Occurrence, Farmer's Knowledge and Current Management Practices of Alternaria Leaf Spot in Kales, Kiambu County, Kenya

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Abstract
Alternaria Leaf Spot (ALS) significantly impacts kale production in Kenya, with high-quality and quantity losses reported in Kiambu County. This study assessed ALS occurrence, farmers' knowledge, and management practices in the Githunguri and Lari sub-counties. Data on demographics, farm characteristics, ALS incidence, and management were collected. Results showed ALS prevalence in 82% of fields, with 42.2% of farmers indicating it affects all growth stages. Most farmers (60% in Githunguri, and 54% in Lari) relied on synthetic fungicides for control, yet 35.6% in Githunguri and 40% in Lari found them less effective. Multinomial logistic regression revealed that household head age, disease incidence, and total farm size were significant negative predictors of farmers' knowledge about ALS. Conversely, factors like the number of farming seasons per year, years of kale farming experience, training reception, and household members involved in farming positively influenced knowledge levels. The study concludes that while ALS is prevalent, reliance on chemical fungicides is common despite reported ineffectiveness, possibly due to improper use. Enhancing farmers' knowledge is essential for sustainable ALS management.

Keywords: Socioeconomic factors, disease incidence, disease severity, survey, training, disease, quality, quantity, incidence

1.0 Introduction

Kale, commonly known as "cabbage cousin" or Sukuma wiki (*Brassica oleraceae var. acephala* D.C.), is a cool-season crop in the Brassicaceae family (Swegarden, 2020). It is one of the most highly demanded vegetables in the world, its output is estimated to reach around 71.4 million tons, with China being the major producer (Ponce *et al*., 2022; Sheng, 2009). It is produced along with other brassicas. Achola (2014) claims that kale is an all-year crop that has been employed when various vegetables were in short supply and can lower poverty rates. Due to its high nutritional content, which includes antioxidants, beta-carotene, vitamin C, and vitamin K, kale is typically in great demand (Ngugi *et al*., 2022). Regular intake reduces the risk of human chronic illnesses, including cancer, diabetes, rheumatoid arthritis, and cardiovascular problems (Vilar *et al*., 2008; Afolabi, 2020). Kale powder has also been extensively used in the manufacturing of pharmaceuticals and nutraceuticals in the beverage and food industries (Khalid *et al*.,

2023; Satheesh and Workneh Fanta, 2020).
Several factors have been reported to constrain the global production of brassica crops kale being inclusive, these include low soil fertility particularly nitrogen and phosphorus, insect pests and diseases such as Alternaria leaf spot (ALS) and powdery mildews (Phophi *et al*., 2017; Mugo *et al*., 2021; Nungula *et al*., 2023; Daniel *et al*., 2023; Seif 2013; Ngugi *et al*., 2021). Others include the lack of reliable markets, the perishable nature of kale leaves, and extreme moisture levels (Emana *et al*., 2015; Shadrack *et al*., 2019). Among the diseases in kale, ALS has been regarded as more threat because of its significant negative impact on both the quality and productivity of kale (Sabry *et al*., 2015; Komhorm *et al*., 2021). Also in Kenya, one of the main obstacles to higher production is the black spot (Alternaria leaf spot) disease of brassicas caused by Alternaria spp. (Rod *et al*., 2009). Up to 45% or more loss of kale leaves has been reported, the disease tends to cause black spots and lesions that render the leaves unmarketable. Alternaria Leaf spot disease was cited by Spence *et al*. (2005) as one of the primary causes of low yields of brassicas, particularly kale. The majority of kale farmers in Kenya use synthetic fungicides to control ALS (Kirarei, 2019).
Inadequate studies have been done to assess the farmer's knowledge and their current management practices and the consequences of the disease management option in Kenya. For instance, a survey by Onditi *et al*. (2021) and Mwakidoshi *et al*. (2023) found that lack of sufficient technical information on symptoms, vectors, and modes of transmission of potato virus was found to be the main limitation to farmers' efforts towards the virus control. Nuwamanya *et al*. (2023) reported that all farmers in the study site were using synthetic fungicides to control Alternaria blight in tomatoes, and 83% of farmers were found to deviate from the recommended dosage and frequency of application (mostly to higher dosages and frequency); this could be attributable to low farmer's knowledge level among other factors.
Generally, there is no research yet that has established the farmer's knowledge of the level of ALS and its management practices in Kenya. Therefore, this triggered the current study to assess the farmers' knowledge level of ALS and its current management practices.

2.0 Materials and Methods

2.1 Study Site

Kiambu County was selected for this study due to its high-altitude kale-growing regions and its reported high ALS incidence. The County Agriculture Office provided data on the population of kale farmers, which made up the sampling frame.
This survey study was conducted in Lari, and Githunguri sub-counties, Kiambu County, Kenya (Figure 1). According to Wawira (2016), the Lari sub-county is largely mountainous located between 36°35' and 36°43' E and 0°50' and 1°40' S. The landscape is divided into two agro-ecological zones: the lower and the upper highland zones, with altitudes varying from 1760 (in the lower zone) to 2610 m (in the upper zone) above sea level, and at an altitude of 1,400 m above sea level. Rainfall is bi-modal and it varies depending on the altitude, with the low altitude zone receiving 700 mm and as much as 1400 mm being recorded in the upper zone (Wawira, 2016). The longer rain typically occurs between mid-March and May, followed by a cold period with light rain falling in wonderful drops from June to August. The short-term rains typically occur between October and November. On average, the annual rainfall is 1600 mm. The temperature range is 13.8-25.8°C. The soils are highly fertile, dark reddish brown, very deep, strongly calcareous, well-drained, and saline. In addition, the soils have high organic carbon content (3-4%), with the phosphorus levels remaining moderate (Makokha *et al*., 2001).

Githunguri is an agricultural town in central Kenya located at - 1° 3' 31.08"S 36° 46' 40.48" E and has an elevation of 1979 meters above sea level. It has a warm summer climate. The sub-county's yearly temperature is 20.4ºC (68.72ºF). Githunguri typically receives about 127 millimetres (5.01 inches) of precipitation and has 210 rainy days (57.49% of the time) annually.

