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Farmers' Knowledge, Control Methods, and Challenges of Managing Bean Leaf Beetles (*Ootheca* spp.) in Uganda

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Abstract: Bean leaf beetles (BLBs) (*Ootheca* spp.) are important field insect pests of the common bean (*Phaseolus vulgaris* L.) in agricultural communities in Sub-Saharan Africa. A survey of 128 farmers was conducted in Arua, Hoima, Lira, and Lwengo districts in Uganda, where the common bean is a major food and income crop. This paper evaluated farmers' knowledge, control strategies, and challenges in managing BLBs. Over 87% of the farmers in Arua and Lira could identify BLBs by local names, compared to less than 45% in Hoima and Lwengo. Less than 8% of the farmers in all districts were aware that BLBs oviposit, diapause, and then emerge from the soil. Many farmers (75%) in Lwengo perceived BLBs infestation as mild, 65.6% in Hoima thought it was moderate, and 78% and 56% in Arua and Lira respectively thought it was severe. The use of chemicals was popular in all districts and also perceived to be the most effective method for controlling BLBs. The reported obstacles to controlling BLBs were a lack of understanding of proper control methods, and the existence of fake insecticides on the market. We recommend that the Ministry of Agriculture, Animal Industry and Fisheries customizes the agricultural extension information packages to include BLBs and cost-effective control strategies for them.

Keywords: common bean; farmers' knowledge; insecticides; control strategies

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1. Introduction

The common bean (*Phaseolus vulgaris* L.) is one of the key pulses grown by about 54% of farmers in Uganda, with an annual production of approximately 707,000 metric tons (MT) [1]. In Uganda, the expected yield of common bean is 2.5–3.5 MT/ha, far higher than the realised yield of 0.6–0.8 MT/ha [2,3]. The low production and productivity of the common bean in Uganda is due to many factors, including biotic (pests, diseases, and weeds), abiotic (water stress and declining soil fertility), and socio-economic constraints (limited extension services and poor quality seed) [4,5]. Bean leaf beetles (BLBs) are among the important field insect pests of common beans in Uganda and East Africa at large [6,7]. *Ootheca mutabilis* Sahl, *O. proteus* Chapius, *O. orientalis* W., and *O. ugandae* Kortenhaus & Wagner sp. n. have all been found in Uganda's various agroecological zones [8].

Bean leaf beetles feed on several leguminous crops, including cowpea (*Vigna unguiculata* L.), soybean (*Glycine max* L.), pigeon pea (*Cajanus cajan* L.), members of the hibiscus family (*Hibiscus* spp.), and okra (*Abelmoschus esculentus* L.) [9]. The BLBs attack roots, leaves, flowers and pods of leguminous crops, causing severe damage to seedlings. The damage may persist through to the post-flowering stages. Yield loss of common bean to BLB infestations in Uganda is estimated at 48.9% [10].

Smallholder farmers dominate crop production in Africa, and they frequently rely on self-learning of techniques to manage field and storage pests [11]. Although several methods have been proposed for the control of BLBs in Uganda, designing and implementing an efficient Integrated Pest Management (IPM) programme for these pests is complicated by a lack of information on farmers' knowledge, perceptions, control methods, and pest management constraints [7]. The collection and comprehension of existing farmers' knowledge of the pest, control methods, and obstacles, are required for the development of sustainable pest control approaches. Farmers' knowledge, perceptions and practices are known to fluctuate within and between places [2,12,13]. These differences could be related to the identification of the pest, perception of pest impact, management practices, and constraints influenced by agroecological or socio-economic factors. In developing an IPM program for smallholder bean farmers in common bean-growing countries like Uganda, data concerning existing farmers' knowledge, management methods, and obstacles experienced in managing BLBs are critical. The goal of this study was to analyse existing farmers' knowledge of BLBs, control strategies with their perceived effectiveness, and challenges to management, to help build a participatory IPM strategy against these pests in Uganda.

2. Materials and Methods

2.1. Study Site

Purposive sampling was used for identification and selection of information-rich agroecological zones, districts, sub-counties, and households where the common bean is a staple food [14,15]. Four districts were selected from four agroecological zones (Table 1; Figure 1). Four sub-counties were selected from each district, depending on the extent of common bean growing. Aroi, Manibe, Katrini and Dadamu sub-counties were selected in Arua (3°1′49.19″ N 30°54′26.9″ E); Buhimba, Kiziranfumbi, Kyabigambire, and Kabwoya in Hoima (1°25′55″ N 31°21′09″ E); Agweng, Ogur, Barr and Aromo in Lira (2°19′60″ N 33°05′60″ E); and Kyazanga, Lwengo, Ndagwe and Malongo in Lwengo (0°25′3.7″ S 31°27°4.9″ E) [1]. In each of the study districts, researchers from the responsible Zonal Agricultural Research and Development Institutes (ZARDIs) were consulted and involved in the selection of locations for the survey.

