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Assessment of Farmers' Awareness, Perceptions, and Management Practices Related to Onion Anthracnose –Twister Disease in Sri Lanka

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ABSTRACT

Onion is a vital crop for the Sri Lankan economy, yet its productivity is severely constrained by anthracnose–twister disease (ATD) caused by *Colletotrichum* and *Fusarium* species. This study assessed farmers' awareness, perceptions, and management practices related to the disease across seven major onion-growing districts: Jaffna, Kilinochchi, Mullaitivu, Trincomalee, Puttalam, Matale, and Anuradhapura. A descriptive cross-sectional survey was conducted among 350 farmers using a structured questionnaire that covered demographic characteristics, agronomic practices, pest and disease management, and farmer knowledge on ATD identification and varietal resistance. Data were analyzed using descriptive statistics and binary logistic regression. Results revealed that most farmers were male, middle-aged, and primarily cultivated shallots, while bulb onion cultivation dominated in Matale and Anuradhapura. ATD was the most prevalent constraint, particularly during the *Maha* season, leading to yield losses exceeding 50 % in several districts. Logistic regression analysis revealed that seasonal conditions, onion variety, land preparation, plant spacing, watering frequency, and irrigation method significantly influenced ATD incidence. Frequent watering and surface irrigation substantially increased disease risk, whereas wider spacing (10 cm × 10 cm), improved land preparation, and reduced irrigation frequency significantly lowered infection probability. Awareness of resistant varieties was limited across most districts, and chemical control remained the dominant management strategy. Overall, the findings highlight the need for integrated disease management approaches that combine improved agronomy, climate-adapted irrigation, farmer education, and the development and adaptation of resistant cultivars to mitigate ATD impacts and sustain onion productivity in Sri Lanka.

Keywords: Anthracnose-twister disease, Agronomic practices, Farmers' awareness, Onion, Survey.

1. INTRODUCTION

Onion is one of the most economically important and widely cultivated spice crops in Sri Lanka, particularly in the Northern, Eastern, and North Central provinces [1]. It plays a vital role not only in the rural economy, providing income, employment, and food security, but also in the national culinary culture, as onions are a staple ingredient in traditional Sri Lankan dishes [2]. Cultivation of onion supports crop diversification and enhances the sustainability of the agricultural system.

Despite its significance, onion production is constrained by several biotic stresses, particularly anthracnose-twister disease (ATD),

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caused primarily by the co-infection of *Colletotrichum* spp. and *Fusarium* spp. This disease causes twisting of leaves, neck elongation, and dark, sunken lesions, which lead to severe yield and quality losses [3,4,5]. It is the most prevalent disease reported in key onion-growing regions of Sri Lanka, namely Jaffna, Kilinochchi, Mullaitivu, Anuradhapura, Matale, Puttalam, and Trincomalee, where humid and warm climatic conditions favour pathogen development [6].

Although fungicides are commonly used, overreliance on chemical control has led to environmental and economic concerns. Integrated disease management and the adoption of resistant varieties remain underutilized due to limited awareness and access to technical information [7]. The use of local landraces like Vethalan and Jaffna Local continues, yet farmers' understanding of disease resistance mechanisms and climate-smart practices is often lacking [8].

In this context, a structured questionnaire survey was conducted among 350 farmers representing seven major onion-growing districts in Sri Lanka. The survey aimed to examine farmers' socio-economic characteristics, land use patterns, varietal preferences, and awareness of major onion diseases, particularly ATD, along with the management practices currently in use. Specifically, the study sought to assess farmers' knowledge and awareness of ATD, identify the existing agronomic, pest, and disease management strategies, and identify the challenges and constraints hindering the adoption of effective control measures.

2. MATERIALS AND METHODS

2.1. Study design and locations

This study utilized a descriptive cross-sectional survey to explore onion farming characteristics, agronomic challenges, crop management practices, and ATD prevalence in selected major onion-growing districts in Sri Lanka, including Jaffna, Kilinochchi, Trincomalee, Puttalam, Mullaitivu, Matale, and Anuradhapura.

2.2. Questionnaire design

A structured questionnaire was designed to obtain a comprehensive set of information. The questionnaire was divided into the following sections: demographic information, farming characteristics, details of onion varieties cultivated, agronomic practices, pest and disease management, awareness of ATD, awareness of resistant varieties, and farmer perceptions. The questionnaire was developed in three languages (Sinhala, Tamil, and English) to accommodate the linguistic diversity of the participants.