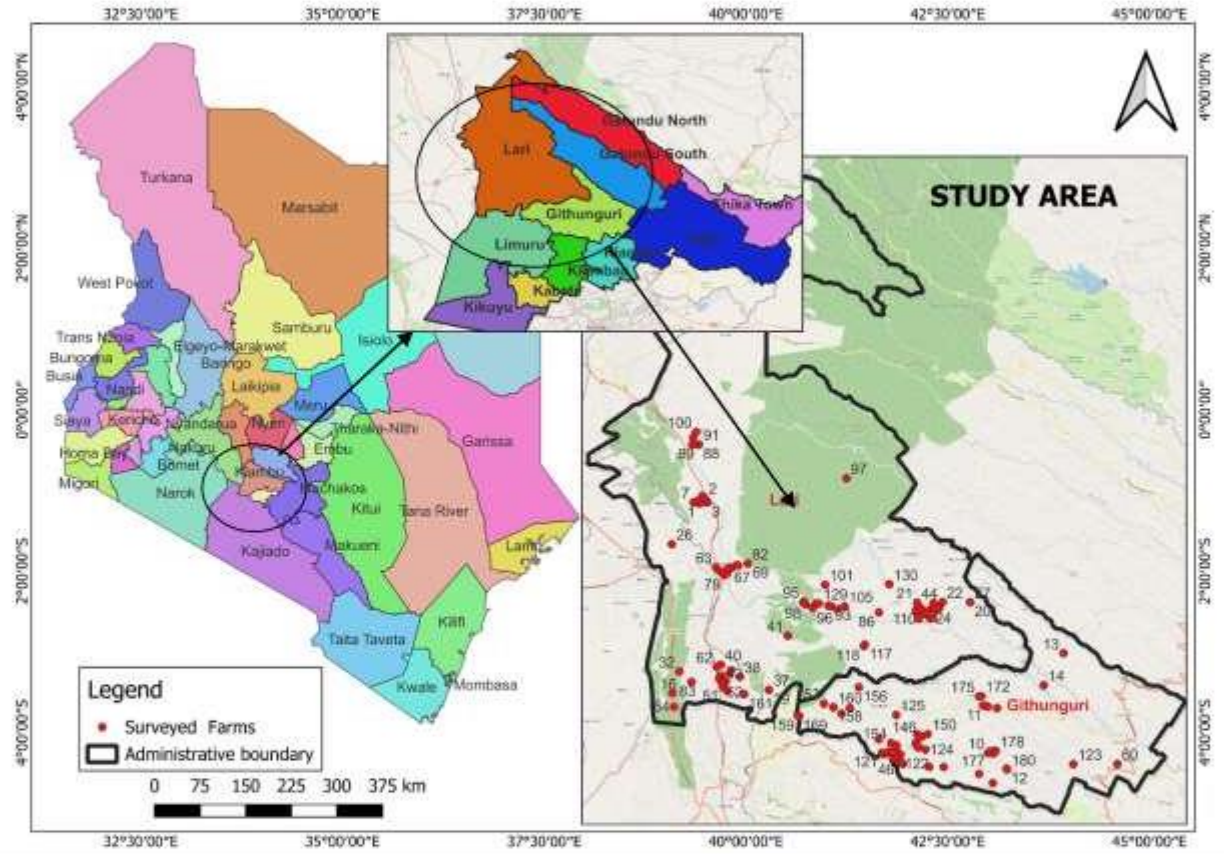

Figure 1: A map showing the study sub-counties in Kiambu County, Kenya and the s surveyed/ studied farms for this study

2.2 Sample Size and Sampling Design

The number of kale fields to be studied in each sub-county was determined by Kara (2015) (Eq. 1),

Were,

Formula: $S = \frac{Z^2*(P)*(1-P)}{C^2}$

(1)

]zP = % of picking a choice expressed as a decimal (0.5). Sample size, Z = Z value (e.g., 1.96 for 95% confidence), C level of precision (0.098). After determining the number of farms required in each area, fields were selected systematically along predetermined routes at 1 km intervals, and fields with size ≥0.25 acres were considered. The nearest kale field was sampled in exceptional cases where no field was available. 180 kale fields were visited; 90 in Githunguri and 90 in the Lari subcounty. The Kenyatta University Graduate School Board provided approval for this study which was then submitted to the

Director General National Commission for Science, Technology & Innovation for obtaining the national research permit. The study obtained the research permit with the license number **NACOSTI/P/23/32158.** Before the start of this study, all participants were thoroughly briefed on its objectives, procedures, risks, and benefits. Participation was completely voluntary, and individuals had the right to withdraw at any time without facing any adverse effects. Informed consent was secured from all farmers, with oral consent obtained to promote clarity and transparency. Each participant received was asked for his/her consent before the beginning of the interview.

To determine ALS disease farmers' knowledge levels, a test of 12 items was included in the questionnaire. The items covered the identification of disease symptoms in the field, knowledge of disease transmission mechanisms, management approaches, and their sustainability. The items were categorized based on binary choice (1 = yes, 2 = no).

2.3 Data Collection

Data was collected through interviews with farmers (using a semi-structured questionnaire) and direct observation of kale production practices. Data collected included demographic variables like farmer's age, gender, income, educational level, experience in kale production; and farm characteristics, e.g. kale field size, total field area, varieties of kale grown, number of cropping cycles per year, varieties grown, irrigation methods, type of farming systems, experience of ALS disease, ALS management practices including pesticide applications and their effectiveness. Farmers who reported to be applying fungicides were asked to identify each product by its trade name and to provide information on the dosage and frequency of sprays. Farmers were also asked to rank the effectiveness of fungicides using a simple rating scale of (1) very effective (2) effective (3) moderately effective (4) less effective (5) non-effective.

Disease incidence was determined by selecting several sampling units in each farm and each sampling unit in each sampling unit, a quadrant was made and the number of diseased plants was counted out of the total number of plants in the quadrant. Then the formula (Eq. 2) explained by Campbell *et al*. (1994) was used to calculate the disease incidence;

$$Disease\ incidence = \frac{Number\ diseased\ plants}{Total\ number\ of\ plants} \times 100 \text{ (Eqn 2)}$$

To determine the overall disease incidence in the field, the average disease incidence for several samples was calculated.

Farmers' knowledge level of ALS was determined by administering a test with twelve items where the farmers had to respond 'Yes' or 'No' based on their understanding of each question. For categorization, a simple scale was used where 0-4 low, 5-8 medium and 9-12 high.

To explain the relationship between the dependent variable (ALS disease knowledge variables) and independent variables (socio-economic factors i.e. interval or ratio scale), multinomial logistic Regression was used, where the following function in SPSS version 22, resulted in a multinomial regression model (Eq. 3).

$$y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \dots\dots\dots\ \beta_nX_n + \epsilon \text{-Eqn (3)}$$

Where X_1...Xn represents a vector of socio-economic predictors influencing ALS disease knowledge levels. ϵ is a random error with a mean of zero and a constant standard deviation σ (Table 1).

Table 1. Definition of multinomial regression variables

Variables	**Definition**
Dependent variables	

ALS knowledge levels Low, Medium, and High

Independent variables

Age HH (years) Continuous variable

1 = None, 2 = Primary, 3 = Secondary, 4 = Tertiary

Gender of HH 0 = Male, 1 = Female Kale Farming experience (years)

Continuous Household members in farming Continuous

Total farm size (acres) Continuous

Kale farm size (acres) Continuous variable

Training on ALS 1 = yes, 2= no

Credit access 1 = yes, 2 = no

Yield in t ha^{-1} Continuous Household monthly income (Kshs) Continuous

Number of trainings per year 1 = One. 2 = Two. 3 = Three. 4 = More than three

Number of kale planting seasons per year (seasons)

How long ALS has been experienced (years)

1 = one, 2 = Two, 3 = Three, 4 = More than three seasons

1 = <One, 2 = Two-three, 3 = four-six, 4 =

> More than seven

Extension service 1 = yes, 2 = no

Disease incidence Continuous

2.4 Ethical considerations

Approval was sought from the National Commission for Science, Technology and Innovation (NACOSTI) to conduct the current study. The permit was granted on Dec 23, 2023, Ref No. NACOSTI/P/23/32158. This permitted me to interview the farmers after passing a Research Ethics review process. The research honoured the subjects' right to remain anonymous and ensured their involvement was voluntary.

2.5 Data Analyses

Data was processed in Microsoft Excel version 2013 and analyzed in SPSS software version 23. The frequencies and means were summarized by descriptive statistics. Multinomial logistic regression was used to assess how socio-demographic factors affected the knowledge levels of individuals with ALS. For each ALS variable, the relationship between farmers and farm variables and ALS knowledge levels was examined using cross-tabulations and descriptive statistics. ANOVA was used to analyze the mean differences (numerical variables) and means were separated using *Independent Samples T- Test* and correlations between the categorical components and ALS knowledge levels were found.

