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# FARMERS' PERCEPTIONS ON CAUSES OF SEED BEETLE INFESTATION IN STORED COWPEA IN GHANA

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## ABSTRACT

The seed beetle (*Callosobrucus maculatus* F.), a highly destructive insect pest, causes significant damage to stored cowpea (*Vigna unguiculata* (L.) Walp) grain and other grain legumes. This study aimed to document perceptions from cowpea producers about the causes of seed beetle infestation and the available control options in Ghana. The Relative Importance Index ranking score was used to identify the most significant causes that lead to seed beetle infestation and control measures against the seed beetle. The study used multi-stage and purposive sampling methods to select 170 respondents from Ghana's in the Guinea Savannah, Sudan Savannah, Forest-Savannah Transition and Semi-Deciduous rainforest zones. The Relative Importance Index ranking analysis identified delayed harvesting, high moisture content of seeds at harvest, improper post-harvest storage, improper storage facilities and conditions; and delayed threshing, as the major factors contributing to seed beetle infestation. Synthetic pesticides were the most used treatment option against beetles in stored cowpea with Phostoxin tablet emerging as the predominant (85.0%) insecticide used. These findings are valuable information for the development of sustainable control strategies against beetle infestation in stored cowpea.

*Key Words*: *Callosobruchus maculatus*, cowpea storage, pesticides, Relative Importance Index, *Vigna unguiculata*

## RÉSUMÉ

Le coléoptère des graines (*Callosobrucus maculatus* F.), un insecte ravageur hautement destructeur, cause des dommages importants aux graines de niébé (*Vigna unguiculata* (L.) Walp) stockées et à d'autres légumineuses à grains. Cette étude visait à documenter les perceptions des producteurs de niébé sur les causes de l'infestation par le coléoptère des graines et les options de contrôle disponibles au Ghana. Le score de classement de l'indice d'importance relative a été utilisé pour identifier les causes les plus importantes qui conduisent à l'infestation par le coléoptère des graines et les mesures de contrôle contre le coléoptère des graines. L'étude a utilisé des méthodes d'échantillonnage à plusieurs degrés et ciblées pour sélectionner 170 répondants des zones de savane guinéenne, de savane soudanaise, de transition forêt-savane et de forêt tropicale semi-décidue du Ghana. L'analyse de classement de l'indice d'importance relative a identifié la récolte tardive, la teneur élevée en humidité des graines à la récolte, le stockage post-récolte inapproprié, les installations et conditions de stockage inappropriées et le battage tardif comme les principaux facteurs contribuant à l'infestation par le coléoptère des graines. Les pesticides synthétiques ont été l'option de traitement la plus utilisée contre les coléoptères dans le niébé stocké; le comprimé Phostoxin est devenu l'insecticide prédominant (85,0 %). Ces résultats sont des informations précieuses pour le développement de stratégies de lutte durables contre l'infestation de coléoptères dans le niébé stocké.

*Mots Clés*: *Callosobruchus maculatus*, stockage du niébé, pesticides, indice d'importance relative, *Vigna unguiculata*

## INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) is a popular leguminous crop that provides protein (23 to 33%), carbohydrates (50 to 60%), fat (1%), crude fiber (18.2%), leucine, valine, minerals (iron and zinc), vitamins and folic acid for human nutrition and livestock feeds (Kirse and Karklina, 2015; Gonçalves *et al.,* 2016; Perera *et al.,* 2016). It generates income for smallholder farmers and grain traders, particularly in sub-Saharan Africa (SSA).

In Ghana, actors in the cowpea value chain in urban and peri-urban areas, depend on cowpea-processed foods and beverages, for their daily meals (MoFA-SRID, 2021). Post-harvest losses mainly attributed to the cowpea beetle (*Callosobruchus maculatus* (Fabricius)), are a major challenge to stored cowpea grain (Adebayo and Anjorin, 2018). Beetle activities begin in the field and progress through storage facilities. Infestation intensifies when harvested pods are delayed in the threshing process and when proper storage practices are not strictly adhered to (Tigist *et al.,* 2018). The activities of the beetles render the grains unsuitable for household and commercial purposes and infestations cause major financial losses as they lower product quality and quantity.

