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How Accurate are Adoption Rates? Testing a Protocol for Pigeonpea in northern Tanzania

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Abstract

High rates of outcrossing make it difficult to obtain accurate adoption rates of improved varieties for often cross-pollinated crops. We developed and tested a protocol for identification of improved varieties of pigeonpea in northern Tanzania. The study was conducted in the 2012 season, in collaboration with the Selian Agricultural Research Institute (SARI) and covered 34 villages in 6 districts, for 704 cases. Each sample of pigeonpea plant was identified twice, once by the farmer and once by the enumerator using the protocol. A sub-sample of 51 plants was photographed in the field for later identification by experts. For improved varieties, the convergence between the farmers' identification and the protocol was 74 percent. For local varieties, the convergence was 65 percent. For mixed varieties, the convergence was only 33 percent. We also compared the identification of improved varieties using the protocol with visual identification by pigeonpea experts using the photographs of the 51 sampled plants. The convergence between the experts' identification and the revised protocol ranged from 41 to 71 percent. A simulation exercise based on a revised protocol significantly increased this convergence, but it remained below 90 percent. Hence, accurate identification of improved varieties of pigeonpea is more complex than previously thought. Protocols based on phenotypic traits are a potential solution to the problem of identifying improved varieties in self-pollinated crops, but more reliable protocols are needed to improve the accuracy of adoption rates for improved pigeonpea varieties in Tanzania.

Keywords: Pigeonpea, varietal identification, adoption

JEL classification: Q160, O300, O330

Contents

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1 Introduction

Adoption studies in smallholder agriculture usually rely on the farmer's own identification of improved varieties. The accuracy of such estimates is open to doubt. Farmers may genuinely not know the true identity of the varieties they have planted, particularly if they obtained the seed through informal exchanges with others. Improved varieties may be known by local names, making them difficult to identify. If farmers use re-cycled seed, the improved variety may lose some important traits that distinguish it from the un-improved varieties, making it questionable whether it really is 'improved'. Accurate adoption rates for improved varieties are particularly difficult for often cross-pollinated crops.[1] High rates of out-crossing result in a wide range of plant types that combine traits from both improved and local varieties.

One way to improve the accuracy of adoption rates for these crops is through protocols that identify improved varieties based on their phenotypic traits. The purpose of this study is to develop and test a protocol for the identification of improved varieties that can be included in a household survey and used to collect adoption data by enumerators who may know little or nothing about the crop in question. When tested and proven, this data represents an alternative (or validation check) to using expert opinion and the farmer's own identification.

This discussion paper reports results from a protocol developed for pigeonpea (*Cajanus cajan*), a tropical grain legume grown predominantly in South Asia and Eastern and Southern Africa. Pigeonpea is the third most important food legume in Tanzania in terms of production, after beans and groundnuts. Pigeonpea is the highest- yielding grain legume grown in Tanzania, producing 1012 kg ha^{-1} compared to 706 kg ha^{-1} and 694 kg ha-^{1} for the common bean and groundnuts, respectively (Abate, 2011). The crop is drought tolerant and, like other legumes, fixes soil nitrogen and serves as a good source of dietary protein. At present, 10–20 percent of Tanzanian pigeonpea grain is consumed at home, and approximately 80 percent is sold at external markets (Lyimo et. al., 2012a). Pigeonpea is a crop of growing importance in Tanzania, with yields increasing by about 2.2 percent each year (Abate, 2011). Natural out-crossing in pigeonpea is high, exceeding 40 % in some cases (Ariyanayagam et. al., 1991: 36). Consequently, this often makes it difficult to distinguish between improved and local varieties.

Since the mid-1990s, a number of development projects have sought to increase pigeonpea production in the Northern, Southern, Central, and Eastern Zones of Tanzania. Notable projects include the Improvement of Pigeonpeas in Eastern and Southern Africa (1992–1998), the Pigeonpea-Based Maize Production in Semi-Arid Eastern and Southern Africa project (PIMASA, 2001–2004), Phase 1 of the Tropical Legumes II project (TLII, 2007–2011), European Community(EC) –International Fund for Agricultural Development (IFAD) project (2012-ongoing) and the Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa project (SIMLESA, 2010–ongoing). These projects supported, and continue to support, pigeonpea production through development of improved varieties, participatory on-station and on-farm evaluation, seed distribution, and farmer training.

[1] Often cross-pollinated crops are defined as crops where the rate of out-crossing is above 5 %.

Effective assessment of the impact of these and future projects requires accurate information on adoption rates. The Standing Panel on Impact Assessment (SPIA), in collaboration with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)- Eastern and Southern Africa, has recently launched an effort to assess the impact of legumes research on adoption and production. A key component of this initiative is an innovative effort to develop a varietal identification protocol for pigeonpea. The objective was to develop an easy-to-use and reliable method that could increase the accuracy of adoption rates, allowing future projects to offer targeted assistance and more accurately estimate the impact of such assistance.