3.0 Results

3.1 Demographic characteristics of the kale farmers

Males constituted the majority of farmers interviewed in the study areas (Githunguri 61.10%, Lari 62.2%). Most respondents (Githunguri 73.3%, Lari 64.40%) had attained the secondary level of education and above, and 21.7% had attained a primary education. A total of 52.2% of interviewed respondents were aged 50 years. Besides, farmers with farming experience between 11-20 years dominated the study with 36.70% of all the respondents. The study also found that 97.20% of respondents are landowners. The average household income in the Lari sub-county was significantly higher at 22794±1371.09Ksh than in the Githunguri sub-county at 21394 ±1226.87Ksh at a 5% probability level (Table 2).

Table 2: Selected demographic variables of kale farmers interviewed in Githunguri and Lari sub counties Kenya, May-2023

Characteristic	Category	Githunguri (n=90)	Lari (n=90)	Overall (n=180)
Gender (% of respondents)	male	61.10	62.2	61.70
	female	38.9	37.80	38.30
Education level (% of respondents)	none	4.40	2.20	3.30
	primary	15.60	27.80	21.70
	secondary	73.30	64.40	68.90
	tertiary	6.70	5.60	6.10
Age (% of respondents)	20-30	3.30	4.40	3.90
	31-40	18.90	16.70	17.80
	41-50	24.40	27.80	26.10
	>50	53.30	51.10	52.20
(% of respondents)	owner	97.80	96.70	97.20
	hired	2.20	2.20	2.20
	manager	0.00	1.10	0.60
Occupation (% of respondents)	farmer	57.80	54.40	56.10
	Farmer+formal	42.20	45.60	43.90
Experience (% of respondents)	1-10	26.70	26.70	26.70
	11-20	41.10	32.20	36.70
	21-30	15.60	28.90	22.20
	>30	16.70	12.20	14.40
Household income		21394 ±1226.87^{b}	22794±1371.09^{a}	22094±918.86

Ownership

SE-Standard Deviation, Means followed by the same letter across the rows indicates that there was no significant difference between two sub-counties at $\alpha = 0.05$

3.2 Selected farm characteristics for the surveyed fields

The study revealed that a higher percentage of farmers in both sub-counties (43.90%) (i.e. 36.7% in Githunguri, 51.1% in Lari) grow kale for two seasons. The majority of farmers 42.20% of farmers recycle their seeds. Most of the interviewed farmers (59.4%) practice both rainfed and irrigation kale farming, 38.90% practice rainfed farming while a minority 1.7% practice irrigation farming.

The majority of farmers practice intercropping (63.30%) in comparison to monocropping (15.60%), crop rotation (20.60%), and the least relay cropping (0.60%). Kale was found to be mostly intercropped with other vegetables and cereals (29.40%) intercrop kale with other crops and mostly (29.40%) intercrop kale with other vegetables such as spinach, cabbage, potatoes, and maize. The average kale yield was significantly higher in Lari 12,196.81Kg/acre than in Githunguri sub county 11, 978.59 Kg/acre, average kale farm size in Lari was significantly higher (0.63acre) than in Githunguri sub-county (0.49acre) the same applied to significantly higher disease incidence 28.34% in Lari sub county than in Githunguri sub-county 31.79% (Table 3)

Table 3: Selected farm characteristics for the surveyed fields in Githunguri and Lari Sub- counties, Kenya, May 2023

Characteristic		Githunguri (n=90)	Lari (n=90)	Overall (n=180)
One		23.30	24.40	23.90
Seasons (% of	Two	36.70	51.10	43.90
fields)	Three	22.20	16.70	19.40
More than three seasons		17.80	7.80	12.80
Seed source (% of	From a certified dealer	44.40	38.90	41.70
fields)	Seedlings from market	15.60	10.00	12.80
From own harvest		34.40	50.00	42.20
Cropping system	Rainfed	37.80	40.00	38.90
(% of fields)	Irrigated	2.20	1.10	1.70
Both		60.00	58.90	59.40
Monocropping		20.00	11.10	15.60
Cropping system	Intercropping	56.70	70.00	63.30
(% of fields)	Relay cropping	1.10	0.00	0.60
Crop rotation		22.20	18.90	20.60
Cereal crops tree/tree crops		2.20	1.10	1.70
None		43.30	35.50	37.80
Cereal crops		4.40	1.10	2.80
Intercrop	Legumes	0.00	1.10	0.60
(% of fields)	Tree/tree crops	0.00	1.10	0.60
Vegetable+cereals	Vegetabl	30.00	28.90	29.40
es+legumes+cerea		7.80	18.90	13.30
Others		1.10	0.00	0.60
Yield (kg/acre in ± (SD)		11,978.59±27.85[b]	12,196.81±40.81[a]	12, 087.70±24.76

Total farm size (Acre±S.E)	1.5519±0.18[a]	1.7850 ± 0.24[a]	1.6685±0.15
ALS incidence (%±S. E)	28.34±0.85[b]	31.78±0.78[a]	30.06±0.59
Kale farm (acres±SE)	0.49 ±.050[b]	0.63±0.65[a]	0.56±.04

SD Standard deviation, Letters indicate significant differences between means at α = 0.05

The major sources of information and awareness on ALS and its management include agro vet shops (28.3% farmers), field days (26.1% farmers) and 22.8% farmers for radio and Television (Table)

Table 4: Sources of information to kale farmers on ALS and its management

What is your source of information about ALS and its management?	Gitunghuri	Lari	Total
Radio/Television	22.2 (20)	23.3 (21)	22.8 (41)
Agrovet shops	30 (27)	26.7 (24)	28.3 (51)
Neighbours	23.3(21)	28.9 (26)	26.1 (47)
Field days	11.1(10)	15.6 (14)	13.3 (24)
Government extension staff	11.1(10)	2.2 (2)	6.7(12)
Private extension staff	-	2.2 (2)	1.1(2)
Newspapers	2.2(2)	1.1 (1)	1.7 (3)

a-Multiple answers allowed. *Figures in parentheses represent the frequencies of the responses.*

3.3 Training on ALS disease

The result indicated that 31.1% of the farmers were able to receive one training once per year while the majority of the farmers 55.6% were not receiving any training about ALS per year (Table 5)

Table 5: Number of training on kale disease management received by kale farmers per year in surveyed sub-counties, Kiambu, Kenya, May 2023

Number of training on ALS attended per year	Githunguri (n=90)	Lari (n=90)	Total n= (180)
None	53.3 (48)	57.8 (52)	55.6 (100)
One	32.2 (29)	30 (27)	31.1 (56)
Two	5.6 (5)	6.7(6)	6.1 (11)
Three	3.3 (3)	4.4(4)	3.9 (7)
More than three	5.6 (5)	1.1 (1)	3.3 (6)

3.4 Choice of kale varieties by farmers

Open-pollinated variety or local kale variety was found to be the most preferred variety with a mean rank (of 3.47±0.18), this was followed by the Ethiopian Kanzira variety (3.04±0.095) and the least preferred kale variety was Tausi F1 (1.72±0.054) (Table 6)

Table 6: Kale varieties preferred for cultivation by farmers in the surveyed sub-counties of

Kiambu, Kenya, May 2023.

