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Farmers' Knowledge, Perceptions and Practices in Managing Weeds and Insect Pests of Common Bean in Northern Tanzania

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Abstract: Weeds and insect pests are among the serious constraints in common bean production in most rural communities. A survey of 169 smallholder farmers was conducted in two common bean-growing districts in northern Tanzania. The aim was to assess farmers' knowledge, perceptions, current management practices and challenges in order to develop sustainable weed and insect pest management strategies. The results revealed that 83% of farmers perceived insect pests as the major constraint in common bean production, while 73% reported weeds as the main drawback. Insect pest management was mainly achieved through the use of synthetic pesticides, however, only 24% of farmers were able to apply, the rest could not afford due to high cost, limited access and lack of knowledge. Only 6.5% of farmers were aware of non-chemical methods and 2.1% did not practice any method in managing insect pests, both in the field and during storage. Moreover, farmers generally relied on experience in managing insect pests and weeds, and about 43% did not see the need to consult extension officers. These findings indicate that there is a need to sensitize and train farmers on the sustainable methods for pest and weed management in common bean farming systems in northern Tanzania.

Keywords: smallholder farmer; *Phaseolus vulgaris*; crop protection; sustainable agriculture; integrated pest and weed management

1. Introduction

Grain legumes are very important crops in rural livelihoods in East Africa, with common bean, *Phaseolus vulgaris* L., being the most essential and major source of protein for most smallholder farmers [1,2]. Common bean also plays an important role in crop rotation and intercropping in most agricultural fields due to its ability to fix nitrogen [3]. In Tanzania, common bean is cultivated in many regions. However, the main areas of production have been the mid to high altitude zones, which experience more reliable rainfall and cooler temperatures since the crop does not tolerate prolonged periods without rainfall [4,5].

Northern Tanzania, particularly the Arusha and Kilimanjaro regions, represent one of the key and most suitable areas for common bean production. This can be attributed to their favorable agro-climatic conditions [1]. Most of the common bean production is carried out by smallholders farmers [6], cultivating less than 2 ha [7] and generally without using fertilizers [8]. The yields obtained are primarily for home consumption [9,10] and only the surplus of around 20% is being marketed [4]. Despite the favorable climatic conditions for common bean production and easy access to international

markets, yields in the two regions are generally low ranging, from 500 to 700 kg/ha [7,8]. This is contrary to potential yields under favorable conditions, which range from 1500 to 3000 kg/ha [11].

Insect pests and weeds are a major drawback of common bean production in northern Tanzania, particularly in smallholder farming systems. Insect pests have been reported to attack common bean both in the field and during storage [12]. The most important insect pests in the field are the bean stem maggots (*Ophiomyia phaseoli)* [13], while during storage the bean bruchids (*Acanthoscelides obtectus*) are the most common [14]. Weeds, on the other hand, have been reported to negatively affect common bean production as well. They compete for resources [15], releasing allelochemicals [16] and harboring insect pests [17,18]. The diversity of pests and weeds have made it very difficult for resource-constraint farmers to manage and control them in a sustainable manner [19,20].

The use of synthetic pesticides and herbicides have been reported as the main and preferred method by most farmers in managing and controlling insect pests and weeds [5,21]. However, there are growing concerns on the safety of such chemicals to consumers and the environment at large [22,23]. Moreover, most smallholder farmers cannot afford a wide spectrum of these herbicides and pesticides [24]. Cultural practices such as intercropping, crop rotation have also been practiced by farmers in trying to control pests and weeds [25]. Nevertheless, no fruitful results have been attained and common bean yields are still below standard under favorable conditions [4].

In spite of these pest and weed management challenges, very little information is available on farmers' perceptions, knowledge, and practices in controlling insect pests and weeds in common bean farms particularly in northern Tanzania [26]. In order to develop an appropriate pest and weed management approach that will eventually be adopted by farmers, their knowledge, perceptions, and practices have to be fully realized and incorporated in the process [27–29]. Therefore, this study highlights farmers' knowledge and perception of weeds and insect pests in common bean farming by examining their current management practices and challenges with a view to develop an effective weed and pest management strategy for smallholder farming systems in northern Tanzania.