2 Methods

This pilot study tests a varietal identification protocol for pigeonpea developed by ICRISAT in Eastern and Southern Africa, in consultation with SPIA. Field sites were identified in consultation with the Selian Agricultural Research Institute (SARI) in Arusha, which also provided logistical support and technical guidance during testing. The protocol was tested in six districts in Tanzania's Northern Zone: Kondoa, Babati, Mbulu, Karatu, Siha, and Arumeru. Each of the study districts had previously been the target of pigeonpea dissemination and improvement projects, or had experienced notable spillover effects from such projects (Lyimo et. al., 2012b). The expected benefit of selecting these districts was to increase the number and diversity of improved varieties captured by the sample, allowing the study to test the protocol's performance in identifying a wide range of varieties.

A research team, consisting of a research assistant and translator, visited 34 villages within these six districts between July 23, 2012 and August 11, 2012. This time frame was selected to correspond with the flowering and podding period for pigeonpea in the Northern Zone. In each district, the research team trained a 2-4 person team of agricultural extensionists to act as enumerators, assisting the research team in administering the protocol and gathering data. The benefits of using enumerators were the ability to reach a greater number of farmers, enable testing of the protocol in a greater number of instances, and the opportunity to observe the ease or difficulty with which the enumerators understood and used the protocol. The research team and enumerators contacted farmers in their fields and used the protocol to conduct scripted interviews. Thus, each test corresponds to an interview with a single farmer in a single field. In total, the protocol was tested 704 times. Table 1 shows the distribution of villages and farmers within the districts visited.

Table 1: Sample sites for protocol testing, northern Tanzania, 2012

District	No. of Villages	No. of Tests
Kondoa	15	156
Babati	6	193
Mbulu	5	153
Karatu	4	147
Siha	1	5
Arumeru	3l	50
Total	**34**	**704**

The draft protocol consisted of a series of 14 questions designed to determine: (1) whether the pigeonpea was a local or improved variety and (2) if the pigeonpea was an improved variety, to identify that variety. The first four questions were intended to determine whether the pigeonpea crop was a local or improved variety. These questions gathered information about maturation time, planting date, and phenotypic expressions particular to local varieties. Once the pigeonpea was classified as a local variety, the interview ended and no more questions were asked.

The final 10 questions were asked only if the pigeonpea had been classified as an improved variety. They were designed to first distinguish between medium- and long-duration improved varieties of pigeonpea, and then identify the specific variety. Once maturation time has been established, the final questions sought to identify the pigeonpea as one of six improved varieties based on unique phenotypic expressions, particularly those relating to flower and pod colour. These improved varieties are ICEAP 00040 (released as Mali), ICEAP 00068 (released as Tumia), the two varieties officially released by the Tanzanian government at the time of testing the protocol, ,and ICEAP 00053, ICEAP 00932, ICEAP 00557 and ICEAP 00554, all of which had been the focus of past dissemination efforts, trials, or other means of diffusion. If the variety could not be determined, the protocol instructed the enumerator to classify the pigeonpea as unknown. A full version of the draft protocol is included as Appendix A.

Each time the protocol was tested, the research team took close-up photographs of the pods and flowers of the corresponding pigeonpea plant.[2] For enumerator-conducted tests, the enumerator was instructed to collect samples of 2–3 flowers and 2–3 pods from a single plant within the corresponding farm, labeling each sample with the farmer's name and village. The research team photographed these samples daily. After the completion of

[2]The criteria for selecting a plant for photographing are that it should be a plant of the majority type (in the event that more than one type is growing in a single field or off-types are present) and it should have both pods and flowers present.

testing, these photographs were used in a verification exercise to elicit expert classifications of the pigeonpea plants included in the pilot test. These expert classifications were the primary method used to evaluate the accuracy of the protocol's findings. The protocol verification exercise is detailed in section 4.1.

The draft protocol was revised based on lessons learnt in the field. These revisions are detailed in Section 5.1.

In advance of pilot testing, the protocol was pre-tested on five pigeonpea farms—three in Babati district and two in Karatu district—from July 20, 2012 to July 21, 2012. Table 2 summarizes the pre-testing results.

Table 2: Summary results from pre-testing of protocol, Tanzania, 2012

Site	Classification	Comments
Babati 1	Local	Likely an "improved local;" presents some improved characteristics
Babati 2	Unknown	Characteristics described do not correspond to a known variety
Babati 3	ICEAP 00053	Farmer was able to identify variety by name
Karatu 1	Unknown	Characteristics described do not correspond to a known variety
Karatu 2	ICEAP 00557	Farmer was able to identify variety by name

Three out of the five pigeonpea crops in the pre-test were successfully identified using the protocol—two as improved varieties, one as local. Two could not be identified because the characteristics reported by the farmer did not correspond to a known variety of pigeonpea. According to question 14 of the protocol, these were classified as unknown. The protocol thus provided a mechanism for classifying all of the pigeonpea varieties encountered during the pre-test. The pre-test confirmed the readiness of the protocol for pilot testing.