Githunguri			Lari		Overall	
Kale variety[a]	%fields	Rank[b] (x±SEM)	%fields	Rank[b] (x±SEM)	%fields	Rank[b] (x±SEM)
OPV (local)	43.7	3.36±1.5	58.9	3.58±1.55	51.49	3.47±0.18
Ethiopian kanzira	26.4	3.00±0.142	33.3	3.09±0.127	29.9	3.04±0.095
Thousand headed	35.6	2.86±0.152	14.4	2.49±0.142	24.9	2.67±0.104
Mfalme 1	17.2	2.24±0.037	15.6	2.34±0.13	16.4	2.29±0.094
Tausi F1	3.4	1.78±0.085	3.3	1.766±0.067	3.4	1.72±0.054

[a]Multiple answers allowed

[b]Farmers ranked the preference of varieties using the scale (1=Not preferred, 2=Less preferred, 3=neutral, 4=preferred and 5=Highly preferred

Interpretation of the mean ranks: 1.00-1.79 -Not preferred; 1.80-2.59-Less preferred; 2.6-3.39- Neutral; 3.4-4.19-Preferred; 4.2-5.00-Highly preferred

3.5 Major factors influencing the selection of kale varieties

The high yielding potential of a variety (99.4% farmers), availability of ready markets (82.1% farmers), earlier maturity of plants (76.5% farmers) and the availability of seeds or seedlings (70.9% farmers) (Figure were the major factors that determined the choice or preference of a certain kale variety (Figure 2)

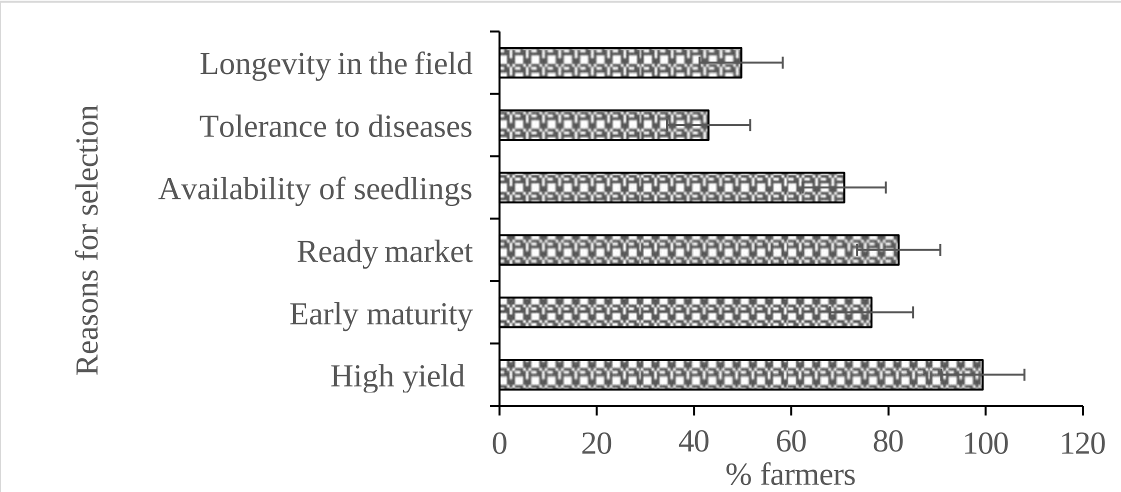

Figure 2: Major factors that influence the choice of kale variety for the five most commonly grown varieties cultivated in the surveyed area, Multiple answers were allowed.

3.6 Kale variety tolerant to ALS

Open-pollinated (local) variety has been majorly reported as a disease-resistant kale variety grown in both sub-counties (Githunguri 43.3%, Lari 51.1). This was followed by Thousand headed (Githunguri 17.8%, 8.9%), Mfalme 1 (Githunguri 20%, Lari 22.2%), Ethiopian kale variety (17.8%, 8.9%), and lastly Tausi F1 variety (Githunguri 0%, 1.1%) (Figure 3)

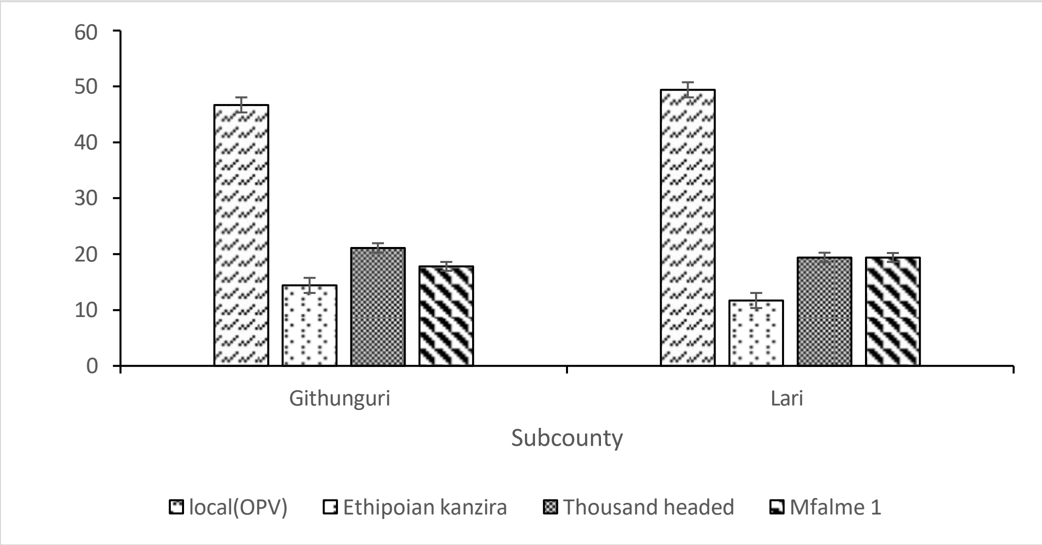

Figure 3: Kale variety tolerant to ALS

3.7 Sources of kale seeds or seedlings

The results indicate majority of farmers (42.8%) farmers) obtain the seeds from previous harvests or recycle the seeds, but also a good proportion of farmers (41.1%) use certified seeds from seed dealers. The least number of farmers (3.3%) borrow seeds from neighbours (Table 6) Factors that determine the choice of kale varieties by farmers (Table 7)

Table 7: Major sources of kale seedlings

	ithunguri (n=90)	Lari (n=90)	Total (n=180)
What is your source of kale seedlings?			
Buy seedlings from the market	15.6 (14)	10.0(9)	12.8 (23)
Borrow from neighbours	5.6(5)	1(1.1)	3.3 (6)
Purchase from a certified dealer	44.4 (40)	37.8 (34)	41.1 (74)
rom the previous harvest (re-cycling of seeds)	34.4 (31)	51.1(34)	42.8 (77)

3.6 Occurrence of ALS

The study revealed that a high proportion of farmers (Githunguri 83.3%, Lari 80.5%) experienced ALS (Figure 5). Furthermore, most farmers reported that they experience the disease throughout all crop growth stages, from seedling to harvesting (38.9% in Githunguri, 45.6% in Lari), while minority farmers (1.1% in Githunguri, 2.2% in Lari) experience ALS only during seedling. Figure 4 shows the typical Alternaria leaf spots developed on kale leaves in the study area.