2. Materials and Methods

2.1. Study Site

The household surveys (HHS) were conducted from October 2018 to February 2019 in 13 villages from the two districts (Arumeru 3°08′ S, 36°52′ E and Moshi rural 3°21′43.2″ S, 37°27′32.4″ E) in northern Tanzania covering the key common bean growing areas in the region (Figure 1). The villages covered were Nambala, Lekitatu, Ndato, Kikatiti, Malula, Maroroni, King'ori, Boro, Kirima Kati, Umbwe Sinde, Maua, Uchau Kusini, and Sambarai. These areas experience a bi-modal rainfall pattern, with the main cropping season running from March to May and the short cropping season from November to January. The zone is also considered high potential for agriculture, with both high and medium elevation (1035 to 1724 m above sea level). The main farming systems comprise of crops such as banana, coffee, and cereals such as maize intercropped with legumes such as common beans.

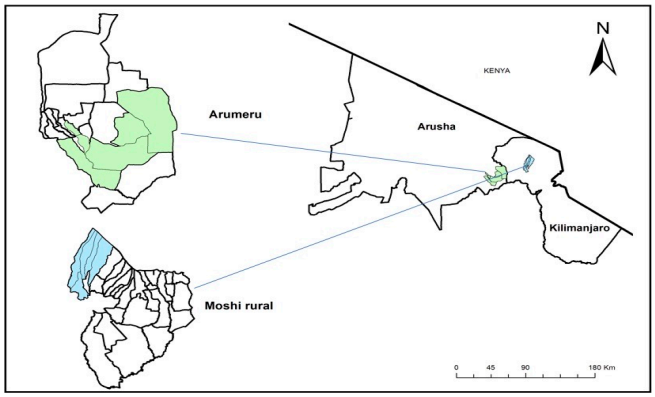

Figure 1. Location of the study area i.e., Arumeru and Moshi rural districts.

2.2. Data Collection

Data on common beans farming and its constraints, particularly insect pests and weeds in northern Tanzania were collected through household surveys and focused group discussions using methodologies described by Midega et al. [30]. In each of the 13 villages visited, the respondents for the interviews were randomly selected using sampling lists provided by the village leaders in both districts. A total of 169 common bean farmers were interviewed, 87 farmers from Arumeru and 82 farmers from the Moshi rural district. The semi-structured questionnaire used comprised of questions on households' demographic characteristics, economic profile, farm characteristics, yields, percentage of yields damaged by pests and weeds, knowledge and perceptions of common bean pests and weeds, pest control methods and practices (Table 1). The questionnaire was pre-tested in a pilot study before being used in the targeted districts. Before starting an interview, a consent form was provided to a respondent, which introduced and explained the aim of the research and asked for approval to continue with the interview. The household data were supplemented by information obtained from the key informant interviews and focus group discussions, which were conducted through organized community meetings in all villages where guiding questions were asked to provoke a discussion on the key aspects of common bean farming and its constraints, particularly weeds and pests, their management and challenges most farmers face.

Table 1. Overview of the questions included in the questionnaire used.

Data Group	Description
Personal data, economic profile and farms characteristics	Gender; Age; Education; Household size; Yields; Land ownership
Knowledge of common bean pests and weeds	Most common and dangerous insect pests and weeds
	Local, common and scientific names of each species
	Perceptions of impact on common bean yields
Pest and weed management practices	Common methods of pest and weed control
	Criteria for the selection of weed and pest control strategy
	Decisions on which methods should be used and for what periods
	Pros and cons of different control methods
	Pesticide use; pesticide products; pesticide rates applied in the field
	Perceptions of the effects of pesticide use (synthetic vs. botanical)
	Levels of knowledge about pesticide safety (synthetic vs. botanical)

2.3. Data Analysis

Survey data were summarized and descriptive statistics (means, standard deviation, and percentages) were calculated using the Statistical Package for Social Sciences (SPSS) version 25. For multiple answered questions, the percentages were calculated for each group of similar responses. The percentages of farmers in the two districts (Arumeru and Moshi rural) who gave similar responses to a question were calculated based on the total number of farmers who responded to each question. Comparative statistical tools, such as Chi-square and one-way analysis of variance (ANOVA), were conducted to assess differences regarding socio-demographic, farm characteristics, knowledge, perceptions and management practices of common bean pests and weeds. The level of significance was set at 0.05 and means were separated by Tukey's HSD (honestly significant difference) test.