Based on beetle devastation, the affected farmers employ traditional pest control methods such as use of wood ash, plant extracts, as well as synthetic pesticides. Cowpea actors perceive traditional methods to provide short-term seed protection, due to their low effectiveness. Moreover, they are labourious to prepare and administer apart from being required in bulky quantities (Osei-Asibey *et al*., 2022).

Over the last decade, farmers and cowpea value chain actors in West and Central Africa have adopted the Purdue Improved Cowpea Storage (PICS) bags for the protective storage of their grains (Baributsa *et al.*, 2013). Though PICS bags adequately protect the seeds as desired, their availability, affordability, flexibility and technical maneuvability of handling them, prevent their active usage by rural farming communities. Therefore, farmers instead resort to the use of synthetic insecticides, like Betallic Super EC, Actellic Super EC, and phostoxin tablets that generate phosphine gas when exposed to air, pyrethrin, and methyl bromide that are pesticidal to the seed beetle (War *et al.,* 2017; Kalpna *et al*., 2022). Although these chemicals protect the cowpea seeds effectively, they expose both the environment and human health to danger.

Adequate knowledge about the possible causes of infestation can aid the development of non-chemical control strategies to reduce over-reliance on synthetic insecticides for controlling seed beetles. A thorough investigation into the underlying causes of infestations of the seed beetle at this stage is essential for ensuring seed sustainability, as seed beetle infestations can lead to significant losses in seed viability and quality. Although previous studies have highlighted some factors contributing to beetle infestation in cowpea, limited information showcasing farmers' understanding and knowledge of the causes of beetle infestation in cowpea in the study area exists (Kumar and Kalita, 2017; Awosanmi *et al*., 2020). Understanding the perceptions of rural cowpea producers about the factors that influence the susceptibility of cowpea grain in storage to beetle infestation, is imperative in designing more efficacious strategies for intervention. The objective of this study was to document perceptions from cowpea producers about the causes of seed beetle infestation and the available control options in Ghana.

## METHODOLOGY

**Study sites.** The study was conducted in four agro-ecological zones (AEZs) in Ghana (Guinea Savannah, Sudan Savannah, Forest-Savannah Transition and Semi-Deciduous rainforest). From these AEZs, four regions were selected for the study. The Northern Region has a large geographical size of roughly 26,524 $Km^2$ and shares a border with Togo. About 75.0% of the population are rural and engage in agricultural activities, which includes production of cowpea as a principal grain legume. Annual rainfall fluctuates between 750 and 1,100 mm, depending on the environmental conditions of the year. Temperatures range between 24.6 and 35.3 $^{O}$C (MoFA-SRID, 2021).

The Upper East Region is approximately 8,842 $Km^2$ land area, and shares borders with Burkina Faso and Togo. The region is 80% rural and agricultural, with cowpea as a household crop. There is one rainy season (May or June through September or October), with the annual mean rainfall between 800 and 1000 mm and temperature ranging from 13 to 45 $^{O}$C, depending on the environmental conditions. The Upper East Region produces 31,460 metric tonnes of cowpea based on average production of 3 years (2018 - 2020) (MoFA-SRID, 2021). The region is 80% rural and agricultural. The native vegetation support crops like millet, sorghum, maize, cowpea, soybean and groundnut.

The Bono East region consists of 603,136 male accounts for 50.1% of the population of 1,203,400 persons with females being 600,264 and accounting for 49.9% (Ghana Statistical Service, 2021). The region has a land area of 23,248 $Km^2$ and experiences a bimodal rainfall pattern, with the major season occurring from March to July and the minor season from August to November, with mean annual rainfall of 750 to 1800 mm. There is usually a short dry spell in August. The area has varying temperatures ranging from 14 to 40 $^{o}$C (MoFA-SRID, 2021). The region primarily focuses on agricultural production, with a range of crops including yam, maize, cassava, tomatoes, watermelon, cabbage, cowpea, soybean and groundnut. The majority of the vegetation is forest, and the soil is generally fertile.

The Ashanti Region has a total land area of 24,389 $Km^2$ and is basically into agricultural production of commodities, including cowpea (MoFA-SRI 2018). The region had 5,440,463 people, of which 2, 679,914 are male and account for 49.3% of the population, and 2, 760,549 are female and account for 50.7% of the population (Ghana Statistical Service, 2021). The major rainy season occurs during March to July, while the minor season runs from September to November. Average daily temperature is around 27 $^{O}$C. The people in the Ashanti Region are basically into agricultural production of commodities such as cocoa, oil palm, citrus, animal rearing and afforestation except those in the Kumasi metropolis that engage mostly in sales activities. The majority of people cultivate crops like cowpea, groundnut, yam, maize, and vegetables. Cowpea output in the region was during 2015 to 2017, amounting to 5,001.18 metric tonnes (MoFA-SRID, 2018).

