local government area (LGA) (B) Bunkure LGA (C) Tsanyawa LGA, and (D) Minjibir LGA, all in Kano State, Nigeria. **Note**: Abortion = flower abortion, Adulteration = adulterated chemicals, Aphids = infestation of field by aphid insects, Drought = incidence of drought occurrence, Diseases = occurrence of plant diseases in the field, Fertilizers = poor access to phosphate fertilizer in local market, Fluctuation = fluctuation in market prices of harvested grains, HCC = high cost of chemicals, Insects = infestation by different insect pests, PSB = damage of cowpea plants by pod sucking bugs, PSF = limited availability of safe and affordable grain storage facilities, *Maruca* = high incidence and damage by *Maruca* pod borer, *Striga* = prevalence of *Striga gesnerioides*, Viability = poor viability of seeds used for planting, *Thrips* = infestation of cowpea fields by thrips, Seeds = limited access to improved seeds of varieties, Seed.Q = poor seed quality used at planting, Shattering = shattering of pods of some varieties at harvest, and Soil = poor soil fertility

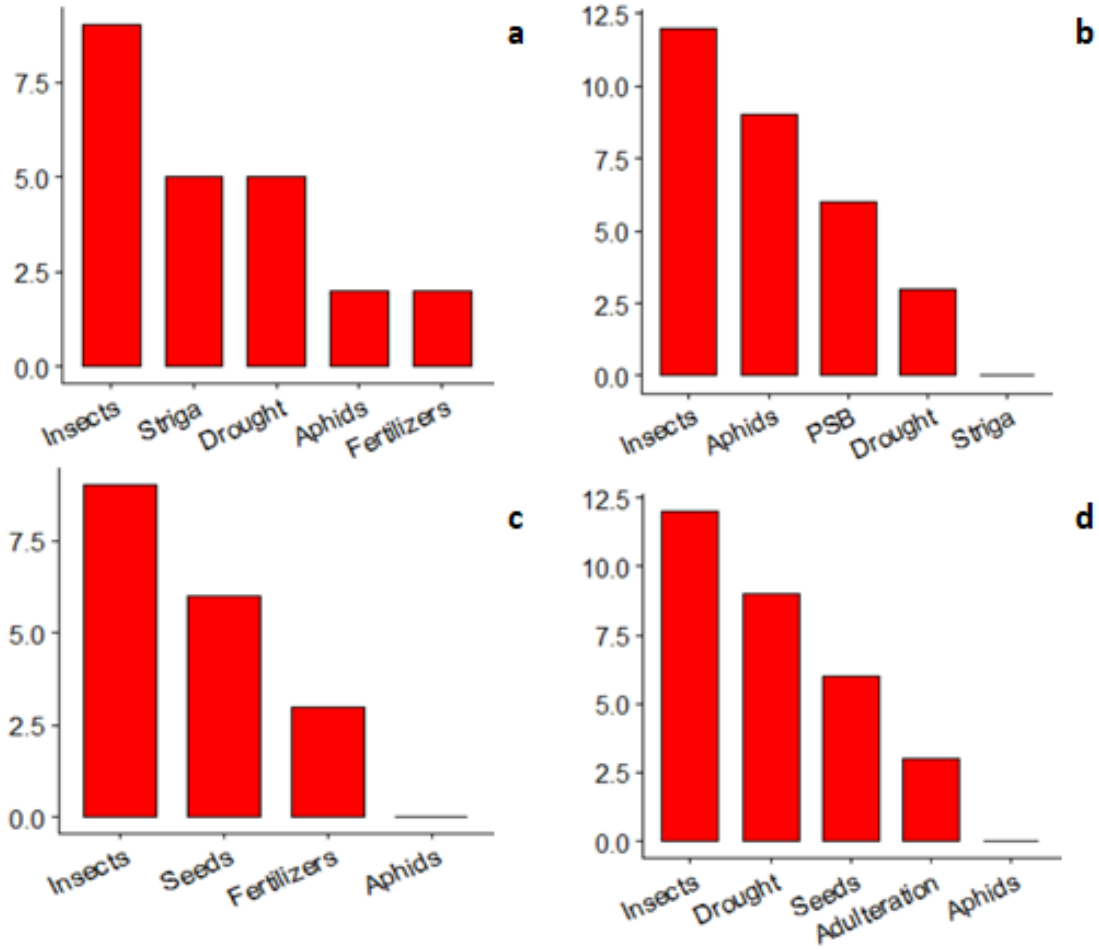

Fig. 4 Farmers' perception of cowpea production constraints using pair-wise comparison ranking in focus group discussions in the Katsina State, Nigeria in 2017. The X-axis represents perceived production constraints identified by farmers whereas the Y-axis is the ranking of the constraints by farmers (A) Matazu local government area (LGA) (B) Kaita LGA (C) Danja LGA, and (D) Dandume LGA, all in Katsina State, Nigeria. **Note**: Adulteration = adulterated chemicals, Aphids = infestation of field by aphid insects, Drought = incidence of drought occurrence, Fertilizers = poor access to phosphate fertilizer in local market, Insects = infestation by different insect pests, PSB = damage of

cowpea plants by pod sucking bugs, *Striga* = prevalence of *Striga gesnerioides*, & Seeds = limited access to improved seeds of varieties.