3. Results

3.1. Socio-Economic Characteristics of the Farmers

Most of the farmers (70.9%) surveyed in the two districts were male. The average age of the farmers did not vary ($p < 0.18$) across the surveyed districts, ranging from a mean of 48.95 years in Arumeru to 51.29 years in Moshi rural. The mean age for all districts combined was 50.12 years, which is in the middle age category (Table 2). The majority of the respondents (78.15%) had primary education, while 8.35% had non-formal education but were able to read and write. There was only a

paltry of 1.15% with tertiary education (college and university) (Table 2). The average household size of farmers comprised of five individuals ranging from 2–11 individuals in the Arumeru and Moshi rural districts, respectively. The respondents in both districts were smallholder farmers who owned an average land size of 0.44 ha. Additionally, the average area allocated to common bean by most farmers was less than 0.2 ha. Common bean was grown both for home consumption and sale by the majority of the farmers (70%), whereas 20% of the farmers reported that the produce was used solely for home consumption and 10% of the farmers reported selling all their produce. Yields of common bean varied significantly ($p = 0.001$) across districts, with a mean yield of 242 kg/ha for all districts (Table 2).

Table 2. Socio-economic characteristics of the respondents, their common bean yields.

Variable		Districts			
		Arumeru	**Moshi Rural**	**Mean (SD)**	**Chi Square**
Gender (%)	Male	74.7	67.1	70.9 (5.37)	$x^2 = 1.197$; df = 1; $p = 0.27$
	Female	25.3	32.9	29.1 (5.37)	
Education level (%)	None	5.7	11	8.35 (3.75)	
	Primary	77	79.3	78.15 (1.63)	
	Secondary	14.9	9.8	12.35 (3.61)	
	College	2.3	0	1.15 (1.63)	
Education (years)	Mean (SD)	7.07 (2.55)	6.29 (2.74)	6.68 (2.65)	$x^2 = 8.73$; df = 7; $p = 0.27$
Age (%)	18–45	44.8	36.6	40.7 (3.54)	
	45–60	35.6	41.5	39 (0.71)	
	>60	19.5	22	20.75 (2.83)	
Age (years)	Mean (SD)	48.95 (12.51)	51.29 (10.13)	50.12 (11.32)	$x^2 = 50.27$; df = 42; $p = 0.18$
Household size (%)	1–5	65.5	56.1	60.8 (4.24)	
	6–10	34.5	42.7	38.6 (2.83)	
	>10	0	1.2	0.6 (1.41)	
Household size	Mean (SD)	4.94(1.57)	5.52(1.74)	5.23 (1.66)	$x^2 = 14.36$; df = 8; $p = 0.07$
Land owned per household (%)	0–1	92	100	96 (5.65)	
	2–3	8	0	4 (5.65)	
Land owned per household (ha)	Mean (SD)	0.5 (0.53)	0.38 (0.18)	0.44 (0.2)	$x^2 = 18.95$; df = 9; $p = 0.02$
Yields (kg/ha)	Common bean	306 (188.11)	178 (81.98)	242 (135)	$x^2 = 79.88$; df = 15; $p = 0.001$

3.2. Common Bean Cultivation Practices

On average, common bean was grown on 0.44 ha per household in both districts visited. This ranged from 0.34 ha to 0.63 ha in the Moshi rural and Arumeru districts, respectively. Intercropping was the most common practice reported by almost all respondents in the two districts. On average, 98% of farmers in both districts reported intercropping common bean with maize as a traditional practice. Crop rotation, on the other hand, was only practiced by few farmers (16%) in the Arumeru district, with common bean being rotated mostly with indigenous vegetables, such as African eggplant (*Solanum aethiopicum*). The majority of the respondents (96%) had experience in common bean cultivation, with an average of 17 years, but the period varied significantly across districts, ranging from nine to 25 years in the Moshi rural and Arumeru districts, respectively (Table 2). However, despite years of experience in common bean farming, yields remained low and varied significantly across districts, with Moshi rural recording the lowest yields (178 kg/ha) and Arumeru with the highest yields (306 kg/ha) in the

year 2019 (Table 2). Most of the farmers (89%) in the two districts indicated that they check and sort seeds that are not damaged by insect pests before planting.