3 Results

3.1 Farmer identification

The primary objective of this study was to test the performance and viability of a varietal identification protocol for pigeonpea. The sample was selected with number and diversity of pigeonpea varieties in mind, not representativeness. The following descriptors therefore summarize the results of protocol testing without intending to serve as an impact assessment of any kind. Therefore, the "adoption rates" reported below are not based on a representative sample of pigeonpea growers, which would have provided a very different results for the adoption rates of different varieties of pigeonpea and of variation in adoption rates between districts..

Table 3 summarizes the classifications the protocol yielded during pilot testing. The protocol identified 28 percent of pigeonpea crops as a pure improved variety. The remaining 72 percent was classified as either pure local (51.8 percent); mixed or unknown (19.9 percent); or could not be identified due to incomplete protocol (0.3 percent). Thus, local varieties were judged to be the most common, followed by mixes. The most common improved type was ICEAP 00040, followed by ICEAP 00053. Other varieties that were identified in very small quantities (3 percent of the sample or less) were ICEAP 00932, ICEAP 00557, ICEAP 00554, and ICEAP 00068.

Table 3: Summary results from protocol classification, Tanzania, 2012

n = 704	Total	%
All Improved	197	28.0
ICEAP 00040	89	12.6
ICEAP 00053	74	10.5
ICEAP 00068	1	0.1
ICEAP 00554	3	0.4
ICEAP 00557	9	1.3
ICEAP 00932	21	3
Local	365	51.8
Mixed/Unknown	140	19.9
Incomplete	2	0.3

Source: Survey data

There were significant variations in the varietal classifications between districts, which are summarized in Table 4. The district with the greatest number of improved classifications was Siha, with 60 percent improved. The Siha sample was much smaller than the other district samples, however (only 10 percent of the size of the next smallest sample), making each instance of improved classification count for a greater proportion of the total sample in Siha as compared to the other districts. The second highest instance of improved classification was observed in Babati (46.1 percent), followed by Arumeru (46 percent), Karatu (22.4 percent), Kondoa (18.6 percent), and Mbulu (13.1 percent). The highest proportion of mixed varieties was observed in Arumeru (54 percent). Mbulu was found to have the highest proportion of local variety (78.4 percent), followed by Kondoa (62.2 percent) and Karatu (60.5 percent). However, as discussed in section 5.1, the greater number of local classifications in high altitude districts (such as Mbulu and Karatu) may have been the result of a failure of the protocol to produce accurate classifications in high altitude areas; thus, the actual percent of local varieties may be much lower. Generally speaking, differences in climate, elevation, and the intensity of past dissemination efforts may account for the some of the variation between districts in terms of types grown.

Table 4: Results from protocol classifications, by district, Tanzania 2012

	Kondoa (n = 156)		Babati (n = 193)		Mbulu (n = 153)		Karatu (n = 147)		Siha (n = 5)		Arumeru (n = 50)	
Variety	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
All Improved	29	18.6	89	46.1	20	13.1	33	22.4	3	60	23	46
ICEAP 00040	8	5.1	30	15.5	18	11.8	22	15	0	0	11	22
ICEAP 00053	8	5.1	56	29	1	0.7	4	2.7	0	0	5	10
ICEAP 00068	0	0	0	0	0	0	0	0	0	0	1	2
ICEAP 00554	0	0	1	0.5	0	0	0	0	0	0	2	4
ICEAP 00557	0	0	0	0	0	0	5	3.4	3	60	1	2
ICEAP 00932	13	8.3	2	1	1	0.7	2	1.4	0	0	3	6
Local	97	62.2	59	30.6	120	78.4	89	60.5	0	0	0	0
Mixed/Unknown	28	17.9	45	23.3	13	8.5	25	17	2	40	27	54
Incomplete	2	1.3	0	0	0	0	0	0	0	0	0	0

Source: Survey data

Protocol question 1 asked farmers to report whether the pigeonpea grown was a local variety by responding ‘Yes’ or ‘No’. In practice, a third possible response emerged, with a number of farmers reporting the variety as a local-improved hybrid, or mixed variety. Table 5 below shows how often farmers’ responses of local, improved, or mixed matched the protocol’s classification (“convergence”), and how often the two classifications were different (“no convergence”). In 72.6 percent of cases, a farmer’s response to question 1 matched the protocol’s classification. While a 72.6 convergence rate suggests that, more often than not, farmers and the protocol came to the same or similar conclusion regarding a pigeonpea’s classification, a lack of convergence in 22.7 percent of cases suggests that there remains significant disagreement or misunderstanding regarding classification.

Table 5: Convergence Rate between Farmer Reponses to Question 1 and Protocol Classification, Tanzania 2012

	Convergence	No Convergence	Missing or "don't know" response
No. of instances	511	160	33
% of all responses	72.6	22.7	4.7

Source: Survey data

It is possible that certain pigeonpea types (local, improved, or mixed) may be easier to identify than others. If this is the case, we should see more convergence between farmers' assessments in question 1 and the protocol's classifications for the types that are easier to identify. Table 6 illustrates the rate of convergence by variety type. By comparing the number of times farmers' variety type assessments matched the protocol classification, we can get a sense of the types that may be easier to identify. The table below gives the number of farmer assessments of a certain type as a percent of the total number of protocol classifications of that type, which represents the maximum number of times a convergence was possible.