**Sampling procedure.** A survey was conducted following a multi-stage approach that combined purposive and random sampling techniques. Four regions were purposefully selected due to their significant cowpea production. Five districts were chosen per region for respondent sampling. This was done in collaboration with Agricultural Extension Agents (AEAs), who assisted in identifying the cowpea-producing communities.

Cowpea farmers were then randomly selected from the communities with the help of opinion leaders. The required sample size was determined using the Yamane (1967) formula, with a confidence level of 95%. The population size of 250 respondents was established as the ideal sample size for the study as shown in Equation 1.

$$n = \frac{N}{1+N\,(e)2}$$

$$\text{sample size: } n = \frac{250}{1+250\,(0.05)2}$$

...................................... Equation 1

Where:

n= sample size; N= population size; and e = the degree of accuracy expressed as a proportion.

Even though the statistical sample size was 153 respondents, a total of 170 respondents were selected and interviewed. This discrepancy was to cater for potential non-responses to certain questions, as well as factors such as errors and omissions. Before commencing the interviews, enumerators clarified the purpose of the research, and the nature of the questions, to the respondents, and assured them about the strict confidentiality of the information shared. In their local dialects, all respondents were verbally asked for their agreement to participate in the study before the interview began.

**Data collection.** Before interviewing the selected farmers, semi-structured questionnaire were designed, and pre-tested on a random sample of 10 respondents to assess the clarity of the questions. Subsequently, the questionnaires were refined based on the feedback received from the pre-test.

Data were collected from April to July 2022 and included demographic information (such as age, gender, educational level, financial status, etc.). The perception of respondents on causes of seed beetle infestation in stored cowpea was elicited by asking respondents to rank on a scale of 1 to 9 of the causes, in order of importance, using a 5-point Likert scale (where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree) (Likert, 1932). The respondents also listed and ranked the various control measures applied against the seed beetle in the various circumstances.

**Data analysis.** The data were analysed using the Relative Importance Index (RII) to rate the magnitude of each cause leading to perceived causes of beetle infestation in stored cowpea. The RII specifies the degree of importance ranking for each cause. The RII was computed to identify the most significant cause(s) of seed beetle infestation. The RII was calculated using the formula described by Kometa *et al.* (1994) as:

$$\text{RII} = \frac{\sum w}{AN} = \frac{5n5+4n4+3n3+2n2+1n1}{5N}$$

...................................... Equation 2

Where:

W = respondents weighing of each cause (1 = strongly disagree to 5 = strongly agree);
A = highest weight (in this case, 5);
N = total number of respondents;
n5 = number of respondents who selected strongly agree;
n4 = number of respondents who selected agree;
n3 = number of respondents who selected neutral;

n2 = number of respondents who selected disagree; and
n1 = number of respondents who selected strongly disagree.

Factors of perceived causes were categorised based on the RII score as shown in Table 1. Perceived causes with the highest (0.99-1.00) and lowest (0-0.2) values indicated the most critical and least important factors respectively that contributed to beetle infestation (Tarek *et al.,* 2022). In addition, Spearman's ranking correlation was performed to ascertain the strength of association between the demographic characteristics and perceived causes of seed beetle in stored cowpea.

The F-stat was used as a comparative procedure to determine variations in the beetle control methods and common pesticides employed by the farmers. The mean separation was done at a 5% probability level. All analyses were performed using the Statistical Package for Social Sciences (SPSS) software, Version 21.