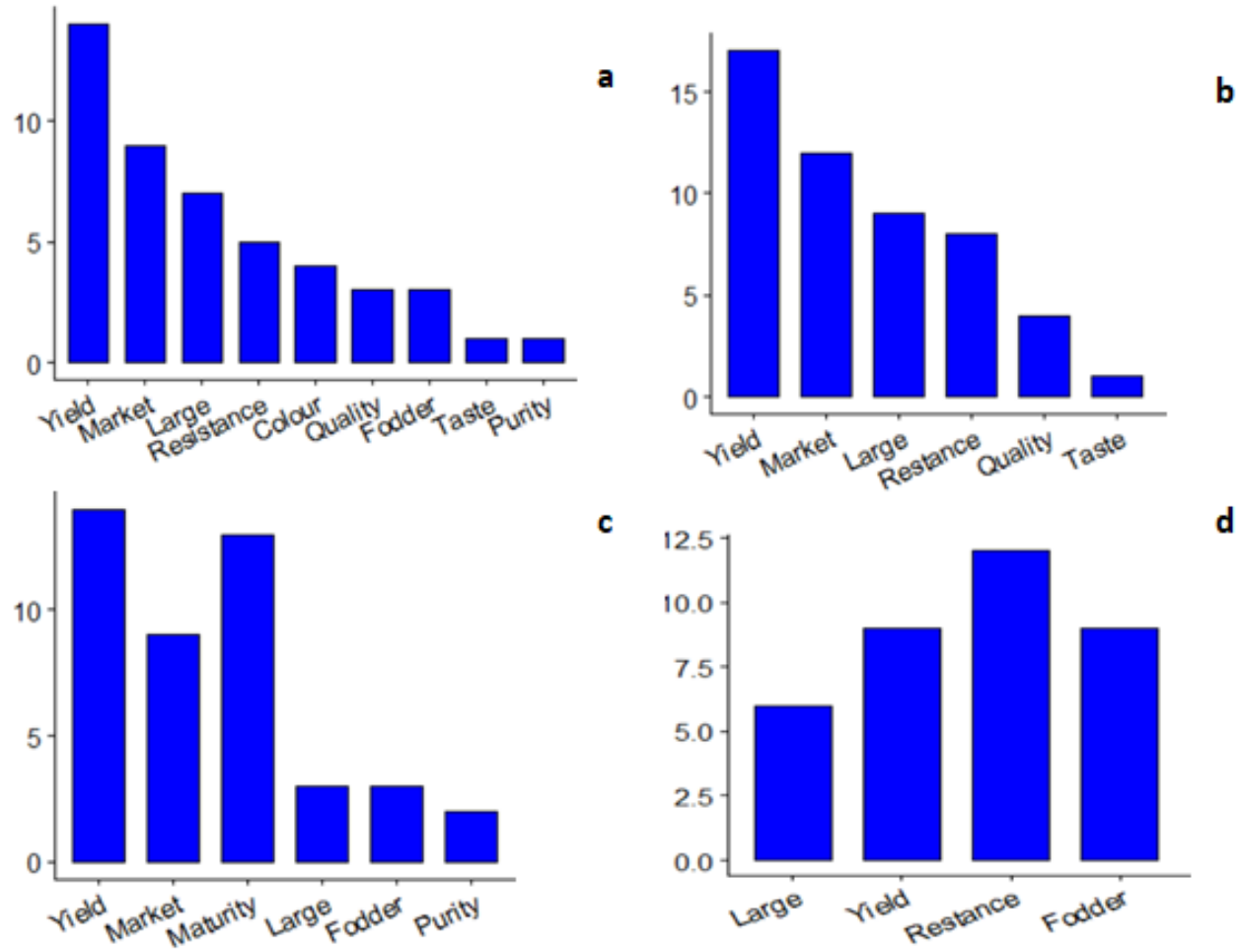

Fig. 5 Cowpea farmers' preferred traits determined using pair-wise comparison ranking in a focus group discussion at Kano State, Nigeria in 2017. The X-axis represents preference traits identified by farmers while the Y-axis is the ranking of farmers' preference traits (A) Albasu local government area (LGA) (B) Bunkure LGA (C) Tsanyawa LGA and (D) Minjibir LGA, all in Kano State, Nigeria. Key: Colour = seed coat colour, Fodder = good fodder quality, Large = large seed size, Maturity = early maturity, Market = good market value, Purity = purity of seeds, Quality = seed quality, Resistance = resistance to insect pests, Taste = good taste, and Yield = high yield