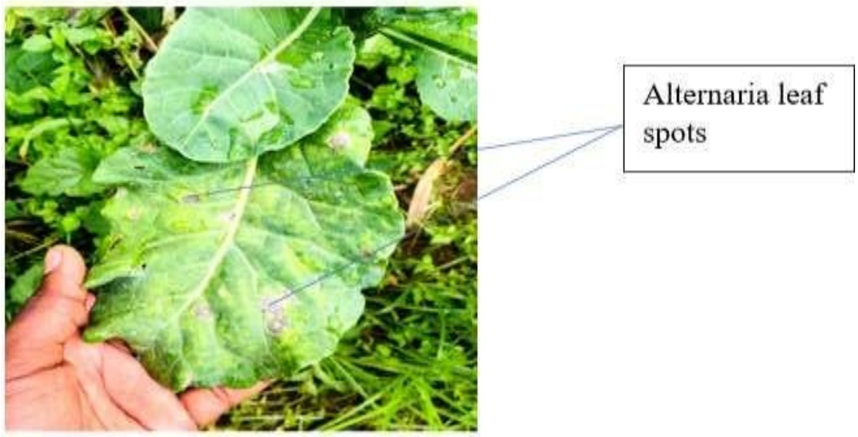

Figure 4: Typical symptoms of Alternaria leaf spots from the study sub-counties (Source: Photo by main author)

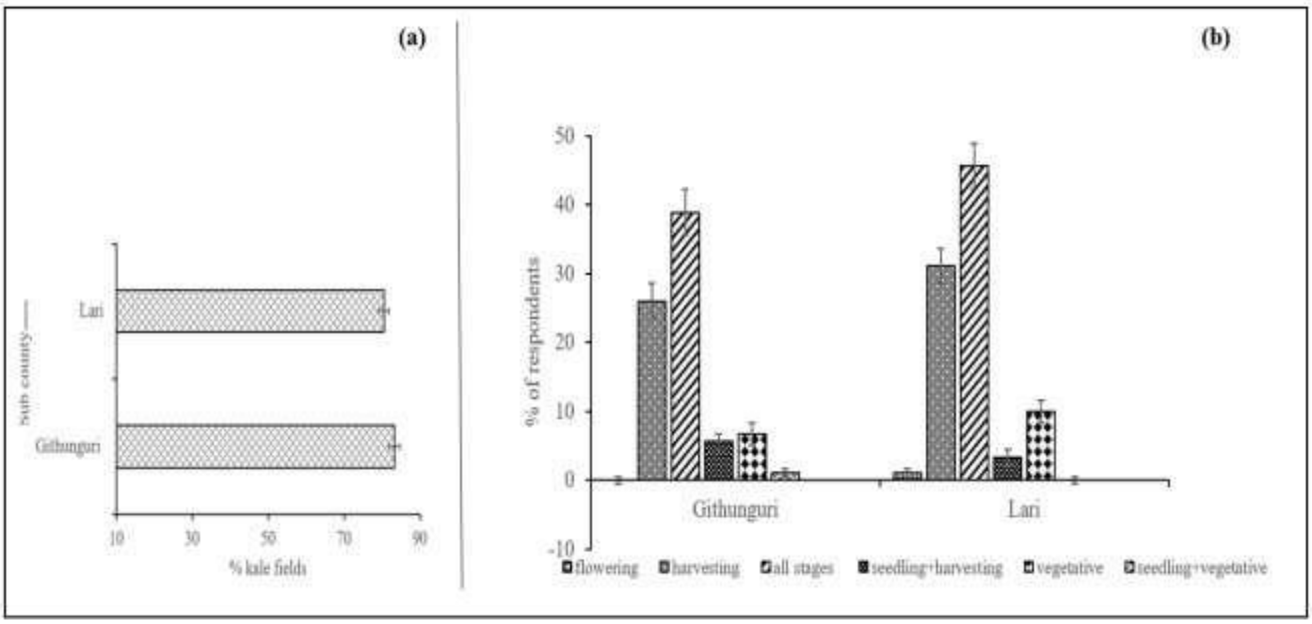

Figure 5(a) Occurrence of ALS in Githunguri and Lari Subcounty (b) The occurrence of ALS at different kale growth stages

3.7 Management approaches employed by kale farmers against ALS

The study found that a high proportion of kale farmers (60% in Githunguri and 54.4% in Lari) were using chemical fungicides to manage ALS. The removal of the infected leaves (pruning) and uprooting of the entire infected plants were techniques used by some farmers (13.9% in Githunguri and 16.1% in Lari) (Figure 3). Furthermore, it was found the frequency of application for most of the farmers (42% in Githunguri and 54.5% in Lari) that apply pesticides against ALS is every fourteen days whereas the least frequency of application of pesticides by farmers was every seven days (14%Githunguri and 6.8% Lari) as shown in figure 6

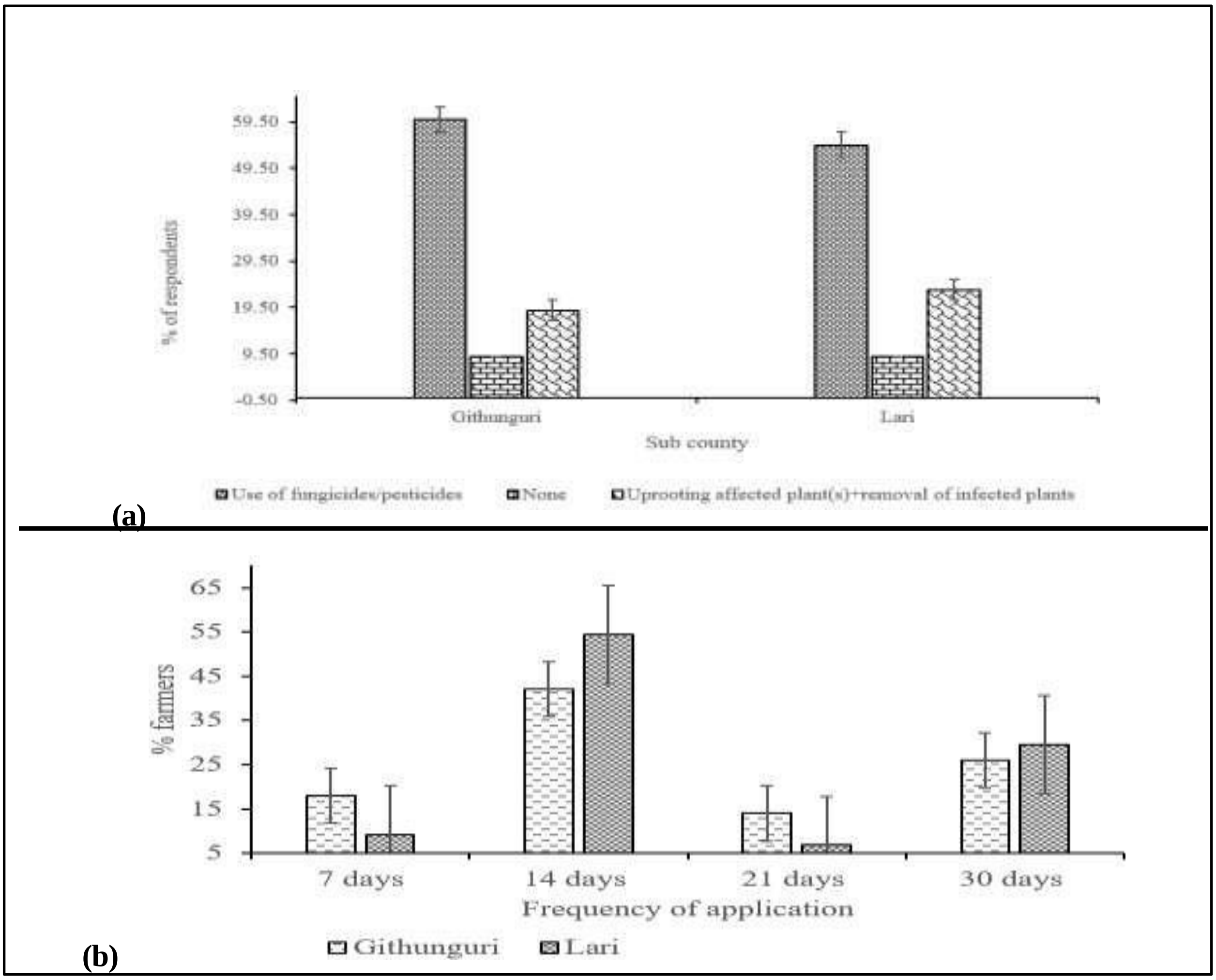

Figure 6 (a) Management approaches used by kale farmers against ALS (b) Frequency of application of pesticides against ALS