## RESULTS

**Demographics characteristics.** The results indicate that the majority (63.5%) of the farmers were male, while 36.5% were female (Table 2). Fifty-nine per cent had no formal education, while 30.6 and 8.3% had received basic and secondary education, respectively. The majority (49.0%) of the producers were aged between 41 and 60 years. Fourty-four percent of the farmers with 59.4% of them having a household size of between 3 and 5 members (Table 2). The income levels of the respondents were notably low, with 87.6% classified as having low income. A significant proportion of respondents (77.1%) had farming experience, and the majority of households (76.5%) owned land measuring up to1.2 hectares

TABLE 1. Interpretation of Relative Importance Index value on causes of beetle infestation

| RII values | Importance level |
|---|---|
| 0.9 - 1.0 | High (H) |
| 0.6 - 0.8 | High-medium (HM) |
| 0.4 - 0.6 | Medium (M) |
| 0.2 - 0.4 | Medium-low (ML) |
| 0 - 0.2 | Low (L) |

Source: Tarek *et al.* (2022)

**Farmers perceptions.** The farmers identified nine causes of beetle infestations in stored cowpea (Table 3). The findings revealed RII values ranging from 0.323 to 0.915, with delayed harvesting emerging as the most significant factor (RII = 0.915).

High moisture content of seeds at harvest ranked second with an RII of 0.831, followed by improper storage after harvest, which had an RII of 0.766, placing it third position. Inadequate storage conditions ranked fourth with an RII of 0.608. However, the use of a non-recommended insecticide ranked last, with an RII value of 0.323 (Table 3).

Among the nine factors perceived by the producers, delayed harvesting, high moisture content of seeds at harvest and improper storage after harvest were ranked as highly significant contributors to beetle infestation (Table 4).

Factors including inadequate storage facilities and condition and delayed threshing were ranked high-medium significance. In addition, poor seed handling, and frequent chemical treatment of seeds were ranked medium significance, while the use of non-recommended insecticides and utilisation of lower recommended insecticide rates were ranked as medium-low significance. Generally, delayed harvesting recorded the highest mean value (4.6) being the main cause of beetle infestation; while high moisture content of seeds at harvest recorded a mean value (4.1), respectively.

**Farmers ability to identify cowpea beetle infestation.** Cowpea producers were consistently able to describe beetle-infested

TABLE 2. Demographics and farm level characteristics of cowpea farmers in the study area

| Characteristics | Sample size (n=170) | Percentage |
|---|---|---|
| **Gender** | | |
| Male | 108 | 63.5 |
| Female | 62 | 36.5 |
| **Education level** | | |
| None | 101 | 59.4 |
| Basic | 52 | 30.6 |
| Secondary | 14 | 8.2 |
| Tertiary | 3 | 1.8 |
| **Age (years)** | | |
| 20-40 | 74 | 43.5 |
| 41-60 | 84 | 49.4 |
| Above 61 | 12 | 7.1 |
| **Marital status** | | |
| Single | 48 | 28.2 |
| Married | 75 | 44.1 |
| Divorced | 28 | 16.5 |
| Widowed | 19 | 11.2 |
| **Household size** | | |
| 1-2 | 45 | 26.5 |
| 3-5 | 101 | 59.4 |
| Above 6 | 24 | 14.1 |
| **Financial status** | | |
| Low income | 149 | 87.6 |
| Middle income | 19 | 11.2 |
| High income | 2 | 1.2 |
| **Farming experience (years)** | | |
| 0-20 | 131 | 77.1 |
| 21-40 | 37 | 21.8 |
| Above 40 | 2 | 1.1 |
| **Land size (hectare)** | | |
| 0-1.2 hectares | 130 | 76.5 |
| 1.6-2.0 hectares | 14 | 8.2 |
| 2.4-4.0 hectares | 26 | 15.3 |

cowpea seeds or grains (Fig. 1). Generally, farmers used three main descriptors to define infested seeds and grains in storage. Fourty-four percent of producers described the presence of holes in seeds or grains as the main symptom of beetle infestation; while the majority (51.0%) indicated that beetle infestation resulted in hollow shells. On the other hand, 5.0% indicated that beetle infestation leads to seed/grain discolouration, which causes them to become powdery.

It was further observed that farmers used diverse means to protect cowpea seeds/grains from beetle damage (Table 5). Most (60.0%) cowpea farmers/producers depended on the use of synthetic insecticides, with 34.0 and 6.0% using the PICS bags and traditional methods, respectively (Table 5). The majority of farmers relied on synthetic insecticides to control beetle infestation, with 85.0% of them using Phostoxin tablets; while 12.0 and 3.0% indicated using Actellic Super EC and Betallic Super EC, respectively (Table 6).