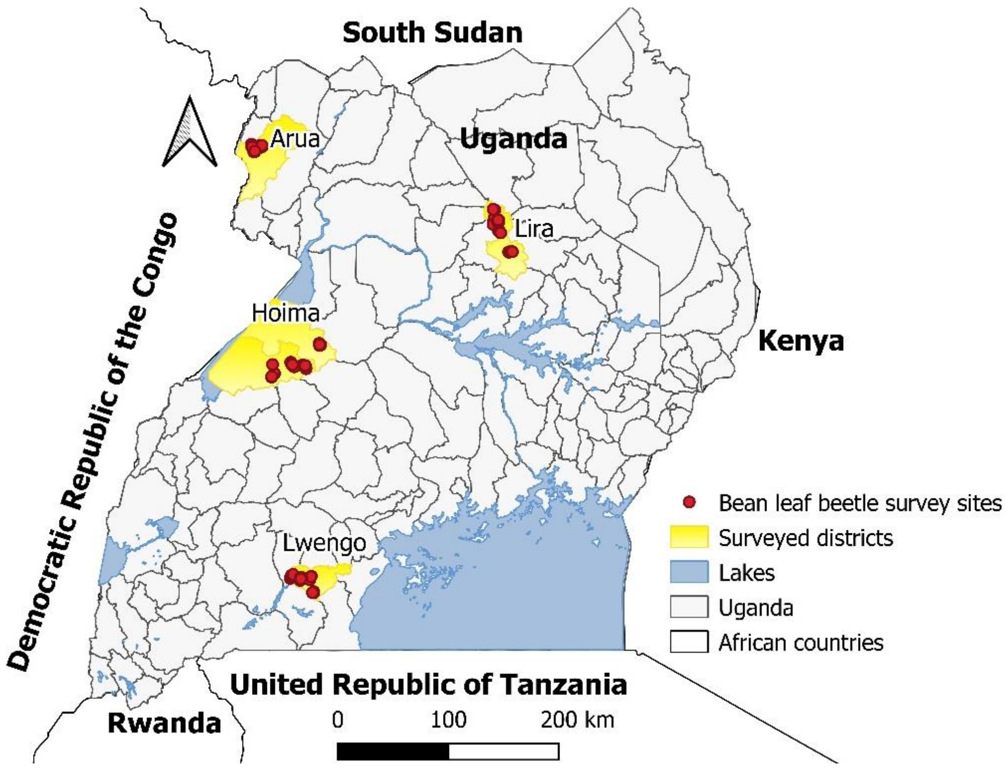

Figure 1. Map of Uganda showing the study sites and districts.

Table 1. Description of the study area.

Agroecological Zone	District	Elevation (masl)	Mean Annual Rainfall (mm)	Mean Annual Temperature (°C)
West Nile Farmlands	Arua	750–780	1250	22.9
Central Wooden Savannah	Hoima	1108–1170	1400	22.6
Northern Moist Farmlands	Lira	1080–1107	1400	23.2
Western Masaka-Mityana Farmlands	Lwengo	1260–1300	1150	20.7

2.2. Data Collection

A total of eight common bean-growing households were selected from each of the 16 sub-counties in consultation with local leaders, constituting an overall total of 128 households, owing to financial limitations. Other studies with even lower sample sizes were used to generate good data and conclusions: Lebesa et al. [16] conducted a survey involving 92 respondents on "Farmers' knowledge and perceptions of blister beetles, *Hycleus* spp. (Coleoptera: Meloidae), a pest of *Desmodium* in western Kenya". The survey on "Farmers' knowledge, perceptions and management of Kersting's groundnut (*Macrotyloma geocarpum* Harms) insect pests in Benin" by Loko et al. [17] involved 83 households. Therefore, results from 128 selected households used in our study are representative enough to make conclusions. A semi-structured questionnaire was used to collect data from March to May 2017, which is the common bean growing season (Supplementary Materials). Although each head of the selected family was a key respondent, other members of the household frequently engaged in the conversation for thorough explanation. Household socio-economic characteristics, farmers' knowledge and perceptions of BLBs, methods of controlling BLBs and their perceived effectiveness, and bean leaf beetle (BLB) management challenges were the topics covered in the survey. Farmers were shown preserved adult BLBs in vials, as well as coloured drawings, to help them identify the pests. Farmers were requested to offer more information on the pests if they were able to recognize them. In areas where farmers could not speak English, an interpreter was involved.

2.3. Data Analysis

Farmers' responses were coded and entered into a Microsoft Office Excel spreadsheet (version 2010). Analysis of variance (ANOVA) was used to examine the continuous data on age and land size dedicated to producing the common bean. Farmers' responses to BLB knowledge and perceptions, control strategies and their perceived effectiveness, and the pest management challenges were recorded as binary data with positive responses receiving a value of one (1) and negative responses receiving a value of zero (0). Generalized linear modelling (GLM) was used to analyze these data, together with binomial distribution error and logit link [18,19]. To uncover major factors of farmers' awareness of BLBs (Table 2), stepwise model selection was used. A GLM test was performed on each explanatory variable (one by one), and the coefficient of each generated table was interpreted. Explanatory variables (determinants) with significant coefficients were kept for modelling. Before fitting the model, knowledge data (0,1) was split into train and test. The 80% train data was used to model training while 20% was used for checking how the model generalized on the unseen data set. To fit the logistic regression model, GLM () function was used. From the model summary, the coefficient of farmers' knowledge was significant. The model was fitted with Maximum Likelihood Estimation (MLE) technique and converged properly, without showing error. Therefore, the model was fit for the collected data. The following is a description of the model for estimating the determinants of probabilities: $\ln[Q_x/(1-Q_x)] = \gamma_o + \Sigma\gamma_i\,\omega_i$; where Q_x is probability for an event to occur (1) and (0) or else; γ_o is a constant; γ_i is a coefficient related to the explanatory variable ω_i; and ω_i is the explanatory variable. R statistical computer program (version 3.4.3) was used to conduct all analyses at $\alpha = 0.05$ [20].

Table 2. Variables identified as determinants of farmers' knowledge and perceptions of bean leaf beetles.

Variable	Description	Type of Variable
Sex	Whether male or female	Positive (1) or negative (0)
Age	Household head age in years since birth	Continuous
Formal education		
Formal education (i)	≤7 years	Positive (1) or negative (0)
Formal education (ii)	≥7 years	Positive (1) or negative (0)
Bean growing experience	Number of years of growing common bean	Continuous
Belonging to bean farmer organization	Whether belongs to common bean farmer organization or not	Positive (1) or negative (0)
Receive advisory services	Whether receives advisory services on common bean or not	Positive (1) or negative (0)
	Source of advisory services	
Source of advisory services (i)	Fellow farmers	Positive (1) or negative (0)
Source of advisory services (ii)	Common bean farmer organizations	Positive (1) or negative (0)
Source of advisory services (iii)	Agro-input dealers	Positive (1) or negative (0)
Source of advisory services (iv)	Public extension workers	Positive (1) or negative (0)
Source of advisory services (v)	Media	Positive (1) or negative (0)
	Purpose of growing common bean	
Purpose of growing common bean (i)	Food	Positive (1) or negative (0)
Purpose of growing common bean (ii)	Sale	Positive (1) or negative (0)
Purpose of growing common bean (iii)	Food and sale	Positive (1) or negative (0)
Land size	Number of hectares devoted to common bean	Continuous
Location	Belonging to a particular district	
District (i)	Arua	Positive (1) or negative (0)
District (ii)	Hoima	Positive (1) or negative (0)
District (iii)	Lira	Positive (1) or negative (0)
District (iv)	Lwengo	Positive (1) or negative (0)

3. Results

3.1. Household Socio-Economic Characteristics

The percentages of males, females, age of farmers and years spent in formal education were not significantly different across the study districts (Table 3). In all districts, the percentage of female farmers was lower than that of male farmers. The area dedicated to growing the common bean was significantly higher in Hoima than in all other districts, with the lowest land area under bean production recorded in Arua and Lwengo.