2.3. Ethical considerations

Prior to the data collection, ethical clearance approval was obtained from the Ethical Review Committee, Faculty of Health Care Sciences, Eastern University, Sri Lanka. Written consents were sought from all participants, and the purpose of the study was clearly explained in all three local languages. Participants were assured of confidentiality, and data were anonymized during analysis and reporting. Respondents were informed that participation was voluntary and that they could withdraw at any time without any consequences.

2.4. Target population and sampling method

The target population consisted of small (<1acre) to medium-scale (1-5 acres) onion farmers actively engaged in cultivation within the selected districts. The Agricultural Instructor (AI) of each area assisted in identifying eligible onion farmers from each district studied. Random sampling was taken within each district to ensure representation from various farming scales, age groups, and levels of experience. A total of 350 farmers (50 from each district) were selected as respondents for capturing regional trends and ensuring statistical validity.

2.5. Data collection

Field surveys were conducted from June 2022 to January 2023. Farmers were initially provided with the questionnaire to complete on their own; however, in cases where farmers had difficulty to reading or writing, or were reluctant to fill the form independently, the interview was conducted verbally, and their responses were carefully recorded. Each interview lasted approximately 15 to 20 minutes, and responses were recorded on printed forms for subsequent data entry and analysis.

2.6. Data processing and statistical analysis

All questionnaires' data were carefully reviewed for completeness and accuracy prior to analysis. The verified data were first entered and organized using Microsoft Excel 2019 and subsequently analyzed using the Statistical Package of IBM SPSS Statistics version 30.0.

Descriptive statistics such as frequencies, percentages, and means were employed to summarize farmers' demographic characteristics, onion farming practices, disease occurrence, and management strategies across the seven study districts. Graphical representations including bar charts and pie charts were used to illustrate key patterns and distributions.

Furthermore, inferential statistics, a binary logistic regression model was developed to identify key determinants influencing the occurrence of ATD in onion fields. The dependent variable was disease presence (coded as 1 = Yes, 0 = No), while independent variables included season, onion variety, land preparation, planting spacing, watering frequency, and method of irrigation. Model adequacy was evaluated using the Omnibus test of model coefficients, Hosmer and Lemeshow fit test, Cox and Snell R^2 and Nagelkerke R^2. All statistical tests were conducted at a 95% confidence level ($p < 0.05$), and results were interpreted in terms of their significance.

3. RESULTS

3.1. Demographic information of farmers

The survey revealed that most onion farmers (approximately 85%) across all seven districts were male, with most farmers (around 70%) falling within the 31–50-year age range, indicating a predominantly middle-aged farming population. Educational qualifications varied across districts; notably, Jaffna (56%), Trincomalee (40%), and Kilinochchi (38%) recorded the highest proportions of farmers with Ordinary Level (O/L) qualifications, while Anuradhapura reported the lowest (16%). Beyond basic schooling, a considerable proportion of farmers had higher education, including Advanced Level (A/L) (10 – 30 %), and notable number possessed diplomas or university degrees, particularly in Anuradhapura (6% diploma) and Trincomalee (6% degree). Overall, the data suggests a reasonably educated workforce engaged in onion cultivation.

Farming remained the primary source of livelihood for most households, with 42%–64% of farmers depending on crop production. A moderate proportion (around 30%) of farmers practiced mixed crop–livestock systems, while the remaining respondents (<14%) were engaged in daily wage labour, self-employment, or private and government-sector jobs. These findings reflect the socio-economic diversity of farming households and highlight the varying degrees of reliance on agriculture across districts (Table 1).

3.2. Farmer experience, cultivation extent, and varietal preferences across districts

The farming experience of onion growers varied notably among districts. Most farmers in Jaffna (42%), Matale (44%), and Puttalam (38%) had over 10 years of onion farming experience, indicating long-term engagement in cultivation. In contrast, Kilinochchi (42%) and Mullaitivu (30%) had more farmers with 5–6 years of experience, reflecting relatively newer involvement in onion farming. With respect to the extent of cultivation, most farmers operated on small to medium holdings (1–5 acres). Bulb onion cultivation, confined to Anuradhapura and Matale, was primarily cultivated on 1–5 acre extents (64–78%), while in the other districts, shallot cultivation predominated on 1–5 acre holdings (58–94%), with only limited small-scale production (<1 acre).