**Relationship between non-parametric parameters.** The Spearman ranking correlation analysis revealed significantly ($P<0.05$) positive associations between high post-harvest seed moisture content and delay in harvesting ($r_s=0.377$, (Table 7). On the other hand, a moderately positive correlation was observed between delay in threshing and improper storage after harvest ($r_s=0.576$), as well as a positive correlation between poor seed handling and improper seed storage ($r_s=0.487$). Additionally, there was a positive correlation between improper storage and high moisture content of seeds ($r_s=0.455$), and a moderate correlation between high moisture content of seeds and delay in threshing ($r_s=0.441$). There was also a correlation between the use of non-recommended insecticides and use of lower recommended rate/dosage of insecticides ($r_s=0.673$).

Negative correlations were found between variables; including gender *versus* use of lower insecticide recommended dosages ($r_s$ = -0.174); and education level *versus* age of respondents ($r_s$= -0.194). Similarly, there was a negative though dismal correlation between the use of lower insecticides recommended doses *versus* the frequency of treatment of seeds with synthetic pesticides ($r_s$= -0.193).

## DISCUSSION

**Farmers perceptions.** Our results identified nine causes of beetle infestation in stored cowpea as perceived by the producers. Although farmers exhibited variations in their percieved causes of the challenges, this demonstrates the diverse knowledge of farmers and their understanding of the causes of the beetle damage in their stored cowpea. This high number of and difference in causes agrees with the results of Manu *et al.* (2019) and Tadesse (2020), who recorded varied causes of insect infestations in stored grains and legumes.

Overall, delayed harvesting, high moisture content of seeds at storage and improper storage were ranked as the most critical contributors for beetle infestation under the prevailing circumstances. The ranking of these factors as the topmost contributors to infestation is supported by findings of previous studies (Hagstrum and Phillips, 2017; Manu *et al*., 2019; Kalpna *et al*., 2022), which obtained a similar ranking of the major influencers of cowpea susceptibility to the beetle.

The high ranking of delayed harvesting as a major cause of beetle infestation may be attributed to the wide perception that beetle infestation starts in the field, where the beetles lay eggs on mature pods (Hagstrum and Phillips, 2017; Kalpna *et al*., 2022). Consequently, delayed harvesting predisposes the grain to accelerated infestation of beetles before they are transported to storage areas where the environment is conducive for their multiplication. The significance of delayed harvesting to beetle infestation conforms to the findings of Kalpna *et al*. (2022), and

TABLE 3. Relative Importance Index ranking score of perceive causes by farmers across study area

| SI. No. | Perceived causes | Strongly disagree | Disagree | Neutral | Agree | Strongly agree | Mean | RII | Rank |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Delayed harvesting | 6 | 4 | 6 | 64 | 515 | 4.58 | 0.915 | 1 |
| 2 | High moisture content of seeds at harvest | 11 | 10 | 21 | 148 | 350 | 4.15 | 0.831 | 2 |
| 3 | Improper storage after harvest | 8 | 2 | 3 | 120 | 365 | 3.83 | 0.766 | 3 |
| 4 | Delayed threshing | 10 | 24 | 15 | 80 | 265 | 3.03 | 0.606 | 5 |
| 5 | Poor seed handling | 24 | 40 | 45 | 56 | 175 | 2.62 | 0.523 | 6 |
| 6 | Inadequate storage facilities and condition | 6 | 8 | 66 | 160 | 155 | 3.04 | 0.608 | 4 |
| 7 | Frequent treatment of seeds with chemicals | 8 | 20 | 45 | 100 | 160 | 2.56 | 0.512 | 7 |
| 8 | Use of non-recommended insecticide | 2 | 12 | 6 | 80 | 110 | 1.62 | 0.323 | 9 |
| 9 | Utilisation of lower insecticide recommended rate/dosage | 3 | 8 | 18 | 88 | 120 | 1.82 | 0.365 | 8 |

RII = Relative importance index.