3.3. Farmers' Knowledge of Weed and Pest Problems in Common Bean

In this study, 88% of the respondents reported that insect pests were the major constraint to effective production of common bean, followed by weeds (73%) and diseases (14%) (Table 3). Amongst the three most common insect pests, bean aphid (*Aphis fabae*) was mentioned by 86% ($x^2 = 0.1$; df = 1; $p = 0.752$) of the farmers as the main insect pest of common bean, followed by bean weevil (*Acanthoscelides obtectus*) (49%) ($x^2 = 4.043$; df = 1; $p = 0.044$) and ootheca (*Ootheca bennigseni*) (44%) ($x^2 = 4.975$; df = 1; $p = 0.026$) (Figure 2). On the other hand, the three most common weeds mentioned by respondents were *Cyperus rotundus* reported by 79.8% ($x^2 = 0.276$; df = 1; $p = 0.599$), followed by *Bidens pilosa* (45.3%) ($x^2 = 57.703$; df = 1; $p = 0.001$) and *Sphaeranthus suaveolens* (37.5%) ($x^2 = 0.638$; df = 1; $p = 0.424$) (Figure 3). The majority of farmers (92%) were able to identify and describe common bean weeds and insect pests by their local names. Only 2% were able to identify the insect pests and weeds upon seeing the pictures. A significant proportion of farmers (77%) mentioned beneficial insects such as ladybird beetle and honey bees as insect pests. Additionally, most of the farmers (84%) reported insect pest occurrence in the field, while 72% of farmers experienced insect pest attacks during storage. A huge proportion of farmers (98%) perceived that insect pests, particularly bean weevils, were causing significant loss of income, shortage of food (77%) and damage of seeds (62%) for planting in the subsequent season. On the other hand, 56% of the farmers described insect pest and weed challenge as being worse at present compared with the past 10–20 years.

Table 3. Perception of farmers on insect pest and weed control strategies in common bean farming.

Variable	District			
	Arumeru	Moshi Rural	Mean	Statistics
Insect Pest Control Methods				
Chemical sprays (pesticides)	85.5	72.2	78.9	$x^2 = 2.87$; df = 1; $p = 0.09$
Cultural	7.3	5.6	6.45	$x^2 = 0.13$; df = 1; $p = 0.72$
Do nothing	3	1.2	2.1	$x^2 = 3.72$; df = 1; $p = 0.05$
Weed Control Methods				
Chemical sprays (herbicides)	67.3	25.9	46.6	$x^2 = 18.71$; df = 1; $p = 0.00$
Mechanical (weeding)	84.5	87.1	85.8	$x^2 = 3.52$; df = 1; $p = 0.03$
Cultural	6.5	0	3.3	$x^2 = 2.00$; df = 1; $p = 0.16$

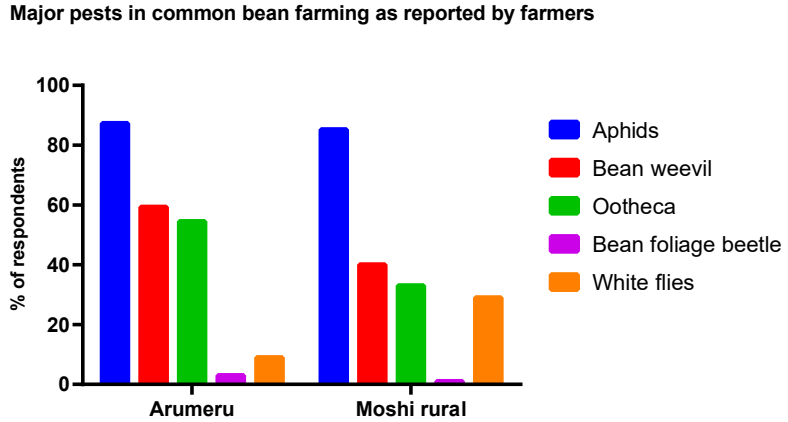

Figure 2. Major pests in common bean farming as reported by farmers in Arumeru and Moshi rural districts.