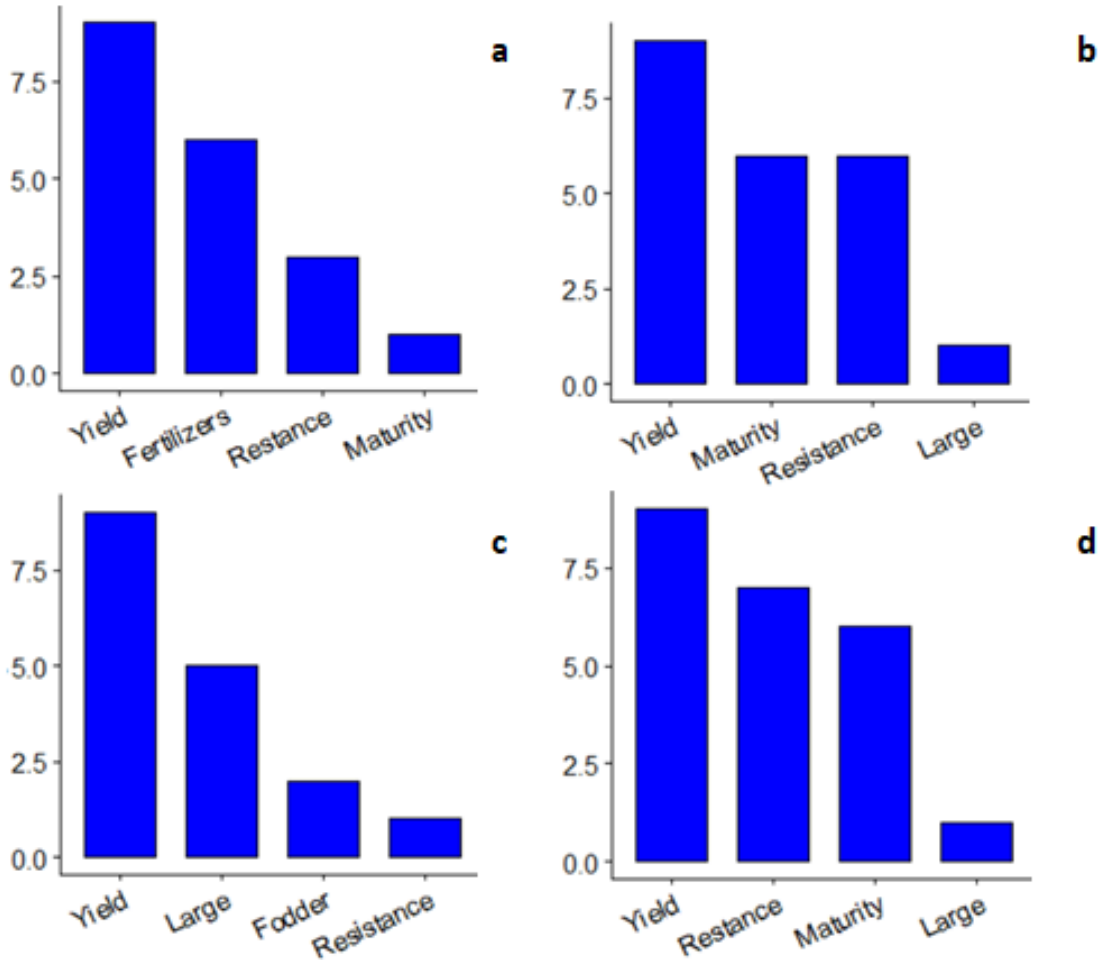

Fig. 6 Cowpea farmers' preferred traits determined using pair-wise comparison ranking in a focus group discussion at Katsina State, Nigeria in 2017. The X-axis represents preference traits identified by farmers while the Y-axis is the ranking of farmers' preference traits (A) Matazu local government area (LGA) (B) Kaita LGA (C) Danja LGA, and (D) Dandume LGA, all in Katsina State, Nigeria. Key: Fertilizers = access to phosphate fertilizer in local market, Fodder = good fodder quality, Large = large seed size, Maturity = early maturity, Resistance = resistance to insect pests, and Yield = high yield

Conclusions

Information gathered from this study has revealed the prevailing cropping system for cowpea, farmers' perceived constraints in production, and farmers preferred traits, providing essential data for designing and implementing breeding programmes for higher genetic gain. Most of the farmers in this study preferred intercropping of cowpea with major cereals. These farmers have had limited exposure to training and guidance from field-day events and interaction with extension workers. Owing to farmers' tradition of intercropping cowpeas with cereal, we, therefore, recommend that there is a need to improve cowpea – cereal intercropping systems that fit the need of most

smallholder farmers. This study found that cultivation of cowpea as sole versus intercropping was also influenced by the age category, gender, use of phosphate fertilizers and attendance of field-days. We further recommend that programmes should be put in place to create awareness of the yield advantage of growing cowpeas as a sole crop and or improved 2:4 cereal-cowpea planting pattern. Cowpea breeding