Table 6: Question 1 Convergence Rate by Variety Type (Local, Improved, or Mixed), Tanzania 2012

	Local	Improved	Mixed
No. of farmer responses	236	146	52
No. of protocol classifications	365	197	140
Convergence rate	64.7	74.1	37.1

Source: Survey data

Out of the 365 cases that the protocol classified as local variety, farmers own assessments concurred in 236 instances (64.7 percent). While the number of protocol classifications in the improved category was smaller at 197, farmers agreed with the protocol's classification of improved in 146 instances, or 74.1 percent of the time. The protocol classified 140 cases as mixed, but farmers' assessments were in agreement in only 52 instances (37.1 percent). These results may suggest that improved types are easier for both farmers to identify and for the protocol to classify. This is plausible given that farmers growing improving varieties are more likely to have been personally engaged in a dissemination program, to have purchased the seeds directly from an Agrovet supplier, or to have sought out high quality seeds through other means, all factors which would increase the likelihood that the farmer would be aware of the type of pigeonpea being grown. In theory, a pure improved variety should also be more readily identifiable by the protocol, since its unique phenotypic expressions should lend themselves to easy and accurate classification.

3.1 Expert Verification

In order to evaluate the accuracy of the protocol's classifications, we conducted a verification exercise composed of 51 pairs of photos and a response sheet. Each pair of photos corresponds to one pigeonpea plant photographed during pilot testing, and includes one close-up photo of the plant's flowers and one close-up photo of the plant's pods. In a small number of cases, the photos are supplemented with additional information about maturation time or growth habit (information which was obtained through pilot testing) to aid in classification.

The primary goal when selecting the 51 plants for the verification sample was to include a diverse range of improved varieties. Thus, while the verification sample is not representative of the protocol's classifications as a whole, it provides an illuminating test of the protocol's ability to classify a broad range of varieties. According to the protocol, 58.8 percent of the sample is classified as an improved variety, 29.4 percent is classified as local variety, and 11.8 percent is classified as mixed or unknown variety.

The two respondents were both scientists specializing in pigeonpea breeding and were therefore considered pigeonpea experts. The verification exercise was conducted in PowerPoint format, with respondents indicating on their response sheets one of the following choices for each of the samples shown: Local, Mixed, ICEAP 00040, ICEAP 00053, ICEAP 00932, ICEAP 00557, ICEAP 00554, ICEAP 00068, Other, or Don't Know. Respondents were placed in separate rooms for the exercise. Table 6 compares the two expert opinions to the protocol classifications.

Table 6 shows a striking lack of convergence across all major types (improved, local, and mixed) between the protocol and either expert's opinion. The first expert classified varieties as improved 1.2 times as often as the protocol did; the second expert did so only 0.8 times as often. Both experts were much less likely than the protocol to classify a variety as local. While the protocol classified 29.4 percent of sample cases as local variety, Expert 2 gave this classification to only 5.9 percent of the sample, and Expert 1 gave a local classification to a mere 2 percent. Expert 2 was much more likely to classify a variety as mixed than either Expert 1 or the protocol, providing this classification in 47.1 percent of cases. In comparison, Expert 2 classified 27.5 percent as mixed, while the protocol provided a mixed classification in only 11.8 percent of sample cases.

Table 6: Verification Exercise Results (n = 51)

	Expert 1		Expert 2		Protocol	
	Total	Percent	Total	Percent	Total	Percent
Total Improved	36	70.5	24	47	30	58.8
ICEAP 00040	10	19.6	4	7.8	10	19.6
ICEAP 00053	7	13.7	0	0	5	9.8
ICEAP 00068	2	3.9	2	3.9	1	2
ICEAP 00554	2	3.9	9	17.6	2	3.9
ICEAP 00557	12	23.5	8	15.7	7	13.7
ICEAP 00932	3	5.9	0	0	5	9.8
ICEAP 00933	0	0	1	2	0	0
Local	1	2	3	5.9	15	29.4
Mixed/Unknown	14	27.5	24	47.1	6	11.8
Total	51	100.0	51	100.0	51	100.0

Source: protocols data and field photographs

Section 5.1 examines problematic usage patterns that may have caused the protocol to produce inaccurate classifications, and suggests some revisions to the protocol. However, the results of the verification exercise suggest that the low rate of convergence among the classifications cannot be attributed solely to flaws with the protocol. This is because there is also a notable lack of convergence between the opinions of the experts themselves. These convergence rates are given in Table 7 below.