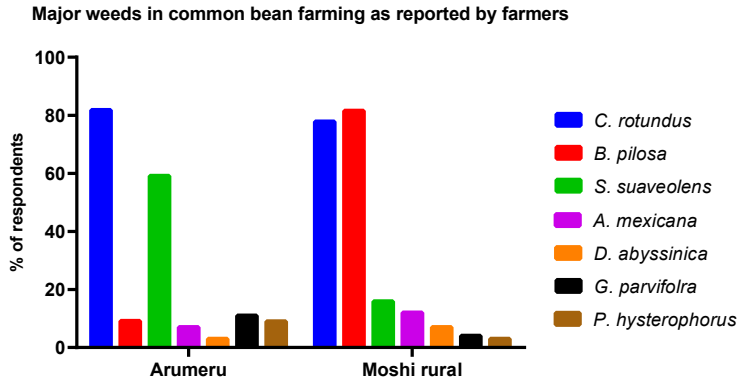

Figure 3. Major weeds in common bean farming as reported by farmers in Arumeru and Moshi rural districts.

3.4. Insect Pests and Weeds Management Practices

In this study, it was found that farmers in both Arumeru and Moshi rural districts apply chemical, mechanical and cultural methods to eradicate the damage caused to common beans as summarized in Figure 4. The use of chemical sprays was perceived by 78.9% of farmers as the main insect pest control method. Additionally, mechanical (weeding) was reported by 85.8% farmers as the main weed control method (Table 3). The cultural methods, such as intercropping and crop rotation, were practiced by most farmers in the surveyed districts. However, only 6.45% regarded them as insect pest and weed control strategies. In both surveyed districts, Profenofos was the most commonly used synthetic pesticide, reported by 33% of farmers, while Glyphosate was reported by 17% of farmers as the most commonly utilized synthetic herbicide. Furthermore, farmers described the use of other different insect pest management techniques such as an increase in dosage of application (22%), rate of application (14%), and mixing synthetic pesticide/herbicide with detergents and/or kerosene (3%). On the shortcomings of chemical sprays, most of the respondents (88%) mentioned harmful effects to human health, while 21% reported that most pesticides are non-selective and kill all insects including harmless ones such as butterflies. On the other hand, only 24% of the farmers were able to afford pesticides and herbicides. Others (67%) complained about the high price, and 60% reported availability and accessibility as the major challenge. Despite the effectiveness of different pest and weed management practices, 3% of the farmers in Arumeru and a paltry 1.2% in the Moshi rural districts did not apply any control methods against insect pests both in the field and during storage (Table 3).

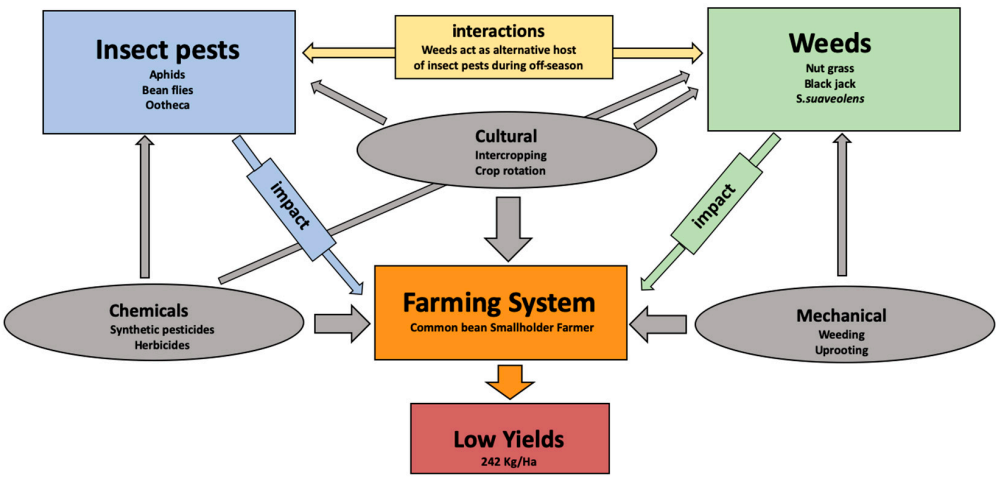

Figure 4. Summary of impact and management strategies for insect pests and weeds in common bean smallholder farming system in northern Tanzania.