Varietal preference showed a clear distinction across districts. Farmers in Jaffna, Kilinochchi, Puttalam, Trincomalee, and Mullaitivu predominantly cultivated shallot (98%–100%), whereas those in Anuradhapura and Matale exclusively preferred bulb onion (100%).

Table 1- Demographic details of farmers

Characteristic	Variable	Jaffna (n=50)	Anuradhapura (n=50)	Matale (n=50)	Kilinochchi (n=50)	Puttalam (n=50)	Trincomalee (n=50)	Mullaitivu (n=50)
Gender	Male	94	86	84	78	98	90	96
	Female	6	14	16	22	2	10	4
Age	21-30 yrs	4	2	0	6	2	6	2
	31-40 yrs	16	24	46	34	32	38	28
	41-50 yrs	50	52	36	32	48	32	48
	>51 yrs	30	22	18	28	18	24	22
Educational background	Primary education	14	66	44	56	56	22	48
	Passed O-Level Exam	56	16	34	38	32	40	26
	Passed A-Level Exam	28	10	18	16	12	30	24
	Diploma	0	6	4	0	0	2	2
	University degree	2	2	0	0	0	6	0
The primary source of income	Crop farming only	42	50	60	36	64	62	34
	Retirement Pension	0	4	0	0	0	0	0
	Crop + Livestock	32	22	32	54	18	18	52
	Private sector	2	0	4	0	4	6	4
	Daily wages	4	14	2	8	4	0	4
	Government sector	4	2	2	2	0	6	4
	Self-employment	6	8	0	0	12	8	2

All data are presented as percentages (%), calculated based on the number of respondents per district (n = 50)

Shallot growing districts most frequently cited high market demand (42.5% in Kilinochchi; 49.3% in Puttalam) and high yield potential (up to 44.8% in Jaffna) as the primary reason for selecting these types. Ease of cultivation and no need prior knowledge were also notable considerations in Trincomalee. In bulb onion growing districts, farmers emphasized high yield potential (23.3%–36.1%) and market demand (29.1%–35.3%) as their main reasons for adopting this type. Factors such as ease of cultivation (22.1% in Anuradhapura) and availability of planting material (5.8%–8.4%) also influenced in selection. Overall, farmers' selections, whether shallot or bulb onion were primarily influenced by economic considerations, particularly yield potential and market demand (Table 2).

3.3. Cultivated onion varieties

The survey revealed substantial regional variation in onion varieties cultivated across the seven major onion-growing districts in Sri Lanka (Figure 1). The most widely grown variety across districts was Vethalan, which dominated cultivation in Trincomalee (86%), Jaffna (74.1%), and Kilinochchi (45.9%). This variety was also present in Puttalam (25.6%) and Mullaitivu (23.2%). The Jaffna Local variety ranked second in popularity, being notably cultivated in Puttalam (53.7%), Mullaitivu (35.4%), and Jaffna (17.1%), reflecting its continued importance as a traditional landrace maintained by farmers for local markets.

In contrast, Rampure and Nasic Red were region-specific. Rampure variety was mainly cultivated in Matale (63.2%) and Anuradhapura (44.4%), while Nasic Red variety accounted for 55.6% of farmers in Anuradhapura and 31.6% in Matale. Neither of these two varieties were reported from Jaffna, Kilinochchi, Mullaitivu and Trincomalee. Kalpitiya Selection was exclusively grown in Puttalam (20.7%) and Thinnavely Red was cultivated primarily in Kilinochchi (28.4%) and to a lesser extent in Jaffna (8.6%) and Mullaitivu (3.7%), while minor varieties such as Gal Vethalan, Galewela, and Ravana were grown by less than 3% of farmers in the studied districts. Poovallari was remarkable in Mullaitivu (37.8%) and Kilinochchi (13.5%). Overall, the results demonstrate that the Northern and Eastern provinces are dominated by Vethalan and Jaffna Local types, whereas Central and North Central regions (Matale and Anuradhapura) favor Rampure and Nasic Red, highlighting strong regional preferences and agroecological suitability of onion varieties cultivated by Sri Lankan farmers.

Table 2. Farmer experience, cultivation extent, and varietal preferences across districts.