TABLE 4. Relative Importance Index of the causes of seed beetle infestation as perceived by cowpea producers in Ghana

| S/N | Percieved causes of infestation | RII | Rank | Significance |
|---|---|---|---|---|
| 1 | Delayed harvesting | 0.915 | 1 | High |
| 2 | High moisture content of seeds at harvest | 0.831 | 2 | High |
| 3 | Improper storage after harvest | 0.766 | 3 | High |
| 4 | Delayed threshing | 0.606 | 5 | High-medium |
| 5 | Poor seed handling | 0.523 | 6 | Medium |
| 6 | Inadequate storage facilities and condition | 0.608 | 4 | High-medium |
| 7 | Frequent treatment of seeds with chemicals | 0.512 | 7 | Medium |
| 8 | Use of non-recommended insecticide | 0.323 | 9 | Medium-low |
| 9 | Utilisation of lower insecticide recommended rate/dosage | 0.365 | 8 | Medium-low |

RII = Relative importance index

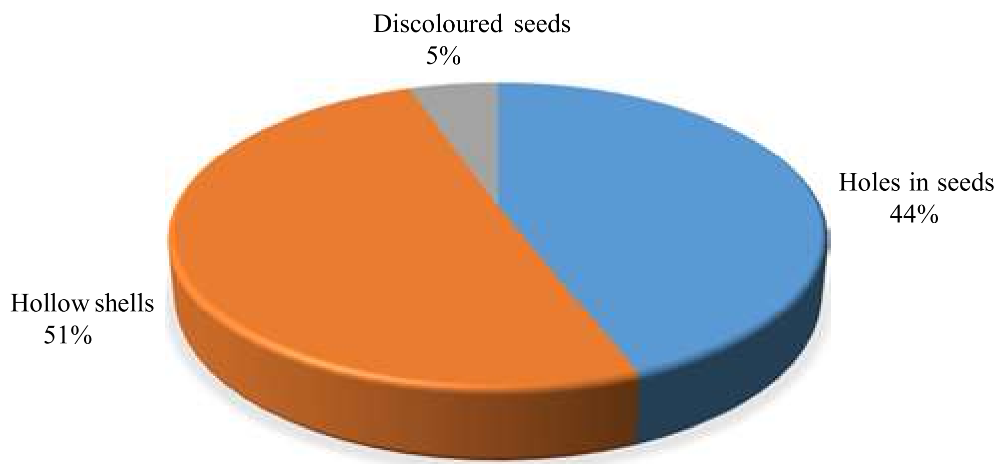


Figure 1. Farmers' description of beetle infestation damage on cowpea seeds in Ghanaian conditions.

TABLE 5. Control methods employed by cowpea producer/farmers in the study area

| Control methods | Regions | | | | Total | F-stat | P-value |
|---|---|---|---|---|---|---|---|
| | Upper East | Northern | Ashanti | Bono East | | | |
| Synthetic pesticides | 26(61.9) | 17(42.5) | 41(93.2) | 18(42.8) | 102(60.1) | | |
| Traditional methods | 0(0.0) | 4(10.0) | 0(0.0) | 6(14.3) | 10(6.1) | 10.946*** | 0.000 |
| PICS bags | 16(38.1) | 19(47.5) | 3(6.8) | 18(42.9) | 56(33.8) | | |

The values in the bracket are the percentage for each column; *** P<.01

TABLE 6. Common pesticides used by farmers in Ghana to control beetle infestations in stored cowpea across the study area

| Name of pesticides | Regions | | | | Total | F-stat | P-value |
|---|---|---|---|---|---|---|---|
| | Upper East | Northern | Ashanti | Bono East | | | |
| Betallic Super EC | 0(0.0) | 0(0.0) | 1(2.3) | 1(3.4) | 2(2.9) | | |
| Actellic Super EC | 4(15.4) | 4(22.2) | 1(2.3) | 2(6.9) | 11(11.7) | 0.408 | 0.747 |
| Phostoxin tablet | 22(84.6) | 13(72.2) | 42(95.4) | 26(89.7) | 103(85.4) | | |

The values in the bracket are the percentage for each column; *** P<.01

Mihiretu and Wale (2013), that timely harvesting and threshing are effective strategies for reducing beetle carryover from the field to storage. However, according to Kumar and Kalita (2017), the limited availability of farm labour and financial constraints faced by smallholder farmers delays farm operations such as timely harvesting and threshing of cowpea which results in the build-up of beetles.

Our results further identified high seed moisture at harvest as a critical factor in beetle infestation in cowpea; which also agrees with earlier reports (Suleiman *et al*., 2013; Gangambika *et al*., 2022; Harshaprada *et al*., 2023), who found that high seed moisture is a major cause and significantly influences beetle and disease infestation in stored grains and seeds. The ranking of seed moisture as a major cause of beetle infestation, suggests the lack of technical knowledge by the majority of farmers to determine the maturity period and right time to harvest cowpea.