4. Discussion

The majority of farmers in this study mentioned insect pests as a serious constraint to effective production of common bean in their farms. The insect pests were alleged to cause an average to major loss on yields, with the responses varying among the pest groups. Similar results were previously reported in common bean and pea smallholder farming systems in Ethiopia, Kenya, and South Africa [19,31,32]. Moreover, smallholder farmers of common bean have been linking the loss of common bean production with insect pest attack. Karungi et al. [33] suggested that, if no serious measures were taken to manage the insect pests yield losses can reach up to 100%. This could have a serious impact on food security of the smallholder farmers.

The perception of farmers that insects are the most dangerous pests in common bean production may be related to the great number of destructive insect species such as aphids, ootheca, and bean stem maggot (Table 3). This corroborates with a study by Ochilo and Nyamasyo [13] that bean aphids and stem maggots can account for yield losses of up to 100%. These insect pests have a high chance of damaging crops and reducing yields, thus causing visible and economical losses that can greatly affect smallholder farmers [34,35]. During the focus group discussions, farmers explained that the major loss of their common bean is caused by insect pests. This confirms further that insect pests are the major constraint in common bean production.

On the other hand, weeds were considered to cause a moderate to low effect on common bean production by competing for nutrients, water, space, and sunlight among others. Additionally, most farmers were aware of the importance of managing weeds in their farms. Pannacci et al. [36] stressed on the importance of combining different weed management strategies for smallholder farmers. The proper weed management strategies enhance crop yields by increasing sprouting of desired crops as well as reducing insect pest population [37]. However, in the absence of proper management practice, weeds may interfere with the normal growth of the desired crops and cause a significant loss in yields [38,39]. This emphasis on the need to train farmers on the different strategies for sustainable weed management.

Furthermore, farmers in the study area were able to identify some few weeds, such as black-jack (B. pilosa) as an alternative host to common bean insect pests during the offseason. Similar observations were also noted by Capinera [18] who pointed out that weeds are potential alternative hosts for insect pests. Weeds may also distract beneficial insects such as pollinators during the flowering stage. This subsequently reduces chances of desired crops to be pollinated thereby decreasing yields at large [40]. Takim [41] reported that weeding in and around the farm greatly reduced the population densities of legume pests such as pod borer (M. vitrata). Therefore, knowledge of weed and insect pest interactions is very important in developing sustainable and cost-effective pest management strategies for smallholder farmers.

The most common method that was frequently used to control insect pests and perceived as effective by most farmers in the two districts is the use of synthetic pesticide. However, this study discovered a knowledge gap in pesticide use. For example, of the farmers visited, most did not remember the name of the pesticides they applied. Farmers also get recommendations on pesticide use from fellow farmers and local agro-input dealers. It was also found that 43% of these dealers have only attained primary education and have had no formal training on pesticide use and safety. The current results are similar to those reported by [5,19,22]. In addition, some farmers reported the mixing pesticide kerosene, detergent soap, and other pesticides to increase their efficiency. Such strategies of improving the effectiveness of pesticides were also reported by Matthews et al. [42] and Oparaeke et al. [43]. However, the effects that these cocktail pesticides may pose to human health and the environment are largely unknown and need further investigation.

Additionally, the majority of farmers (43%) did not see the need to consult extension officers despite the challenges they face on pesticide use and safety. This could be attributed to improper application, the use of non-recommended pesticides, lack of personal protective equipment, and use of a mixture of pesticides with other compounds. These practices may lead to economic loss to

farmers, adverse effects on the environment and health-related problems associated with pesticide use to smallholder farmers particularly in developing countries [5,22,44–47]. It is, therefore, important for farmers to consult extension officers on issues related to pesticide application and safety.