Table 7: Verification Exercise Convergence Rates (n = 51)

	Expert 1			Expert 2			Protocol	
	Total	**%**		**Total**	**%**		**Total**	**%**
Protocol	13	25.5	Protocol	8	15.7	Expert 1	13	25.5
Expert 2	12	23.5	Expert 1	12	23.5	Expert 2	8	15.7
Both	17	33.3	Both	17	33.3	Both	17	33.3
None	9	17.6	None	14	27.5	None	13	25.5
Total	51	100.0	Total	51	100.0	Total	51	100.0

Source: protocols data and field photographs

Table 7 shows how often one expert's classification converged with the classification provided by the other expert, the protocol, both, or neither. For these calculations, only an exact match was counted as a convergence. For example, if the first expert identified the variety as ICEAP 00040 and the second expert identified the same variety as ICEAP 00053, this would not have been counted as a convergence even though both scientists classified the pigeonpea as an improved variety. Both experts would have been required to classify the variety as ICEAP 00040 to have been counted as a convergence.

In 74.5 percent of cases, the protocol's classification was in convergence with at least one of the experts' classifications. Perhaps most surprisingly, the experts' classifications were in convergence with each other only 56.8 percent of the time. These low rates of convergence warrant further examination to uncover the cause of the discrepancies in classification. One explanation may be that the two experts – one a plant breeder and the second a research technician – did not have equal knowledge of pigeonpea or equal skills in identifying different traits.

A number of factors may have contributed to the low convergence rate between the experts' classifications. Farmers in the field likely had access to information than the experts did not have during the verification exercise, including the origin of the seed planted, climate and altitude information, information on length of photoperiod, and knowledge of the full profile of phenotypic expressions, which includes growth habit, pea size, pea shape, pea color, stem color, etc. This may help explain why the rate of convergence between farmers' assessments and protocol classifications was higher than that between the protocol's classifications and those of the experts. It may also help explain why the convergence between expert opinions was much smaller than expected. The lack of convergence within the expert opinions suggests that pigeonpea could be more difficult to classify than originally thought, and may require more information than is provided by photographs of pods and flowers.

In Table 8, the criteria for "convergence" were relaxed to provide a more generous estimate of convergence. The exact match requirement was relaxed, so that any two classifications of an improved variety were counted as a convergence, regardless of whether the two parties identified the same improved variety. In addition, local and mixed varieties were grouped together. In essence, Table 8 estimates convergence rates with only two categories of classification: improved and not improved.

Table 8: Modified Verification Exercise Convergence Rates

	% Convergence
Expert 1-Expert 2	72.5
Expert 1-Protocol	68.6
Expert 2- Protocol	64.7

Source: protocols data and field photographs

Even after manipulating the convergence criteria to increase agreement, the experts' classifications only converged in 73 percent of sample cases. This means that in 27 percent of sample cases, two experts looking at the same photographs were unable to come to the same conclusion regarding whether the pigeonpea pictured was or was not an improved variety. This result may suggest that there is a great deal of complexity involved in classifying varieties, and that even expert agreement may be more difficult to come by than was previously thought.

4 Discussion and Recommendations

Several exogenous factors may have affected the protocol's ability to accurately classify varieties. The experience and aptitude of the enumerator—which might determine the extent to which the enumerator probed for complete and accurate responses, the ability of the enumerator to proceed through the questions in the appropriate order, the likelihood that the enumerator would or would not skip questions, etc.—could have influenced protocol responses.

Moreover, as the previous section suggests, the process of correctly identifying a pigeonpea variety may be more complex than previously thought. Given the level of disagreement around varietal classification even among pigeonpea experts, it is likely that the accuracy of protocol responses may be influenced to some extent by the complexity of pigeonpea identification.

In addition to exogenous factors, a number of patterns relating to the protocol's operation and use were identified throughout the course of testing. These problematic patterns derived from the structure of the protocol itself. A description of these patterns and a summary the revisions made to correct for them follows.

Pattern 1: Under-classification of mixed varieties

The draft protocol lacked a mechanism for classifying mixed or hybrid varieties. As a result, mixed varieties were often classified inaccurately as either pure local or pure improved. Because mixed varieties are quite common, making up about 20 percent of protocol classifications despite a lack of language to identify them in the draft protocol, a mechanism to classify them was needed.

To correct for this pattern, two new classifications were created: Mixed-Local and Mixed-Improved. The revised protocol distinguishes between mixed varieties that present predominately local traits, and varieties that present a mix of mainly improved traits. Varieties that take more than nine months to mature, but present atypical pod or flower coloration, are classified as mixed-local. Those that take less than nine months to mature, but present traits that do not correspond with an existing improved variety are classified as mixed-improved. The rationale behind the creation of these classifications is that while they allow distinctions to continue to be made between local and improved varieties, they also allow for more accurate representation of the frequency of mixed varieties.