Unavailability of devices for farmers to determine the right moisture content of seeds before storage also makes the grain highly predisposed to beetle infestation. Seeds are hygroscopic, and therefore absorb water from the atmosphere, hence a high initial moisture content can significantly increase its moisture level during storage making it easily deteriorate and attacked by the beetle. (Amjad and Anjum, 2002; Awosanmi *et al*., 2020). High seed moisture content according to Awosanmi *et al*. (2020) provides ideal condition for beetle oviposition and larval development. Again, high seed moisture level softens the cowpea seed coat, making it easier for beetles to penetrate and access their contents ( Kumar and Kalita (2017).

High seed moisture content is greatly influenced by the storage condition. It is therefore not surprising that farmers ranked improper storage after harvesting as the third most critical factor for beetle infestation in stored cowpea. Small-scale farmers lack suitable storage facilities; typically they store grains in plastic containers, woven polythene bags, jute bags or open shed and sometimes in buildings used as warehouses (Awosanmi *et al*., 2020). Such structures used by farmers expose seeds to different temperatures which are often conducive for insect pest infestation. In addition, environments with high relative humidity (RH), facilitate the seeds ability to absorb moisture from the atmosphere, thus increasing their moisture content. The results of the current study on the contributory role of improper storage conditions and higher seed moisture content on beetle infestation agrees with previous works by Lawrence and Maier (2011), Suleiman *et al*. (2013) and Awosanmi *et al*. (2020), who found a strong relationship between these factors.

**Control methods.** From the present study, it is evident that the most widespread control method employed by farmers is the use of

TABLE 7. Correlation coefficients of non-parametric causes of seed beetle infestation of cowpea seeds

| Factors | GEN | AG | EDU | FS | DH | HMCS | ISHC | DTHR | PHS | ISC | FTS | ULDS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GEN | | | | | | | | | | | | |
| AGE | 0.076 | | | | | | | | | | | |
| Edu | -0.078 | -0.194* | | | | | | | | | | |
| FS | -0.060 | 0.069 | -0.068 | | | | | | | | | |
| DH | -0.069 | -0.103 | 0.071 | 0.051 | | | | | | | | |
| HMCS | 0.046 | -0.118 | 0.087 | 0.125 | 0.377** | | | | | | | |
| ISHC | -0.138 | -0.008 | -0.037 | 0.087 | 0.190* | 0.206* | | | | | | |
| DTHR | -0.107 | -0.053 | 0.013 | 0.024 | 0.203* | 0.159 | 0.576** | | | | | |
| PHS | -0.140 | -0.102 | -0.076 | -0.045 | 0.053 | 0.014 | 0.487** | 0.441** | | | | |
| ISC | -0.158 | 0.010 | -0.013 | -0.115 | 0.098 | -0.142 | 0.260** | 0.285** | 0.455** | | | |
| FTS | -0.032 | -0.066 | -0.074 | -0.014 | -0.143 | -0.119 | 0.060 | 0.130 | 0.212* | 0.244** | | |
| UNIG | -0.081 | -0.048 | -0.099 | -0.107 | 0.002 | 0.117 | 0.199* | 0.171 | 0.114 | 0.009 | -0.082 | |
| ULDS | -0.174* | -0.040 | -0.002 | -.0111 | 0.065 | 0.083 | 0.250** | 0.224* | 0.126 | 0.094 | -0.193* | 0.673** |

**. * significant at the 0.01, 0.05 level, respectively. GEN = gender, EDU = education level, FS = financial status, DH = delay in harvesting, HMCS = high moisture content of seeds after harvest, ISHC = improper storage after harvest, DHTR = delay in threshing, PHS = poor handling of seeds, ISC = improper storage facilities and condition, FTS = frequent treatment of seeds with chemicals, UNIG = using non-recommended insecticide for grain treatment and ULDS = utilisation of less recommended insecticide for grain treatment synthetic pesticides. This finding conforms to the findings of Soumia *et al.* (2017) that farmers relied heavily on synthetic pesticides to minimise losses caused by insect pests in stored cowpea grains/seeds. Despite the harmful effect of synthetic insecticides and the strong advocacy to minimise their use, we found that 85% of farmers in the study area used synthetic insecticides, agreeing with the results of Osei-Asibey *et al.* (2022), who found that 58% of cowpea farmers used synthetic insecticides as protectants. The divegency in results of the two studies could be due to differences in agroecological conditions. The overreliance on synthetic insecticide may be due to limited knowledge of farmers on the availability or lack of access to more safe alternative protectants such as biopesticides. However according to Massomo (2019) farmers reliance on synthetic insecticides could be due to their quick action, broad spectrum and the response to fear of economic loss resulting from insect attack.