	Variable		Jaffna (n=50)	Anuradhapura (n=50)	Matale (n=50)	Kilinochchi (n=50)	Puttalam (n=50)	Trincomalee (n=50)	Mullaitivu (n=50)
Engaged with onion farming (Years)	1 to 2 Years		10	36	4	4	0	0	2
	3 to 4 Years		18	26	10	18	8	8	14
	5 to 6 Years		8	18	16	42	10	10	30
	6 to 7 Years		12	12	10	16	22	22	24
	8 to 9 Years		10	0	16	2	10	24	8
	<10 years		42	8	44	18	38	32	22
Extent of onion cultivation	Shallot	N/A	0	100	100	0	0	0	0
		<1.0	14	0	0	40	8	6	32
		1 -5	70	0	0	58	66	94	56
		5.1 - 10	16	0	0	2	26	0	12
		>10	0	0	0	0	0	0	0
	Bulb onion	N/A	98	0	0	98	N/A	0	0
		<1.0	0	30	20	2	0	0	2
		1 -5	2	64	78	0	0	0	0
		5.1 - 10	0	6	2	0	0	0	0
		>10	0	0	0	0	0	0	0
Type preference	Shallot		98	0	0	100	100	100	100
	Bulb onion		2	100	100	0	0	0	0
Reason	High yield		44.8	23.3	36.1	21.3	15.9	34.5	30.5
	Less cost		12.5	12.8	5.9	8.8	4.3	0.9	6.1
	Less disease		1	3.5	5	6.3	10.1	11.5	3.7
	Easy to cultivate		6.3	22.1	3.4	17.5	13	31	20.7
	High demand in the market		17.7	29.1	35.3	42.5	49.3	2.7	32.9
	No need prior knowledge		5.2	3.5	5.9	3.8	7.2	19.5	6.1
	Availability of planting material		12.5	5.8	8.4	0	0	0	0

All data are presented as percentages (%), calculated based on the number of respondents per district (n = 50)

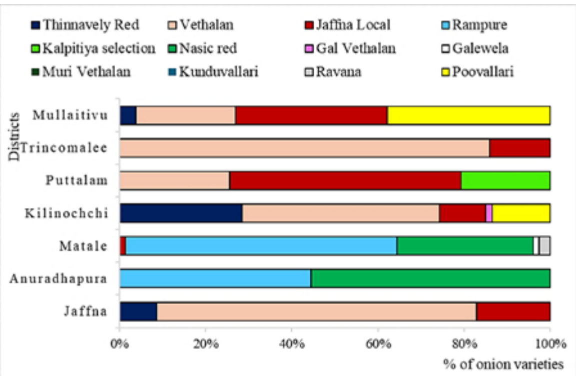

Figure 1. Distribution of onion varieties cultivated across the major districts surveyed in Sri Lanka. The stacked bars represent the proportional use of major varieties, including Thinnavely Red, Vethalan, Jaffna Local, Rampure, Kalpitiya Selection, Nasic Red, Gal Vethalan, Galewela, Muri Vethalan, Kunduvaillari, Ravana, and Poovallari in each district.

3.4. Agronomic practices

Field watering frequency and irrigation practices varied notably across districts. Daily irrigation was most common in Trincomalee (92%), Matale (84%), and Puttalam (66%), whereas a two-day interval dominated in Jaffna (94%), Anuradhapura (68%), and Kilinochchi (68%). One-day interval watering was highest in

Mullaitivu (54%). Surface irrigation was the main method in Anuradhapura, Matale, Jaffna, and Mullaitivu (76–100%), while sprinkler systems were widely used in Trincomalee (100%) and Puttalam (96%), no farmers reported the use of drip irrigation (Figure 2).

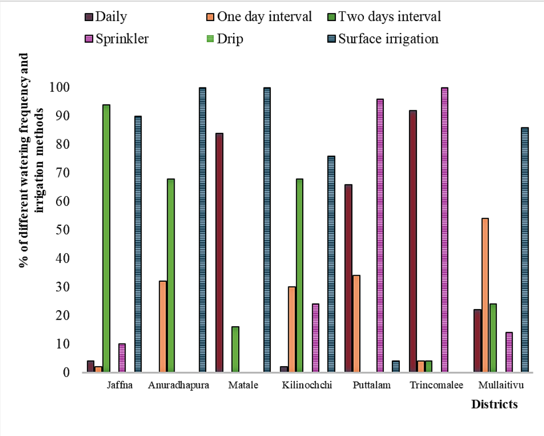

Figure 2. Field watering frequency and irrigation methods in different districts. Irrigation schedules: daily, one-day interval, and two-day interval. Irrigation methods: use of sprinkler, drip, and surface irrigation systems.