programmes in Nigeria should take into account that resistance to pests is the major constraints to the increased productivity of the cowpea. It can be inferred from findings from this study, that high-yielding cowpea varieties, with large seed size and resistance to insect pests, are likely to be adopted by most farmers in the northern savannah of Nigeria and areas with similar ecologies.

Abbreviations

ABU: Ahmadu Bello University Nigeria

FGD: Focus Group Discussion

IAR: Institute for Agricultural Research

IITA: International Institute of Tropical Agriculture

SSA: Sub-Saharan Africa

Declaration

Ethics approval and consent to participate

The design of this study was reviewed and approved by the Legumes and Oilseeds Research Review Committee of the Institute for Agricultural Research (IAR) Zaria as an internal interview process. The informed consent of participants was always obtained verbally before interviews and focus group discussions were conducted, as well as the option to participate or withdraw from the conduct of the study, was orally given to the participants.

Consent for publication

Not applicable

Competing interests

The authors declare no conflict of interest.

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Authors' contributions
SBM conceived and designed the experiments; performed the experiments; analyzed and interpreted the data, wrote the first draft of the paper. DKD, MFI, PBT, VG, and MLU conceived and designed the experiments; participated in the interpretation of the data and revised the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The data presented in this study are available within the article and supplementary materials.

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