Table 3. Household socio-economic characteristics of common bean farmers in the study districts in 2017.

Variable	District Arua (n = 32)	Hoima (n = 32)	Lira (n = 32)	Lwengo (n = 32)	Overall Mean (n = 128)	ANOVA and Chi-Square *F* Value	χ^2 Value
Males (%)	70.0 ± 4.1	72.5± 2.5	72.5 ± 0.3	55.0 ± 2.9	67.5 ± 4.2		7.263 $^{n.s.}$
Female (%)	30.0 ± 5.1	27.5 ± 3.1	27.5 ± 3.1	45.0 ± 3.6	32.5 ± 3.7		7.263 $^{n.s.}$
Age (years)	38.9 ± 2.6	43 ± 2.6	44.8 ± 2.6	43.6 ± 2.5	42.6 ± 1.3	0.972 $^{n.s.}$	
Formal education							
≤7 years (%)	65.0 ± 8.7	45.0 ± 14.4	62.5 ± 4.8	45.0 ± 14.2	54.4 ± 5.4		6.679 $^{n.s.}$
≥7 years (%)	35.0 ± 8.7	55.0 ± 14.4	37.5 ± 4.8	55.0 ± 13.2	45.6 ± 5.4		6.679 $^{n.s.}$
Land devoted to common beans (ha)							
	0.5 ± 0.1 ^{a}	1.7 ± 0.4 ^{b}	1.0 ± 0.1 ^{c}	0.5 ± 0.2 ^{a}	0.9 ± 0.2	14.655 ***	

Mean ± standard error (SE) of mean percentage of household socio-economic characteristics followed by different superscript letters are significantly different at *** $p \leq 0.001$; n.s. = not significant.

3.2. Farmers' Knowledge and Perceptions of Bean Leaf Beetles

Farmers were asked to identify and provide local names of BLBs. Bean leaf beetles were identified and given local names by the majority of farmers (65%). Most farmers in Arua (96.9%) and Lira (87.5%) could identify BLBs by the local, whilst less than 50% of the farmers in Hoima and Lwengo could identify the pest by the local name (Table 4). However, the remaining farmers in Lira (12.5%) mistook BLBs for fireflies (Coleoptera: Lampyridae), locally known as *Otit*. Bean leaf beetles are known as *Odukudua* in Arua, *Bunyunyuzi* in Hoima, *Ogere* in Lira and *Buvuvumira* in Lwengo. The percentage of farmers who recognized the appearance of holes in leaves as a sign of BLB damage varied significantly across districts. A majority of farmers in Arua (90.7%) and Lira (93.8%) were more aware that holes in common bean leaves were symptoms of BLB damage than those in Hoima (56.3%) and Lwengo (65.6%). Percentages of farmers who reported incidences of premature senescence and wilting of bean plants as signs of BLB infestation were low and statistically comparable across districts. Similarly, low and statistically comparable percentages of farmers had knowledge of the biology of BLBs (i.e., they oviposit, emerge and diapause in soil).

Table 4. Knowledge and perceptions of bean leaf beetles across the study districts in 2017.

	District					
Variable	**Arua (*n* = 31)**	**Hoima (*n* = 32)**	**Lira (*n* = 30)**	**Lwengo (*n* = 32)**	**Overall Mean (*n* = 125)**	**χ^2 Value**
Knowledge and identification (local name) of BLBs (%)						
Knowing local name of BLBs	96.9 ± 3.1 ^{a}	43.8 ± 21.3 ^{c}	87.5 ± 5.1 ^{ab}	31.3 ± 14.9 ^{cd}	64.9 ± 11.1	49.370 ***
Knowledge of foliar damage by BLBs (%)						
Holes on leaves	90.7 ± 3.1 ^{a}	56.3 ± 21.9 ^{b}	93.8 ± 6.3 ^{a}	65.6 ± 14.8 ^{b}	76.6 ± 11.5	19.476 ***
Premature senescence	9.4 ± 3.1	12.5 ± 8.8	8.3 ± 3.2	21.8 ± 16.4	14.6 ± 7.9	6.948 $^{n.s.}$
Wilting	15.6 ± 3.1	9.4 ± 3.1	12.8 ± 2.8	6.3± 3.6	11.0 ± 3.2	4.042 $^{n.s.}$
The knowledge that BLBs:						
Lay in soil (%)	9.4 ± 3.1	6.3± 3.6	6.3± 3.6	6.3± 3.6	7.1 ± 3.5	0.338 $^{n.s.}$
Emerge from soil (%)	3.1 ± 3.1	3.1 ± 3.1	3.1 ± 3.1	3.1 ± 3.1	3.1 ± 3.1	2.804 $^{n.s.}$
Diapause in soil (%)	12.5 ± 5.1	0.0 ± 0.0	3.1 ± 3.1	3.1 ± 3.1	4.7 ± 2.8	6.524 $^{n.s.}$
Perception of the magnitude of BLB infestation (August-November season 2016)						
Minor	0.0 ± 0.0 ^{a}	25.0 ± 8.8 ^{b}	9.3 ± 3.6 ^{a}	75.0 ± 11.4 ^{c}	27.3 ± 6.0	61.240 ***
Moderate	21.9 ± 13.9 ^{b}	65.6 ± 23.1 ^{a}	34.4 ± 16.4 ^{b}	25.0 ± 11.1 ^{b}	36.7 ± 16.1	19.654 ***
Severe	78.1 ± 5.1 ^{a}	9.4 ± 3.1 ^{b}	56.3 ± 18 ^{a}	0.0 ± 0.0 ^{b}	40.0 ± 6.6	70.231 ***

Mean ± SE of mean percentage of farmers reporting knowledge and perceptions of bean leaf beetle followed by different superscript letters in the same row are significantly different at *** $p \leq 0.001$; n.s. = not significant.