On the contrary, mechanical methods (weeding) were perceived by the majority of farmers as the most effective weed control strategy in the two districts visited. Similarly, Pannacci and Tei [48] showed that a mechanical method can be an effective and fast non-chemical method of controlling weeds in different agro-ecosystems. Furthermore, most farmers in the study area perceived mechanical weeding as a traditional and the only method for weed control in maize and common bean farms over the years. Additionally, they were not aware of any other weed control methods such as the use of herbicides. Moreover, Bilalis et al. [49] highlighted the use of saline water and organic fertilizers as alternative strategies in managing weeds in common beans farming. These weed control practices should be encouraged to smallholder legume farmers, as they are cost-effective and safe compared with the use of chemicals.

Cultural practices such as intercropping and crop rotation were also practiced by most farmers in the study area; common bean being intercropped mostly with maize, and for crop rotation, maize and common bean were rotated with vegetables such as African eggplant. The main reasons for practicing intercropping and crop rotation reported, were for increasing productivity of farmland, enhanced soil fertility and risk minimization in case one crop fails. Correspondingly, legume farmers in Ethiopia gave similar reasons for practicing intercropping and were not aware of the other benefits such as pest and weed control [31,50]. Nevertheless, only a handful of farmers were aware that intercropping and crop rotation can be used as pest and weed management practices.

The knowledge gap identified in this study warrants for capacity building of farmers on the integrated weed and pest management strategies for controlling damage caused by weeds and insect pests in common bean production in Northern Tanzania. Furthermore, this study has proposed a framework (Figure 5), which stresses the importance of integrating extension services in managing insect pests and weeds by translating research findings into sustainable farming practices such as Integrated Pest Management and Integrated Weed Management that can easily be adopted by smallholder farmers in developing countries.

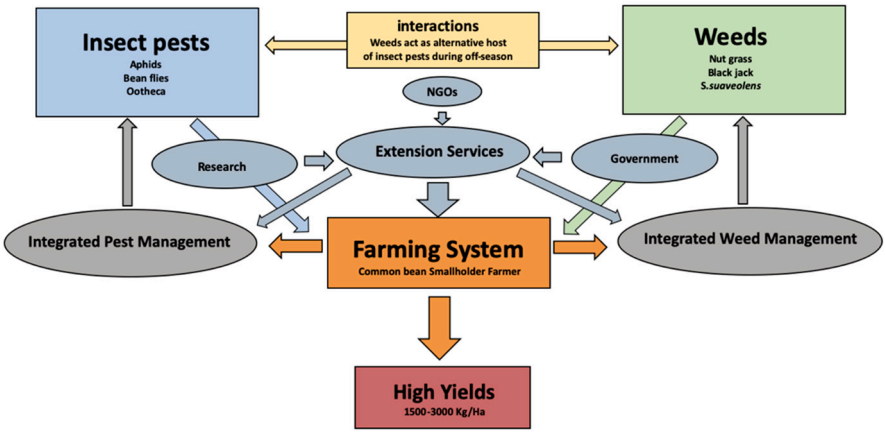

Figure 5. Proposed framework for the management of insect pests and weeds in common bean smallholder farming system in northern Tanzania.

5. Conclusions

The current study has confirmed that insect pests and weeds are perceived by common bean farmers in northern Tanzania as the major setback in the effective production of crops. Synthetic pesticides were reported as the main method for insect pest control. However, most farmers were not able to apply them due to reasons such as accessibility and affordability. There exists a knowledge gap in the area of integrated weed and pest management among most farmers in the surveyed districts.

This can be addressed through different capacity building training to farmers. The findings from this study urge the need to consider extension officers as key players in linking farmers with government programs, non-governmental organizations (NGOs) and agricultural research findings, as proposed in Figure 5. This will contribute to the development of an efficient, low-cost and environmentally friendly pest and weed management strategy that can be easily adopted by resource-constraint farmers. By implementing such measures, we aspire to see sustainable common bean production.

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Conflicts of Interest: The authors declare no conflict of interest.

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