Pattern 2: Farmer difficulty in quantifying maturation time

Question 2 of the original draft protocol directed the interviewer to ask farmers, "Does it take more than 9 months to mature? (Yes/No)". This question often proved to be a stumbling block in the protocol, as farmers tended to think more in terms of planting and harvesting dates rather than duration. In order to obtain an estimate of time to maturity, it was necessary for the interviewer to probe for the planting date and the date the crop would be ready to harvest. The interviewer then calculated the time between planting and the earliest possible harvest date. Because this process became a standard part of administering the protocol, it was incorporated into the revised version, and replaced the original question 2.

Note that this question was phrased to target maturation time to avoid, as much as possible, inaccurate estimates based on when the farmer actually harvested as opposed to the earliest possible date s/he could have harvested.

Pattern 3: Significant variation in planting time

The original draft protocol was designed to distinguish between local and improved varieties based on planting time. Question 3 directed the interviewer to ask, “When did you plant the pigeonpea?” and record the response as either falling within the time frame of November to December, or February to March. A November-December planting time, coupled with a maturation period of less than nine months, led to a classification as an improved variety; a February-March planting time led to further questions aimed at discerning whether the plant was local or improved.

This distinction was consistently problematic, primarily due to significant regional variation in planting times, even within the same variety. For example, January was a commonly reported planting month in Mbulu and Karatu for variety ICEAP 00040, while this same variety was often planted in April in Arumeru. The original protocol gave no direction for a variety planted in either January or April. Furthermore, the significant variation in planting times suggested that this question would often fail to measure what it sought to measure. It was therefore omitted in the revised version. Field observation suggested that maturation time alone was a consistently accurate predictor of whether a variety was local or improved, so this change was deemed acceptable.

An adjustment to mitigate the effect of altitude, which is associated with temperature and photoperiod, on maturation time was also added to the revised version. During pilot testing, farmers in very high altitude areas (1500 m above sea level and higher) consistently reported longer maturation times for improved varieties. It should be noted that a prolonged maturation time in high altitude areas, as was observed, contradicts existing research on the effect of temperature and photoperiod, which vary with altitude, on maturation time (Silim et. al., 2007). It should be noted that a prolonged maturation time in high altitude areas, as was observed, contradicts existing research on the effect of temperature and photoperiod, which vary with altitude, on maturation time (Silim et. al., 2007). However, in the revised version, a footnote was included to adjust the cut-off time for long-duration improved variety to 11 months instead of nine, and the cut-off time for medium-duration improved variety to eight months instead of six. More research is needed before the above altitude adjustment can be added to the protocol with confidence.

Pattern 4: Imprecise colour descriptors

The protocol originally contained descriptions of pod and flower colours that could be open to multiple interpretations. For example, question 10 instructed interviewers to ask, “Are the flowers streaky?”, referring to a particular colour pattern in which the outside of the flower is yellow with red stripes, and the inside is solid yellow. However, a pigeonpea flower may also be ivory with black streaks. The imprecision of this question thus at times led farmers to respond that a flower's colour was “streaky,” even if it did not present the specific yellow and red pattern that question 10 was intended to identify.

To correct for this pattern, shorthand descriptors of colors, such as “streaky,” were eliminated. These were replaced with more precise colour descriptions, such as “yellow with red streaks.” Respondents were also instructed to refer to the underside of the flower when describing the colour, because it is the underside that presents the unique phenotypic expressions described in the protocol.

In addition, probing was found to be very necessary in order to elicit accurate colour descriptions from farmers. The difference between ivory and yellow, for example, may seem very subtle and was difficult at times for farmers to articulate. It was thus often necessary to ask follow-up questions to clarify the colour a farmer was intending to describe. Thus, directions to probe for complete colour descriptions were added to the protocol. It should be noted that the best way to elicit accurate colour descriptions is likely to incorporate colour photographs or other visual tools into the protocol itself.

Pattern 5: Uncertainty around treatment of off-types

At the beginning of pilot testing, some enumerators attempted to collect samples from multiple types of pigeonpea plants observed in a field, resulting in some samples being collected from a minority of “off-types” (irregular varieties) rather than just the majority type. To ensure that only the majority variety would be identified, instructions were added to the protocol, directing respondents to consider only the majority type of pigeonpea they grow, ignoring off-types.

Pattern 6: Uncertainty regarding mixed responses to Question 4

Question 4 instructs the interviewer to ask, “Does the crop: spread out when it grows, have yellow flowers & straight pods.” Originally, the draft protocol instructed questioners to classify as a local variety in the case of an affirmative response, and as a modern variety in the case of a negative response, but gave no direction for how to proceed if the variety displayed a mix of these characteristics. The final protocol directs the interviewer to ask a follow-up question regarding mixed varieties in the event that a variety displays a mix of the characteristics described in the original question 4. Depending on the response to the follow-up question, the plant is either classified as mixed-local (if it displays a common set of characteristics identified with local mixes) or it is classified as improved and the interviewer proceeds through the remainder of the protocol questions.

The full revised protocol is included as Appendix B. While the revised protocol reflects the accumulated lessons learned during pilot testing, this version has not itself been pilot tested, nor has it been scrutinized for accuracy by pigeonpea experts. However, the revised protocol does represent a suitable starting point for discussion on ways to improve the protocol going forward.