We asked farmers to rank the perceived severity of BLB infestation of the common bean during the August to November 2016 growing season as minor, moderate or severe. An overall mean of only 27.3% of farmers considered BLB infestation of common beans to be minor, with Lwengo (75%) recording a significantly higher percentage than other districts. Bean leaf beetle infestation was rated moderate by 36.7% of the farmers, with Hoima (65.6%) recording a significantly higher percentage than other districts. In comparison to Hoima and Lwengo, where less than 9.4% of farmers reported severe BLB infestation, the majority of farmers in Arua (78.1%) and Lira (56.3%) rated infestation by BLBs as severe.

We asked farmers if they knew of any other crops attacked by BLBs besides the common bean. In order of popularity, cowpea, soybean, and pigeon pea were reported as alternate host crops for BLBs (Figure 2). A significantly higher percentage of farmers reported that BLBs attack cowpea in Lira than in other districts. Soybean in Arua and Lira was reported as the alternate host of BLBs by significantly higher percentages of farmers than in Lwengo, but no farmers reported soybean as a host for BLBs in Hoima. The percentages of farmers who reported that BLBs infest pigeon peas were significantly higher in Arua and Lira than in Hoima, whilst no farmers mentioned BLB attacks on pigeon peas in Lwengo.

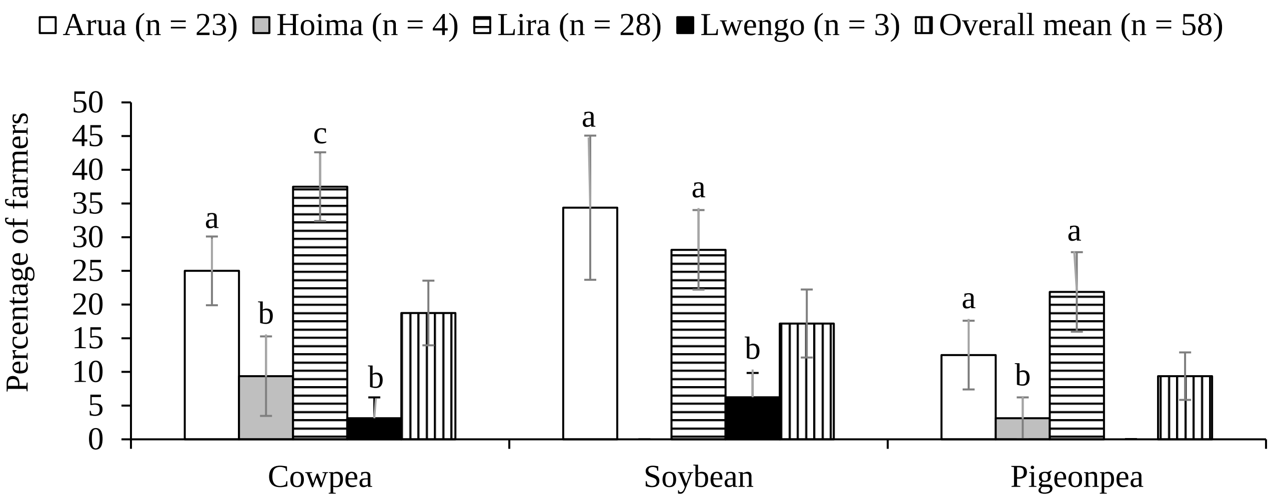

Figure 2. Mean (%) ± SE of mean e of farmers reporting other crops damaged by bean leaf beetles across the study districts in 2017. Bars with different letters for a crop are significantly different.

There was no significant difference between districts in the percentage of farmers who reported that BLB infestation occurs only during the first, second, or both common bean growing seasons. However, a majority (77%) reported that BLBs occur in the first season, whilst a moderate percentage (15%) reported their occurrence in the second season. Only 8% of the farmers reported that BLBs occur in both seasons (Figure 3).

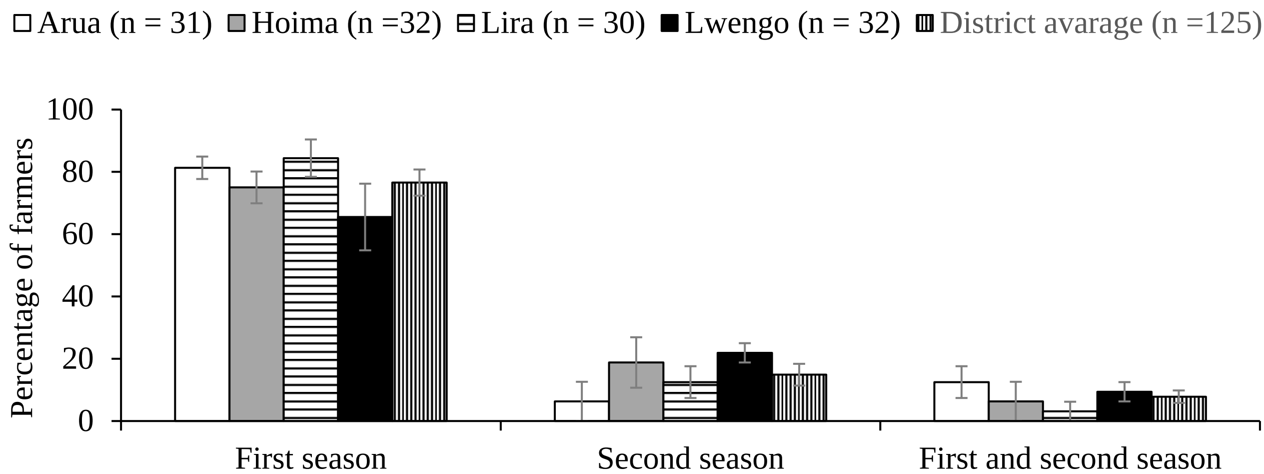

Figure 3. Mean (%) ± SE of mean of farmers reporting seasons of high occurrence of bean leaf beetles across the study districts in 2017.

3.3. Determinants of Farmers' Knowledge of Bean Leaf Beetles

Logit results revealed that farmers' understanding of BLBs was significantly and positively influenced by location (represented by Arua and Lira), belonging to bean farmers' organizations, and years of experience in cultivating the common bean (Table 5). The male gender and access to common bean consulting services were both significant and negative predictors of farmers' knowledge of BLBs.

Table 5. Determinants of farmers' knowledge of bean leaf beetles in the study districts in 2017.