3.7.1 Fungicide used by farmers against ALS.

Ridomil gold® fungicide is used by a greater number of respondents from both sub-counties (Githunguri 31.1%, Lari 30%) Mistress® fungicide (4.4% in Githunguri, 7.8% in Lari) followed by Daconil® insecticide (Githunguri 3.3%, Lari 7.8%), Greencop® fungicide (3.3% in Githunguri, 4.4% in Lari) and the least applied pesticide in both sub-counties were Linkmill Gold® (Githunguri 3.3%, Lari 1.1%) (Table 8)

Table 8: Pesticide products used by kale farmers to control ALS in Githunguri and Lari sub-counties, Kiambu county, Kenya

Fungicide	Active ingredients	Resistance risk FRAC Resistance risk (Code/meaning)	% of farmers Githunguri	of farmers in Lari
Ridomil gold®	Metalaxyl +Mancozeb	4/High) + (M3/Low)	31.1	30

Mistress®	Cymoxanil+ Mancozeb	27/Low to Medium) + (M3/Low)	4.4	7.8
Daconil®	Chlorothalonil	M5 /Low	3.3	7.8
Greencop®	Copper Oxychloride	M1/Low	3.3	4.4
Linkmil Gold®	Metalaxyl+Mancozeb	(4/High) + (M3/Low)	3.3	1.1
Others			13.3	5.6
No fungicide used			41.1	43.3

FRAC = Fungicide Resistance Action Committee. *The risk codes were obtained online at* https://www.frac.info

3.7.2 The decision to control ALS

The study revealed that the majority of farmers (65.4%) initiate control against ALS when observing the field's disease symptoms. Twenty per cent (20.7%) use their own experience, while only 7.2% follow the extension recommendations and the least number of farmers consider the changing of weather conditions to initiate control ie. when the conditions become humid or during wet seasons (Table 9)

Table 9: Factors that determine farmer's decision to control ALS

		Githuinguri	Lari	Total
When do you decide to control ALS[a]?				
When I see disease symptoms		(68.8) 75	62.5(80)	65.4(155)
My own experience		21.1(23)	20.3 (26)	20.7(49)
Changing weather conditions		3.7(4)	7.0(9)	5.5(13)
Follow extension recommendations		6.4(7)	7.8(10)	7.2(17)
At a particular crop growth stage		-	-	-

3.7.2 Effectiveness of Pesticides Used against ALS

The majority of the respondents to this study reported that the pesticides used against ALS were less effective (Githunguri 35.6%, Lari 40%), while a small proportion reported that the pesticides were Very effective (3% in Githunguri and 0% in Lari). However, some respondents reported that the pesticides were effective (15.6% in Githunguri and 6.7% in Lari) (Figure 7).

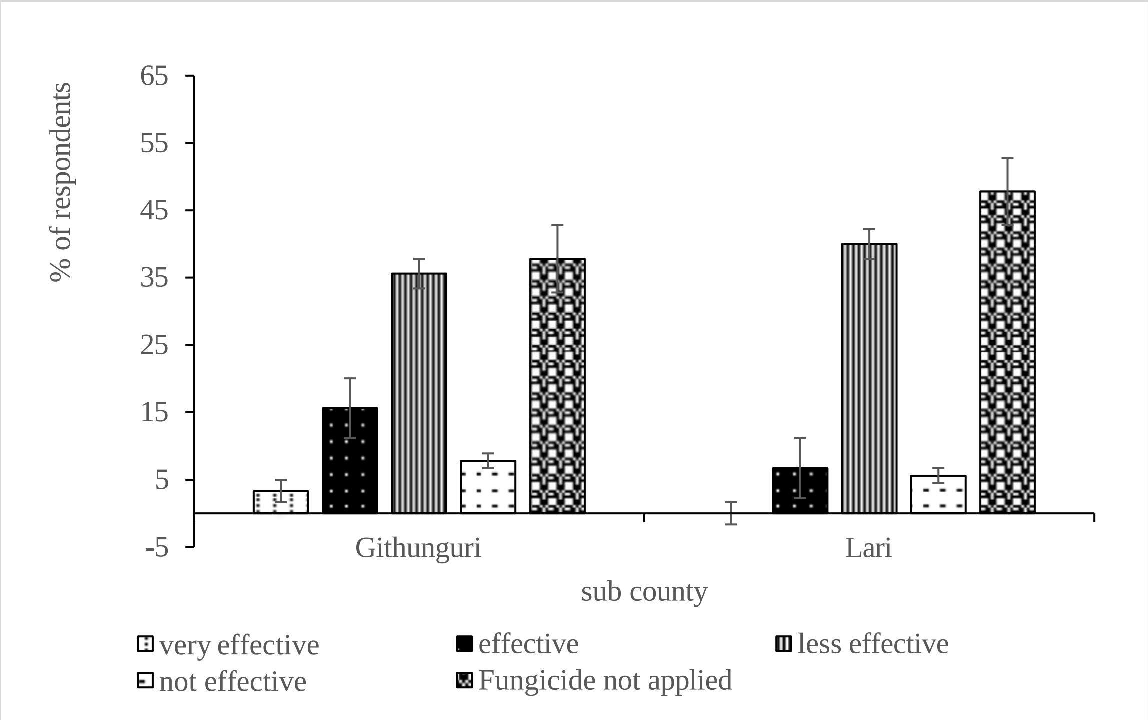

Figure 7: Effectiveness of pesticides used against ALS

3.8 Farmer's knowledge level of ALS and its management

For most of the items (8 out of 12), farmers' knowledge levels ranged between low to medium levels (Table 10).