In an attempt to separate the effect of exogenous factors like enumerator aptitude and the inherent complexity of varietal classification, a simulation was conducted using the revised protocol to generate anticipated classifications for the samples included in the verification exercise. If the revised protocol does indeed increase the accuracy of the protocol’s classifications, which would need to be verified through further field testing, the remaining difference in convergence rates should approximate the general effect of exogenous factors on varietal classification.

To simulate the testing of the revised protocol, the researcher used the sample photos included in the verification exercise and the responses to questions 1, 2, 3, 4, 5, and 7 in the original draft protocol to produce anticipated responses to the revised protocol questions. Note that this method likely resulted in a particularly generous estimate of the rate of convergence because the simulation assumed that farmers would answer in accordance with the physical evidence presented by the photographs. The simulation also assumed that farmers would supply the same responses when asked the same or similar questions on both protocol versions. Thus the possibility of human error on the part of the farmer was significantly reduced. Moreover, the groupings used to produce the results of the Modified Verification Exercise displayed in Table 8 (improved/not improved) were also used here, further increasing the likelihood of convergence. Table 9 shows the new convergence rates between the expert classifications and those yielded by simulated testing using the revised protocol.

Table 9: Verification Exercise Convergence Rates, Revised Protocol Simulation

	% Convergence
Expert 1-Expert 2	72.5
Expert 1-Revised Protocol	88.2
Expert 2- Revised Protocol	82.4

Source: simulation exercise

Table 9 shows that while the convergence rate between the experts' opinions remains the same regardless of the protocol version used, the rates of convergence between each of the experts and the revised protocol increased from the corresponding rates produced using the original draft protocol. The convergence rate between Expert 1 and the protocol increased from 68.6 percent with the original protocol to 88.2 percent with the revised version. For Expert 2, this rate increases from 64.7 percent to 82.4 percent. These increases are notable and suggest that there is room for improvement in the original protocol.

However, the inability of even a significantly revised version of the protocol to achieve a convergence rate of more than 90 percent gives cause for concern. Especially considering that the bar for convergence was set very low in this exercise, we would expect this rate to be much higher. This result suggests that key elements of pigeonpea varietal classification are still being overlooked and omitted in the revised protocol; however, this result may also tell us that even a well-honed protocol may fail to yield reliable classifications as the result of exogenous factors, which deserve further study.

5 Conclusions

Accurate information on the adoption of improved varieties is essential for effective impact assessment. However, there is no scientific ‘gold standard’ for identifying improved varieties of self-pollinated crops. One solution to this problem is for plant breeders to develop a protocol based on phenotypic traits. However, experience with a protocol for pigeonpea in northern Tanzania revealed some difficulties with this approach.

A comparison of farmers’ own identification of improved varieties with the identification based on the protocol showed reasonable agreement for improved varieties (74 percent), a slightly lower agreement for local varieties (65 percent) and weak agreement for ‘mixed or unclassifiable varieties (37 percent). This suggests that farmers find it easier to identify improved varieties than either local varieties or mixed varieties that show both improved and local traits. Given the correspondence between the protocol and farmers’ identification, we might conclude that adoption rates based on farmers’ own identification of improved varieties are reasonably accurate.

However, when the identifications made by the protocol were compared with the identification made by two pigeonpea scientists, the results showed an unexpected lack of agreement. While the protocol classified 59 percent of the sample as ‘improved’, the experts classified between 47 and 71 percent as improved. In about one-third of the cases, experts looking at photographs of the same plant disagreed about whether the plant was an improved or a local variety. Revisions to the protocol significantly improved this convergence, but it remained below 90 percent. This suggests that the protocol is not yet a sufficiently reliable instrument for identifying improved varieties of pigeonpea. Conversely, if the protocol is sufficiently reliable, this suggests that expert opinion based on photographic evidence alone is not an accurate method of identifying improved varieties of pigeonpea.

A revised protocol for pigeonpea was developed based on these findings but this revised protocol will itself require testing by farmers and by pigeonpea experts before it can be scaled-up for use in household surveys. The experience with pigeonpea in Tanzania illustrates both the potential value of such protocols but also the difficulty of designing a protocol that is sufficiently accurate to identify improved varieties given the complex mixtures found in often cross-pollinated crops.

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Appendix A: Text of Original Draft Protocol

i). Local vs. Modern Variety of Pigeonpea?

No.	Question
1	Is this a local variety of pigeonpea? (Yes/No)
2	Does it take more than 9 months to mature? (Yes/No)
	IF ANSWER IS YES => CLASSIFY AS LOCAL VARIETY (no more questions)
	IF ANSWER IS NO, GO TO QUESTION 3
3	When did you plant the pigeonpea: NOV-DEC __ or FEB-MAR __
	IF NOV-DEC => CLASSIFY AS MODERN VARIETY AND GO TO QUESTION 5
	IF FEB-MAR, GO TO QUESTION 4
4	Does the crop: spread out when it grows, have yellow flowers & straight pods?
	IF YES, => CLASSIFY AS LOCAL VARIETY (no more questions)
	IF NO, => CLASSIFY AS MODERN VARIETY AND GO TO QUESTION 5

ii) Which Modern Variety of Pigeonpea ?