Variable	Estimate	SE	z-Value
Arua district	4.810	1.228	3.919 ***
Lira district	2.434	0.726	3.355 ***
Belong to bean farmer organization	1.715	0.702	2.440 *
Years of bean-growing experience	0.052	0.025	1.971 *
Male gender	−1.886	0.833	−2.264 *
Receive advisory service on common beans	−2.202	0.681	−3.230 **

A significant difference at *** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$.

3.4. Control of Bean Leaf Beetles

3.4.1. Methods of Controlling Bean Leaf Beetles

In order of popularity, the use of purchased synthetic insecticides, delayed sowing by two weeks from the start of the season, mixed cropping with other non-leguminous crops, early planting within the first week of the season, residue burning, and botanical insecticides (locally/homemade plant extracts including ash) were the farmers' reported strategies for suppressing BLBs (Figure 4). In Lira and Lwengo, the percentages of farmers using synthetic insecticides were significantly higher than in Arua and Hoima. Delayed sowing was reported by significantly higher percentages of farmers in Arua and Lira than in Hoima; however, this practice was not reported in Lwengo. Meanwhile, farmers in Arua and Hoima used mixed cropping at a significantly higher rate than in Lira and Lwengo. Early planting and the use of botanical insecticides were practiced by a few farmers, and the percentages were not statistically different across the study districts. Residue burning was carried out by many more farmers in Hoima and Lira than in Arua, but the practice was not reported in Lwengo.

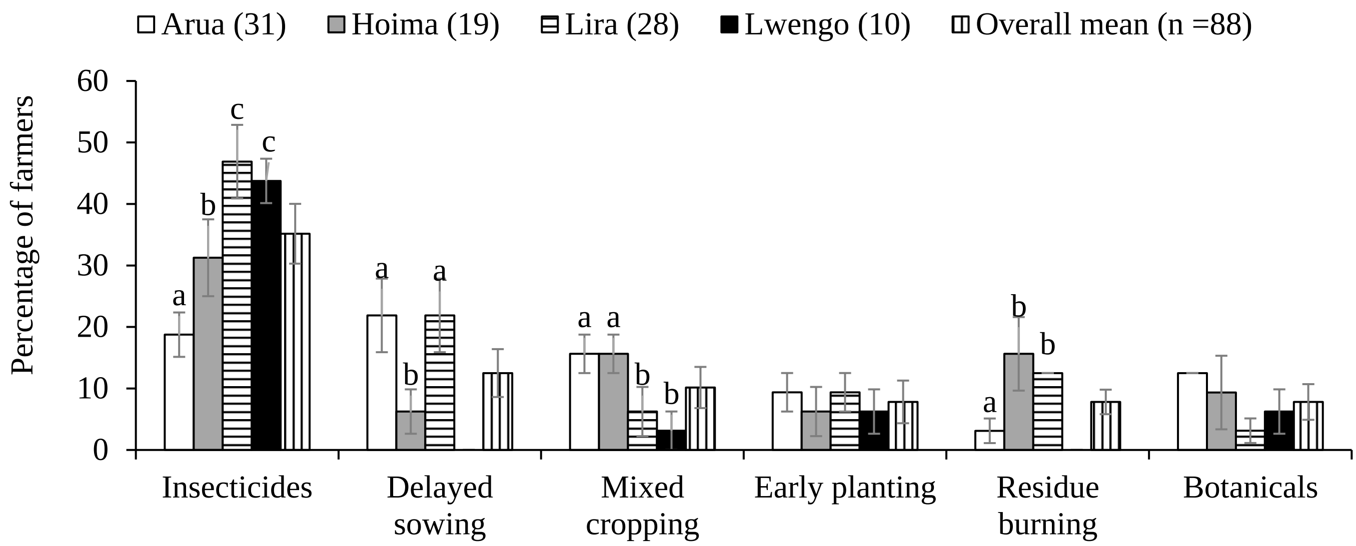

Figure 4. Mean (%) ± SE of mean of farmers reporting different control strategies for bean leaf beetles across the study districts. Bars with different letters within a control method are significantly different.

3.4.2. Perceived Effectiveness of Methods of Controlling Bean Leaf Beetles

The majority of farmers (70.1%) who used insecticides perceived that they were effective, while 51.9% who used botanical insecticides perceived that they were moderately efficacious (Table 6). An equal percentage of farmers (approximately 47% each) rated delayed sowing as effective and moderately effective. Mixed cropping, residue burning, and early planting were among the approaches perceived to be ineffective (by 64.5%, 60.3%, and 59.2% of the respondents, respectively).

Table 6. The percentage of farmers who reported different bean leaf beetle control methods and their perceived effectiveness in 2017.

Control Method	Grading			
	Effective	Moderate	Not Effective	χ^2 Value
Early planting (n = 5)	11.1 ± 3.4 [a]	29.7 ± 1.1 [b]	59.2 ± 5.0 [c]	68.238 ***
Delayed sowing (n = 17)	46.9 ± 2.1 [a]	47.1 ± 2.2 [a]	6.0 ± 1.9 [b]	59.509 *
Residue burning (n = 10)	4.8 ± 3.5 [a]	34.8 ± 1.1 [b]	60.3 ± 4.4 [c]	71.246 ***
Mixed cropping (n = 7)	4.6 ± 3.0 [a]	9.8 ± 2.4 [a]	64.5 ± 2.3 [b]	214.560 ***
Insecticides (n = 38)	70.1 ± 1.9 [a]	19.8 ± 1.9 [b]	9.8 ± 2.0 [c]	84.201 ***
Botanicals (n = 11)	10.1 ± 2.1 [a]	51.9 ± 2.1 [b]	37.0 ± 2.2 [c]	57.065 ***

Mean (%) ± SE of mean of farmers reporting perceived effectiveness followed by different superscript letters in the same row are significantly different at *** $p \leq 0.001$; * $p \leq 0.05$.

3.4.3. Types of Insecticides Used to Control Bean Leaf Beetles

The commonly used insecticides in order of popularity across the study districts were: Roket® (Profenofos EC 40% + Cypermethrin EC 4%), Dudu-cyper® (Cypermethrin EC 5%), LB-Ambush® (Cypermethrin EC 5%), Fenkil® (Fenvalerate EC 2% and Tafgor® (Dimethoate EC 40%) (Table 7). Roket® was used by 12.5% of the farmers. Lwengo had a higher percentage (21.9%) of farmers using Roket® than other districts, which were each represented by less than 13%. The percentages of farmers who used Dudu-cyper 5 EC (7%), LB-Ambush® (7%), and Tafgor® (4.7%) were not statistically different across districts.