Our results, further revealed high use of phostoxin tablet in cowpea seed storage. This agrees with the findings of Osei-Asibey *et al.* (2022), and Berchie and Maaledoma (2021), who reported the extensive use of phostoxin tablets in the control of leguminous beetles due to their ease of application and high pest-repelling efficiency. This is inspite of the fact that they pose concerns to the environment, human health, pest resistance and other non-target organisms (Gourgouta *et al*., 2019). In the present study, farmers identified and ranked improper storage as a major contributor to beetle infestation in stored cowpea. This is supported by the fact that only about 30% of the farmers stored seeds or grain in the Purdue Improved Cowpea Storage (PICS) bags. This contrasted slightly with the results obtained by Osei-Assibey *et al.* (2022), who reported 40% usage of the PICS bags in the protection of cowpea seeds/grain.

Despite its effectiveness in protecting cowpea against beetles, adoption and use by farmers was found to be low. This can be attributed to their unavailability and high cost, both of which are prohibitive to adoption of this technology among cowpea farmers. Furthermore, traditional methods such as the use of wood ash, were less efficient (6.1%) suggesting that such methods, provide only temporary grain protection and require large quantities of stuff to be sufficiently effective.

**Farmers ability to identify cowpea beetle infestation.** The farmers were consistently able to identify the beetle-caused damage on the cowpea seeds or grains.They observed hollow shells, holes in seed and discoloured seed as major damage inflicted on the seed by beetles. Although the educational background of farmers was relatively low (59.4%), they were able to recognise the characteristic damage on the seeds. This suggests that their familiarity with the beetle comes from years of farming experience. The findings revealed that 77.1% of the farmers had over 20 years of farming experience, enabling them to identify cowpea beetle damage early and take timely action. However**,** the degree of education may have an impact on one's decision for instance to choose objectively between alternative techniques. Having most farmers being uneducated may lower the search for information regarding effective pesticides, application rate, storage method, and cultural practices to minimise losses associated with beetle infestation. Furthermore, an educated farmer is in a position to leverage their knowledge to implement cost-effective measures to minimise beetle damage, leading to better control and profitability. This finding agree with Osei-Asibey *et al.* (2022) who reported 60% of uneducated farmers in their study.

**Relationship between non-parametric parameters.** The positive correlation of ($r_s$ = 0.576) observed between delayed threshing and improper storage at harvest means that there is a fair association between the two parameters. The low-income level of majority of farmers may hinder their ability to afford simple machines like mechanical threshers causing farmers to rely on family/human labour, leading to delays in threshing, thereby exposing harvested pods to beetle infestation. Seeds left unthreshed for longer time after harvesting become more susceptible to beetle attack due to weakening of protective layers (Awosanmi *et al.*, 2020). Again, the low financial status of farmers limits their ability to purchase proper storage and handling facilitities to preserve the intergrity of seeds. The reliance on substandard structures and limited technological know-how for proper post harvesting handling of seeds increases susceptibility of cowpea in storage to beetles attack.

## CONCLUSION

The present study has shown that the most critical factors responsible for beetle infestation in stored cowpea are delayed harvesting, high moisture content of seeds at harvest and improper storage after harvest. Similarly, factors such as inadequate storage facilities and conditions, delayed threshing and poor handling of seeds were considered by farmers as moderately important causes; while the use of non-recommended insecticide and application of lower rate/dosage of recommended insecticides were reported as the least important causes of beetle infestations in stored cowpea. On the other hand, the use of synthetic pesticides was identified as the mostly preferred protectants against the beetle infestation in stored cowpea, with phostoxin tablets being the most widely used insecticide.

The findings of the present study will provide valuable information that could assist in the development and promotion of appropriate interventions to manage cowpea beetle infestation in store.

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