Table 10: Farmers' response on items in the test for their knowledge of ALS and its management in Githunguri, Lari sub-counties, Kenya

Qn	Yes	No	Knowledge level
1 Alternaria; leaf spots in kale can cause Yield loss of up to 45%if not managed	99.4% (179)	0.0056% (1)	High
2 Alternaria leaf spots appear round, grey, to black concentric rings that Look like a target	99.4% (179)	0.0056% (1)	High
3 During the rainy season, the Alternaria Leaf spot is less severe than in the dry season	53.89% (97)	46.11% (83)	Low
4 The source of kale seedlings has nothing to do with ALS	53.8% (97)	45(81)	Low
5 Alternaria leaf spot disease is not a seed-borne disease	61.11% (110)	38.9% (70)	Low
6 It is cheaper to use botanicals than chemical fungicides to manage Alternaria leaf spots	60% (108	40% (72)	Medium

There are some kale varieties resistant/tolerant of Alternaria leaf spots	55% (99)	45% (81)	Medium
8 Copper and Sulphur-containing Pesticides are safer than other synthetic. fungicides when used to manage Alternaria leaf spots	47.7% (86)	52.2% (94)	Low
9 Fungicides to control ALS in Kales are usually sprayed directly on the plants	73.9% (133)	26.1% (47)	High
10 The fungicides to control leaf spot Diseases are usually applied at a frequency of 7-14 days	82.78% (149)	17.2% (31)	High
11 Management of Alternaria leaf spots disease using chemical pesticides causes more negative than positive effects on both humans and the environment	14.4% (26)	85.6% (154)	Low
12 Management of ALS using chemical Fungicides increase the quality of the kale produce	76.7% (138)	23.33% (42)	Low

*(*percentage of respondents followed by the number of respondents)*

3.4 Socio-economic variables influencing farmers' knowledge of ALS and its management Age of household head (β =-1.324, Odds=1.665), disease incidence (β = -0.027, Odds = 0.235), credit access (β =-0.293, Odds= 0.096), total farm size (β = -0.766 Odds= 2.815) were significant negative predictors of farmer's knowledge on ALS disease (Table 5).

The significant predictors determining whether a farmer's knowledge level was moderate relative to high about ALS disease included number of seasons per year (β = 0.848, Odds=7.855), number of years of experience in kale farming (β = 0.03, Odds = 0.019), whether a farmer receives training/not (β = 0.002, Odds = 0.01), number of trainings per year (β =0.472, Odds= 2.942) age (β =-1.324, Odds=1.665), credit access (β =-0.293, Odds=0.096), and number of household members in farming (β = 0.471, Odds = 6.694) and total farm size (β = -0.051, Odds= 0.081).

Table 5: Socio-economic variables influencing farmers' knowledge of ALS and its management

	Low			Moderate		
	β	Odds	Sig	β	Odds	Sig
Intercept	6.688	1.966	.161	7.704	9.497	.002
Age of HH Head	-1.324	7.432	.005**	-1.182	15.163	.000**

No. of Seasons per year	1.162	7.746	.005**	-.848	7.855	.005**
Occupation of a farmer	-1.162	1.655	.198	.448	.833	.361
Years of experience in kale farming	.077	3.643	.101	.003	.019	.0090**
Credit access	-.293	.096	.757	1.237	.479	.010**
Number of trainings per year	.215	.179	.000	-.472	2.942	.0001**
How long ALS has been experienced	1.644	12.190	.000**	-.861	10.078	.002
Whether extension service received	-.132	.052	.819	-.008	.001	.979
Kale farm size	.149	.025	.874	-.122	.095	.758
Whether a farmer receives training/not	.290	.490	.484	.002	.000	.001**
Income per month	.000	.048	.826	.000	.886	.347
No. of Household members in farming	.277	.685	.408	.471	6.694	.010**
Incidence of ALS	-.027	.235	.628	-.081	6.889	.009**
Gender	-0.079	0.007	0.934	0.169	0.123	0.726
Education	-0.127	0.002	2.204	-0.153	0.149	0.858
Total farm size	-0.766	2.815	0.003**	-0.051	0.081	0.004**

a. The reference category is: high

Regression analysis indicated how long the farmer has experienced ALS (β = 1.644, Odds = 12.190), number of seasons per year (β = 1.162, Odds = 7.746), number of pieces of training per year (β =0.215, Odds= 0.00) and total farm size (β = -0.766 Odds= 2.815 were significant predictors for low relative to high knowledge in integrated on ALS disease and its management.

4.0 Discussion

4.1 Socio-demographic variables and farm characteristics and their impact on farmer's knowledge

The observed dominance of male-headed households was an implication that at the household level, men make almost all agricultural and farm-related decisions. This finding was in line with findings from previous research conducted in Kenya (Nguetti *et al.*, 2018; Ochilo, 2019; Mwakidoshi *et al* 2023). The

dominance of males in the study can be explained by the fact that men hold and control the means of production including land and capital (Barasa *et al*., 2019; Anang *et al*. 2013).
A large number of the kale farmers interviewed were aged 50 years or older. The results are inconsistent with those of Mwangi *et al*. (2015) who found that the production of vegetable/kale is dominated by the younger age group (21-40) and the 31-50 years have been characterized by great access to important factors of production. For this study, the fact that kale is less capital-intensive and can be grown even in smaller home plots favours the adult population to dominate.
The fact that most farmers have attained formal education implies that farmers can obtain and comprehend disease management approaches. Awan *et al*. (2012) found that there is a strong relationship between the level of education and a better understanding of disease management strategies. Nevertheless, the study found that there was no connotation between the level of education and the farmer's knowledge of ALS and its management.
The majority of farmers are experienced farmers which implies that they have a better understanding of entire kale production. Such findings are in line with the study by Pratiwi and Suzuki (2017) who found that the more the farmer is experienced, the better the understanding of the crop and higher abilities to adopt the knowledge from other farmers or experts.
The fact that most of the farmers had attained formal education implies that they can obtain and comprehend disease management approaches. Karienye *et al*. (2020) found that there is a strong association between the level of education and a better understanding of disease management strategies. Nevertheless, the study found that it was found that there was no association between the level of education and the farmer's knowledge of ALS and its management.
When compared to less experienced farmers, the more experienced ones were likely to have medium to high knowledge of ALS and its management. This is probably because knowledge is related to their Experience of growing crops on their farms, indicating they have better knowledge about crop behaviour and the associated biotic and abiotic stresses (Toffolini *et al*., 2017; Oliver *et al*., 2010; Richards, 2002; Seleiman *et al*., 2021).
Stuiver *et al*. (2004) also found similar results that farmers tend to create knowledge from practical familiarities, rather than formal research. Farmers typically learn from real-world experiences rather than from formal research and experiments. Even if farmers conduct intentional testing, the nature of their studies differs greatly from that of scientists. Another study by Oreszczyn *et al*. (2010), indicated that farmers cannot depend on face face-to-face interactions as a primary tool for gaining knowledge than practical experience. Because of they're the nature of the community farmers have distributed practices.
On farmer's training, the study revealed that the more trained farmers are likely to have medium to high knowledge of ALS and its management. This might be probably attributed to the fact that farmer training helps to improve their skills in agricultural practices such as good agricultural practices including pest and disease management (Pretty, 2008, Emeana *et al*., 2019). Sajeev *et al*. (2012) also found similar results that training improves farmers' skills and knowledge of the practices from planting to harvesting, with pest and disease management being included.
But also, a study by Nakano (2023), discovered that training attendees greatly raised the adoption of suggested technologies and saw a considerable boost in paddy harvests. Later on, non-participants' performance also improved, and those farmers caught up to the participants. The farmers who had experienced ALS for a longer time previously were likely to have medium to higher knowledge of ALS and its management, this is because a longer time when a farmer faces disease gives a farmer a better

understanding of the disease. Islam *et al*. (2020), also found farmers who had experience of Anthracnose for the last five cycles or more 99% of those farmers had higher knowledge compared to those who had fewer cycles of disease experience.