Table 7. The percentage of farmers who used different insecticides to control bean leaf beetle in the survey districts in 2017.

	District					
Variable (%)	Arua (n = 8)	Hoima (n = 9)	Lira (n = 17)	Lwengo (n = 15)	Overall Mean (n = 49)	χ^2 Value
Rocket 44 EC	9.4 ± 6.0 [a]	6.3 ± 3.6 [a]	12.5 ± 5.1 [a]	21.9 ± 3.1 [b]	12.5 ± 4.5	4.042 *
Dudu-cyper 5 EC	3.1 ± 3.1	3.1 ± 3.1	9.4 ± 6.0	12.5 ± 8.8	7.0 ± 5.2	6.925 [n.s.]
LB-Ambush 5 EC	3.1 ± 3.1	15.6 ± 9.4	6.3 ± 3.6	3.1 ± 3.1	7.0 ± 4.8	4.638 [n.s.]
Fenkil 2 EC	3.1 ± 3.2 [a]	3.1 ± 3.1 [a]	18.8 ± 3.6 [b]	3.1 ± 3.1 [a]	7.0 ± 3.2	7.554 *
Tafgor 40 EC	6.3 ± 3.6	3.1 ± 3.1	3.1 ± 3.1	6.3 ± 3.6	4.7 ± 3.4	0.681 [n.s.]

Mean (%) ± SE of mean of farmers reporting insecticides used followed by different superscript letters in the same row are significantly different at * $p \leq 0.05$; n.s. = not significant.

3.4.4. Perceived Effectiveness of Different Insecticides Used to Control Bean Leaf Beetles

We asked farmers to rank the perceived effectiveness of various insecticides used to control BLBs. Equal percentages of farmers (lower than 50% each) who used Rocket 44 EC perceived that it was effective or moderately effective. A majority of farmers (84.2%) who used Dudu-cyper 5 EC and LB-Ambush 5 EC (73.8%) perceived that they were effective (Table 8). Meanwhile, Fenkil 2 EC was perceived to be ineffective by 56.8% of farmers who used it, while equal percentages of farmers (about 45% each) who used Tafgor 40 EC rated it as moderately effective or not effective.

Table 8. The percentage of farmers who perceived the effectiveness of different insecticides to control bean leaf beetle in the survey districts in 2017.

	Grading			
Insecticide	Effective	Moderate	Not Effective	χ^2 Value
Rocket 44 EC (n = 16)	45.2 ± 10.7 [a]	43.4 ± 6.3 [a]	10.4 ± 6.0 [b]	18.938 *
Dudu-cyper 5 EC (n = 9)	84.2 ± 5.1 [a]	15.8 ± 3.6 [b]	0.0 ± 0.0 [c]	26.802 ***
LB-Ambush 5 EC (n = 9)	73.8 ± 8.1 [a]	21.9 ± 3.1 [b]	3.1 ± 0.2 [c]	50.128 ***
Fenkil 2 EC (n = 9)	2.1 ±2.9 [a]	41.1 ± 3.1 [b]	56.8 ± 3.6 [b]	28.146 *
Tafgor 40 EC (n = 6)	9.4 ± 1.6 [a]	44.8 ± 6.0 [b]	45.8 ± 3.1 [b]	28.146 *

Mean (%) ± SE of mean of farmers reporting perceived effectiveness followed by different superscript letters in the same row are significantly different at *** $p \leq 0.001$; * $p \leq 0.05$.

3.4.5. Challenges of Controlling Bean Leaf Beetle in the Study Districts

Farmers in all districts indicated the following key obstacles in managing BLBs: lack of awareness of appropriate pest control measures, pesticide inaccessibility, fake/counterfeit insecticides on the market, and high prices of insecticides (Figure 5).

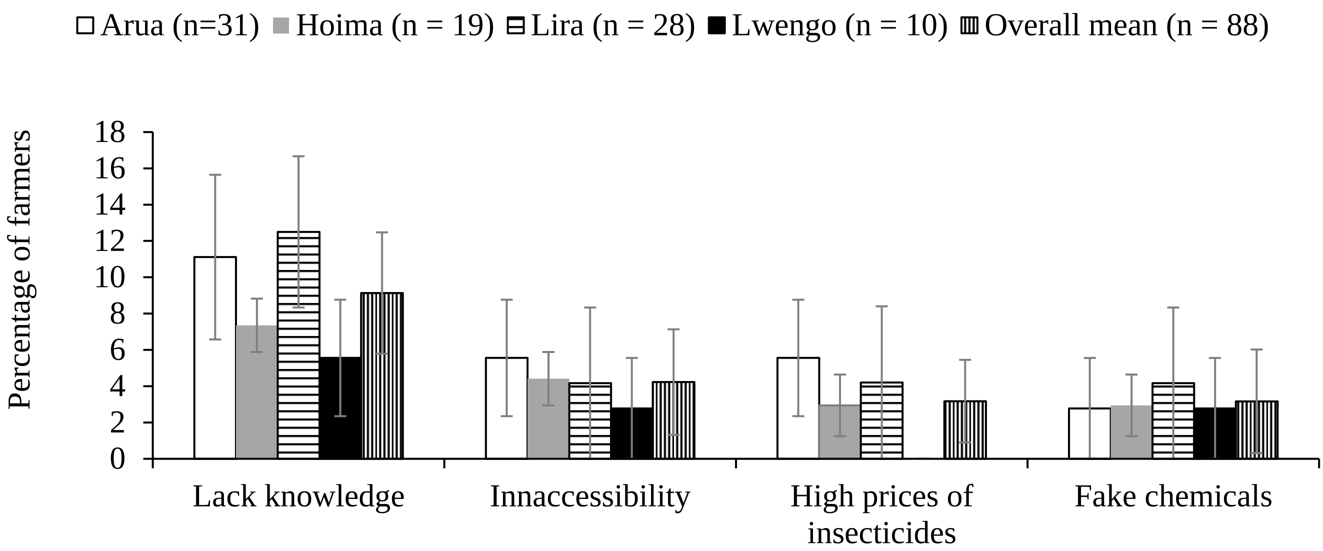

Figure 5. Mean (%) ± SE of mean of farmers reporting challenges of bean leaf beetle control across the study districts in 2017.