No.	Question
5	Do you know the name of this modern variety (Yes/No)
6	If yes, what is the name? (write name)
7	Does this variety take more than 6 months to mature? (Yes/No)
	If NO, go to question 8
	If YES, go to question 11
8	Are the flowers yellow? (Yes/No).
	If YES, go to question 9
	If NO, go to question 10.
9	Are the pods light green or dark green?
	If light green => ICEAP 00554
	If dark green => ICEAP 00068
10	Are the flowers streaky? (Yes/No).
	If YES => ICEAP 00557

11 Are the pods green? (Yes/No).

If YES => ICEAP 00053

If NO, go to question 12.

12 Do the pods have dark stripes? (Yes/No).

If YES => ICEAP 00932

If NO, go to question 13.

13 Are the pods striped? (Yes/No).

If YES => ICEAP 00040

14 If this sequence doesn’t follow, i.e., there are mixed characteristics => Unknown variety

Appendix B: Revised Protocol

Instructions: Respondents should consider only the majority type of pigeonpea they grow, ignoring off-types.

No.	Question
1	Is this a local, improved, or mixed variety of pigeonpea? (Local / Improved / Mixed)
2	How long does it take the pigeonpea to mature? *Probe for maturation time by asking for planting month and month the crop will be ready to harvest, then calculating the time between the two:* __________ __________ __________ (Write planting month) (Write month ready to harvest) (Write **maturation time**, in months) IF MATURATION TIME IS **MORE THAN 9 MONTHS***, GO TO **QUESTION 3** IF MATURATION TIME IS **9 MONTHS OR LESS***, CLASSIFY AS I**MPROVED VARIETY** AND GO TO **QUESTION 5**
3	Does the crop: spread out when it grows, have solid yellow flowers and straight pods? (Yes / No) IF **YES**, CLASSIFY AS **LOCAL VARIETY** (STOP) IF **NO** (OR PART NO), GO TO **QUESTION 4**
4	Is the color of the flower's underside red or reddish? (Yes / No) IF **YES**, CLASSIFY AS **MIXED-LOCAL** (STOP) IF **NO**, CLASSIFY AS **IMPROVED VARIETY**, AND GO TO **QUESTION 5**
5	Do you know the name of this improved variety? (Yes / No)
6	If yes, what is the name? (Write name)
7	Does this variety take **6 months or less**** to mature? (Yes / No) IF **YES**, GO TO **QUESTION 8** IF **NO**, GO TO **QUESTION 10**
8	What color is a typical flower's underside? *Probe to get flower color.* IF J**UST YELLOW,** GO TO **QUESTION 9** IF **YELLOW WITH RED STREAKS**, CLASSIFY AS **ICEAP 00557** (STOP) IF **ANY OTHER COLOR** (i.e. red, mottled red, ivory, etc.), CLASSIFY AS **MIXED-IMPROVED** (STOP)
9	What color are the pods? *Probe to get pod color.* IF **LIGHT GREEN,** CLASSIFY AS **ICEAP 00554** (STOP) IF **DARK GREEN**, CLASSIFY AS **ICEAP 00068** (STOP) IF **ANY OTHER COLOR** (i.e. green and black, green and red, black), CLASSIFY AS **MIXED-IMPROVED** (STOP)
10	What color is a typical flower's underside? *Probe to get flower color.* IF **IVORY, WHITE, OR LIGHT GREEN,** GO TO **QUESTION 11** IF **ANY OTHER COLOR** (i.e. yellow, red, etc.), CLASSIFY AS **MIXED-IMPROVED** (STOP)
11	What color are the pods? *Probe to get pod color.* IF **GREEN AND BLACK,** GO TO **QUESTION 12** IF **JUST GREEN**, CLASSIFY AS **ICEAP 00053** (STOP) IF **GREEN AND RED/BROWN**, CLASSIFY AS **ICEAP 00576-1** (STOP) IF **ANY OTHER COLOR** (i.e. all black, etc.), CLASSIFY AS **MIXED-IMPROVED** (STOP)
12	How much green and how much black? IF **ABOUT 50-50 GREEN AND BLACK** (with vertical stripes), CLASSIFY AS **ICEAP 00040** (STOP) IF **MORE BLACK,** CLASSIFY AS **ICEAP 00932** (STOP) IF **ANY OTHER MIX**, CLASSIFY AS **MIXED-IMPROVED** (STOP)
13	If this sequence doesn't follow and variety cannot be identified, classify as **UNKNOWN VARIETY**

* In very high altitude areas (1500 m above sea level and higher), adjust this cut-off time to 11 months.

** In very high altitude areas (1500 m above sea level and higher), adjust this cut-off time to 8 months.