The study revealed that farmers who have more kale seasons in a year are likely to have medium to high knowledge of ALS. This is probably because different seasons may have different levels of Alternaria leaf spot incidences, also among other factors since the pathogen is more favoured in the cool season thus more ALS disease incidences and severity may be higher during the cool season than in the humid season (Rop *et al*., 2009; Jantasorn *et al*., 2017). The kale farmers who receive training are likely to have medium to high knowledge when compared to those who do not receive training this probably training equips them with the knowledge that contributes to the proper management of crop diseases (Nyagwansa *et al*., 2021). Considering that kale can take between three to six months in the field, when a farmer does two or more seasons in a year, will have kale in the field for almost a whole year which can be attributed to the quick multiplication of the inocula and across the successive seasons (Abuley *et al*., 2019 and Fry, 2007). According to Damicone and Roberts (2009), the tendency of growing kales all year round in the field increases the chances for higher ALS disease incidences, this is because *A. brassicicola* tends to persist in the soil and crop debris. Therefore, repeated growing of kale in the same field will enable the pathogen to build to damaging levels.

Infected seeds or seedlings are one primary source of *A. brassicicola* inoculum (Köhl *et al*., 2010). The authors also noted that ALS does not only affect the leaves but also it damages the fruit-bearing pods and branches which turn black upon being colonized by *A. brassicicola*. The pathogen mycelium will tend to grow both externally and internally for the seeds of the affected crops. The pathogen will survive in seeds and when planted will result in lower germination rates and infected seedlings. Also, Harvey (1986) recommended that the pathogen may survive on seed; purchase seed tested for the disease and a farmer has to be careful when saving seed.

Intercropping of kale with other vegetables such as cabbage, broccoli, and cauliflower increases the chance of the spread thus increasing ALS incidence in kale (Carrillo-Reche *et al*., 2023). Lodha *et al*. (2018) found that lower disease severity was experienced in kales intercropped with cereals.

In line with these, results, Rasanjali *et al*. (2021) and Mwakidoshi *et al*. (2023) reported that the advancement of farmers' knowledge and skills depends on improved agricultural training programs. According to Yang *et al*. (2008), farmers who attended Farmer Field School (FFS) considerably improved their knowledge of vegetable pests, insect and disease ecology, natural enemies, and pest management; conventionally trained farmers did not significantly improve their knowledge in any of these sections.

Khoury and Makkouk (2010) on revealing the importance of training farmers on disease management insisted that training and awareness creating to farmers remain an important factor towards Integrated Disease management (IDM). The study recommended that farmers should be equipped with the necessary knowledge to evolve into better field managers through intensive training that uses collaborative approaches. This knowledge should then be translated into appropriate decision-making tools and useful tactics for control.

Farmers with credit access are more likely to have medium to high knowledge compared to those without credit access. This is probably because access to credit increases access to information including information on pests and disease outbreaks and management (Deichmann *et al*., 2016; Agyekumhene *et al*., 2018; Sekabira *et al*., 2022). Other studies such as Arnold *et al*. (2021), found that farmer's knowledge is positively influenced by RCB loan availability. For instance, the farmers who obtained higher technical competencies than those who did not.

It was revealed that households with more people engaged in kale cultivation were probably more knowledgeable about the symptoms and treatment of ALS disease, ranging from medium to high knowledge. According to a study by Zossou *et al*. (2020), there is a household-level exchange of agricultural information and expertise, therefore the larger the household, the greater the degree of knowledge about crop management. According to Whitehouse (2011), the majority of African societies share this solidarity of skills and knowledge exchange at the household level.

The level of knowledge for the younger kale producers regarding ALS and its management was moderate relative to high. This is inconsistent with the findings of Macharia *et al*. (2014) and Mwaura *et al*. (2021), who found that younger farmers, in comparison to their older equivalents, lack the expertise necessary to possess enough knowledge of integrated inputs. According to a different study by Ebewore and Isiorhovoja (2019), a farmer's age was statistically significant at $P<0.05$ for predicting their level of plant disease management knowledge.

A large proportion of farmers reported to acquire information on ALS from Agrovet shops and their neighbours, therefore there is a need to disseminate knowledge of ALS and its management through mass media such as Radio and Television but also physical training programs.

4.2 Occurrence of ALS

The existence of humid conditions and extended periods of wetness in the study area year-round is responsible high occurrence of ALS, for instance, Lari experiences relatively cold conditions because of its location on the windward side of the Aberdare Range. As a result, it receives a considerable amount of rainfall per year. According to Sharma and Ghosh (2017), humid and warm climate favours the growth and infection of plants by fungal pathogens. Furthermore, extended leaf wetness promotes the infection of the pathogen on the leaf, thus the longer the leaves remain wet, the greater the chance of infection also humidity may serve as the agent of Alternaria spores' dispersal (Reddy and Reddy, 2016; Ramegowda, 2007). But also, Bauer et al. (2022) and Marmara (2024) indicate that in humid conditions plants become more stressed and thus become susceptible to infection.

4.3 Management Practices for ALS

The study revealed that most farmers in the studied sub-counties were mainly relying on synthetic pesticides to manage ALS. This result was consistent with the results found by Ngaiza et al. (2024) and Lagerkvist et al. (2012).

The study also established that there were no kale varieties resistant to ALS however the local or Open pollinated Variety (OPV) was reported to be a tolerant variety when compared to other varieties. Therefore, there is a need for Kenyan breeders to develop more tolerance or resistance against ALS. The observed cultural practice of removing infected leaves (de-leafing) from the infected plants is not a best practice as it compromises the yield by reducing the number of harvestable leaves (Sosnowski et al., 2009). The majority of farmers re-cycle their seeds, this may increase the severity of ALS because ALS can be transmitted through seeds (seed-borne diseases). Mancini and Romanazzi, (2014) and Gebeyaw, (2020), reported that when seeds are harvested from infected plants, the fungal spores or mycelium can adhere to the seed surface or be present within the seed tissues and when the infected seeds are sown the pathogen will spread to emerging seedlings, causing early symptoms of leaf spot and affecting plant health. Also, according to Sharma et al. (2018), Damicone (2014) and Jagadeesh et al. (2022), inadequate treatment of the seeds with fungicides may favour the survival of the pathogen until sowing.

The majority of farmers also reported that most of the fungicides against ALS are less effective. This may be attributable to inappropriate choice of active ingredients, dosage and frequency of application and pathogen developing resistance to certain fungicides (Corkley et al., 2022; Baibakova et al., 2019). The use of higher doses of fungicides has been reported to render the development of fungicide-resistant strains among pathogens (Nuwamanya et al., 2023). Farmers need to be sensitized on the importance of rotating fungicides and using a diversity of fungicides to minimise the chances for *Alternaria spp* to develop resistance

Conclusion

Despite the Alternaria leaf spot in the study sub-counties being a serious problem to kale production, its management is still unsatisfactory. This may be attributable to Farmers' knowledge of ALS and its management being less adequate. Therefore, there is a need to provide more capacitation to farmers on disease management. Extension agents should increase their interactions with farmers to continuously help farmers and remind them of the existing and new approaches to managing the disease. More training for kale farmers and also farmers to be encouraged to attend and join farmer groups where the knowledge can be easily disseminated. Furthermore, farmers need also to be trained.

The proper choice of pesticides, appropriate dosage frequency of usage but also rotation among different active ingredients. Plant breeders need to develop kale varieties with the potential trait to resist or highly tolerate ALS.

Declaration of Competing Interest

The authors state that none of their known conflicting financial interests or personal connections could have had an impact on the work that is reported in this paper.

Contributions

Data availability statement

Data is available from the corresponding author upon reasonable request

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