4. Discussion

The purpose of this survey was to examine farmers' current knowledge of BLBs, control measures, and challenges in managing these beetles in Uganda. The survey was carried out in four districts, each of which was chosen from one of the four agroecological zones where the common bean is a staple food. The survey indicated that there were more male than female respondents. This could be attributed to the fact that in many African societies, men are usually quicker to talk to interviewers or visitors than women in rural settings [21]. Knowledge and perception studies where males outnumber females have been previously reported in Tanzania, Benin, and Uganda [17,22,23]. This implies that deliberate efforts must be made to include women in the development and application of strategies for managing BLBs in the surveyed districts. Astonishingly, the number of years of formal education did not influence farmers' knowledge of BLBs, control measures, and the challenges in managing these pests. This is contrary to the assertion that farmers who have attained more than seven years in school are more literate and knowledgeable about pests and diseases of crops and their management than those with seven or fewer years of formal education [17,24]. This may imply that farmers learn about BLBs through experience-sharing with fellow farmers, especially in the case of endemic pests. Certainly, informal farmer-to-farmer interactions remain important information-sharing channels on plant agronomies in Africa [11,25]. Therefore, the development and implementation of an IPM programme for BLBs must involve all common bean farmers, regardless of education level.

Unlike Hoima and Lwengo, most farmers in Arua and Lira could recognize BLBs and gave them local names; they also knew that adult beetles damage leaves of the common bean. The damage caused by premature stages of BLBs were least-known in all the study districts. In Northern and Eastern Uganda, BLBs have been reported as major common bean pests since the 1990s [10,26,27]. This is corroborated by UNDP [3] and Halerimana et al. [10] during biological monitoring surveys, which found a higher number of BLBs in Northern and Eastern Uganda than in Central and Western Uganda. Halerimana et al. [10] reported three species of BLBs belonging to the genus *Ootheca* (i.e., *O. mutabilis*, *O. proteus*, and *O. orientalis*) in the four agroecological zones (West Nile Farmlands, Northern Moist Farmlands, Western Masaka-Mityana Farmlands, and Central Wooden Savannah) in Uganda. Whereas *O. mutabilis* is present in all four agroecological zones, *O. proteus* is reported in Northern Moist Farmlands, West Nile Farmlands, and Central Wooden Savannah; *O. orientalis* is only present in Central Wooden Savannah.

Farmers get acquainted with the pest which stays longer in an area and also share knowledge on locally available control measures. Wilhelmina et al. [28] emphasize that farmers' learning and knowledge-sharing are important factors that influence how they view and generate local solutions to pest problems. This supports the findings of our survey, as many farmers in Lira and Arua districts were able to identify BLBs to the extent of mentioning coined local names for the pests. A limited number of farmers were aware that BLBs oviposit (lay eggs), diapause, then emerge from the soil. Ampofo and Massomo [29] had similar findings for *O. bennigseni* in Tanzania. It implies that farmers are unable to link the earliest signs of BLB damage (wilting and premature senescence) to bean plants due to lack of information, and hence fail to take a timely action against the pests [6,30]. To bridge the existing knowledge gaps (about the biology and ecology of BLBs) among common bean farmers, our findings will be extended to the respective ZARDI researchers who participated in the survey. The ZARDI researchers will pass on the findings to common bean farmers and extensionists as part of the process to enhance the proper management of BLBs.

The majority of farmers were aware of alternate host crops (mainly cowpea, soybean, and pigeon pea) for BLBs, with a higher percentage of farmers in Arua and Lira noting cowpea and soybean than in Hoima and Lwengo. Our findings are supported by earlier reports that BLBs are native African cowpea pests that have evolved to feed on various leguminous crops [6,31,32]. Northern Uganda has more known host crops than Central and Western Uganda, which could explain the high prevalence and damage caused by BLBs. This suggests that specific BLB control techniques for Arua and Lira must be developed to manage the pests across a variety of host plants. The perceived magnitude of BLB infestation as minor in Lwengo, moderate in Hoima, and severe in Arua and Lira shows that BLBs are of trivial importance in Lwengo. This is consistent with the reports by Kyamanywa et al. [27] and Halerimana et al. [10], who reported Northern and Eastern Uganda as the regions most-affected by BLBs. The prevailing ecological and biological factors have been pinpointed for the disparities in BLB damage [6,32]. Indeed, according to Halerimana et al. [10], the high prevalence of BLBs in Northern and Eastern Uganda is due to the abundance of host plants and favourable climatic conditions.

The farmers' perception that a high abundance of BLBs occurs during the first crop-growing season is in line with the findings by Kyamanywa et al. [27]. Mwanauta et al. [30] attributed the appearance of BLBs in the first crop-growing season to the obligatory diapause of teneral adults before and after the first season. As a result, teneral adults always emerge at the start of the first season and begin feeding on the leaves of newly planted common beans. Farmers' knowledge of the seasonal abundance of BLBs can be used to educate them on tillage practices, such as ploughing before and after the first season to reduce pest attacks. Ploughing buries larvae and pupae into the soil where they cannot emerge, or exposes them to natural enemies and adverse weather conditions [9].

Belonging to a particular district, membership in farmer organizations, and years of experience in cultivating beans were all positive drivers of farmers' knowledge of BLBs, while the male gender and receiving agricultural advisory services on the common bean were negative predictors. Farmers' knowledge varying by location indicates that BLBs have a varying bearing depending on the study region, and hence farmers who face their severe impact are more aware of them. Our findings revealed that more farmers in West Nile Farmlands and Northern Moist Farmlands (Arua and Lira districts of Northern Uganda, respectively) are more aware of BLBs than their counterparts in Western Masaka-Mityana Farmlands and Central Wooden Savannah (Lwengo and Hoima districts of Central and Western Uganda, respectively). This finding supports that of Halerimana et al. [10] that BLBs are known field insect pests of the common bean in many districts of Northern

Uganda. This indicates the need for prioritisation of BLB control interventions in Arua and Lira districts over other common bean-growing areas. The positive correlation of being a member of a farmer organization and knowledge of BLBs indicates that interactions among farmers expose them to information about bean pests. This is supported by the report by Mendesil et al. [11] that belonging to farmer organizations gave opportunities for Ethiopian farmers to exchange crop management information. Bean farmer organizations in Uganda would therefore provide a platform for farmer engagement in the development and promotion of cost-effective BLB control techniques. Our data showed that the duration of experience of growing the common bean influenced farmers' knowledge of BLBs. This is supported by the report by Van Mele and Van Chien [25] that the life-long experience of growing a crop, gained through regular observations and information exchange, enables the farmers to understand pests that affect it. Farmers with more experience in common bean growing would be key in promoting awareness of BLBs among fellow farmers with less experience. The experienced farmers would participate in the development and championing of strategies for managing the pests.

The fact that the male gender is a negative predictor of farmers' awareness of BLBs could be due to the distinct tasks performed by men and women in bean gardens, as previously noted by UNDP [3]. Indeed, because of the critical responsibilities women play in its production, the common bean was once associated with women [33] and referred to as a woman's crop. As a result of their experience with continuous common bean cultivation, women are more familiar with bean farming than men [21]. Our findings are similar to those of Khan et al. [34], who found that knowledge of the Napier stunt disease was negatively associated with the male gender in Kenya. However, for men and women, working together in bean growing would lead to the successful management of BLBs, as both will be sharing knowledge about these pests and probable control tactics. Surprisingly, receiving advisory services was also a negative predictor of farmers' understanding of BLBs. This could indicate that the advice provided by extension service personnel was either insufficient or not customized to BLBs. It is worth noting that crop production in Uganda is hampered by outdated agricultural extension information that is not responsive to farmers' requirements, as well as insufficient research and results dissemination on crop pests [35]. This necessitates the updating of information packages as well as the retraining of extension workers in Uganda in the biology, ecology, and control of pests of common beans, including BLBs.

The application of synthetic pesticides was reported as the most common method of controlling BLBs, and perceived as the most efficacious method. Several studies have documented farmers' beliefs that using synthetic insecticides is the best way to control insect pests [6,13,36]. Farmers perceived that the synthetic pyrethroids Dudu-cyper 5 EC and LB-Ambush 5 EC are the most effective pesticides for controlling BLBs. Certainly, foliar application of synthetic pyrethroids including Karate 5 EC (lambda-cyhalothrin) or Cypermethrin 5 EC is known to be effective in minimizing crop damage by adults of *O. bennigseni* and *O. mutablis* [2,3]. We noted that many farmers in the study districts used insecticides they perceived as either ineffective or moderately effective (e.g., Fenkil 2 EC and Tafgor 40 EC) to control BLBs. This suggests the absence or weaknesses in the agricultural extension service systems on the management of BLBs in the study districts, which results in farmers acquiring incorrect advice from unreliable sources. Barungi [37] reported that the failure of Uganda's public extension system to reach a large number of smallholder farmers and other vulnerable groups has led to an increase over time in farmers sourcing agricultural advice from fellow farmers, non-governmental organizations/community-based organizations, radio and call centers. Much of the advice obtained outside the government extension system is usually unverified. This indicates the need for government to validate agricultural advisory training/extension materials prepared by non-state extensionists before they are disseminated to farmers. Extension service providers should also sensitise common bean farmers on effective classes of insecticides (especially synthetic pyrethroids) that can be incorporated into an IPM strategy against BLBs. Roket 44 EC, which was used by the majority of farmers in controlling BLBs in all districts, was perceived to be effective or moderately effective. Roket 44 EC is a combination of an organophosphate and a synthetic pyrethroid, and may negatively impact a broad range of insects (including useful ones). Reliance on synthetic insecticides, on the other hand, may disrupt natural pest management systems, increase the risk of pesticide residues in crops, damage the farm environment, and leads to the appearance of secondary pests [38]. To curb the consequences of overuse of synthetic insecticides, there is a need to develop and promote environmentally-friendly spray regimes (as part of an IMP strategy), as well as sensitise farmers on the judicious use and handling of insecticides. Delayed sowing is another way of preventing BLB crop damage as reported by several farmers in Arua and Lira, with some farmers believing that it was effective and others believing that it was moderately effective. This is in agreement with Buruchara et al. [9] that delaying common bean sowing helps to avoid the coincidence of high BLB populations and the vulnerable stages of beans. While delaying sowing lowers BLB damage, studies by Halerimana et al. [10] showed that delayed sowing from two to four weeks after the onset of rains may result in a significant decrease in yield. As a result, it may be prudent to plant early and use other cost-effective BLB control methods. Researchers who participated in the survey (from respective ZARDIs) should pass on the findings to agricultural extensionists and farmers for proper planning and implementation of delayed sowing to control BLBs.

The lack of awareness of appropriate control practices was one of the most significant obstacles in managing BLBs. In Uganda, there is currently no validated package for controlling BLBs. Halerimana et al. [10] assert that there are no all-inclusive, prearranged, control strategies for BLBs in Uganda. This necessitates hastening the development and dissemination of cost-effective BLB control techniques. Fake insecticides on the market have also been recognized as a major barrier to controlling BLBs. This is in line with an increase in the number of complaints by farmers to the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) that pesticides on the Ugandan market are ineffective [39]. Duplication of chemical labels to imitate those approved by the government is one of the vices among dealers of fake chemicals. However, MAAIF is working to curb this through increased enforcement, inspections and court prosecutions [2]. Furthermore, several factors are responsible for the purported fakeness of pesticides, including poor storage, inappropriate application, and the use of contaminated, unauthenticated, and expired pesticides [11]. Implementation of widespread farmer sensitization on proper chemical handling could be one of MAAIF's remedies to farmers' complaints.

5. Conclusions

Farmers in Arua and Lira were more knowledgeable about BLBs than their counterparts in Hoima and Lwengo. However, there was insufficient knowledge among farmers in all districts regarding the damage caused by premature stages of BLBs, and soil being the medium for the lifecycle of the pests. The current perceived magnitude of common bean infestation by BLBs was minor in Lwengo, moderate in Hoima, and severe in Arua and Lira. The main method of controlling BLBs, and also the one perceived as most effective, was the use of synthetic insecticides. However, delayed planting was commonly practiced in Arua and Lira. The main challenges faced by farmers in controlling BLBs were a lack of knowledge of appropriate control practices and fake chemicals on the Ugandan market. Our findings highlighted the need to develop an information package, based on cost-effective BLB control practices. We recommended the retooling of extension service providers, who will bridge the existing knowledge gaps (the biology and ecology of BLBs; practices of controlling the pests; and judicious use and handling of chemicals) on BLBs among farmers.

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