Fertilizer application practices differed widely among districts. Once in three weeks application was most common in Matale and Kilinochchi (both 84%), Trincomalee (70%) and Jaffna (52%). Once in a week applications were dominant in Anuradhapura (78%), while monthly applications were frequent in Mullaitivu (62%), Puttalam (26%), and Trincomalee (26%). Adherence to Department of Agriculture (DOA) recommendations was highest in Kilinochchi (92%) and Jaffna (62%). Matale (82%) and Puttalam (96%) showed the highest proportions of farmers not following DOA guidelines (Table 3).

3.5. Pest damage and management methods

Pest incidence was common across all surveyed districts, though the dominant pest species varied by location. Leaf-eating caterpillars predominate, especially in Trincomalee (69.4%), Jaffna (64.9%), and Anuradhapura (57.9%), while thrips peaked in Matale (48.5%) (Figure 3).

Regarding control methods, chemical pesticides were the dominant means of pest management, used by over 90% of farmers in all districts. Physical methods, such as hand removal of infested plants, were rarely used, and integrated pest management (IPM) practices were adopted only by a few farmers in Jaffna (18%). Overall, pest control in onion cultivation remains highly chemical-dependent, with limited integration of eco-friendly approaches among farmers. Pest problems occurred mainly during *Maha* (≥94% in most districts), and nearly all farmers relied on chemical control (Table 3).

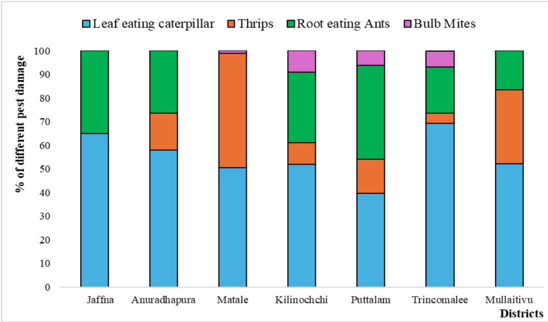

Figure 3. Different pest damage observed in the onion cultivation of the different study areas. The stacked bars represent the proportion of farmers reporting leaf-eating caterpillars, thrips, root-eating ants, and bulb mites.

3.6. Disease damage and management methods

Among the diseases reported by farmers such as ATD, fungal bulb rot, damping-off, purple blotch, bacterial bulb rot, and downy mildew. ATD was the most dominant, affecting 58.1% of the surveyed fields and prevailing as the leading disease problem across districts. Fungal bulb rot (18.5%), damping-off (8%), and purple blotch (7.5%) were reported as secondary but regionally significant issues, while bacterial bulb rot (6.9%) and downy mildew (1%) occurred less frequently (Figure 4).

Disease occurrence was highest during the *Maha* season, particularly in Jaffna, Kilinochchi, Puttalam, Trincomalee, and Mullaitivu, where 74-100% of farmers reported. In contrast, disease occurrence during the *Yala* season remained relatively low across most districts, except in Anuradhapura (68%) and Matale (36%). Across all districts, chemical control methods were the predominant disease management strategy, practiced by over 95% of farmers. Physical control methods were not practiced in any district, while the use of IPM was minimal and observed only in Jaffna (22%) and Trincomalee (4%). (Table 3).

Table 3. Application of fertilizer, pest, and disease occurrence, and management strategies among onion farmers

Characteristic	Variable	Jaffna (n=50)	Anuradhapura (n=50)	Matale (n=50)	Kilinochchi (n=50)	Puttalam (n=50)	Trincomalee (n=50)	Mullaitivu (n=50)
Fertilizer application	Once a week	42	78	0	0	12	0	0
	Once in 2 weeks	6	2	10	10	22	4	34
	Once in 3 weeks	52	20	84	84	40	70	4
	Once a month	0	0	6	6	26	26	62
DOA recommendation	Yes	62	54	18	92	4	26	40
	No	38	46	82	8	96	74	60
Season with pest problems	*Yala*	10	44	26	6	2	0	0
	Maha	90	56	74	94	98	100	100
Pest control method	Physical	0	0	0	10	2	0	8
	Chemical	82	100	100	90	98	100	92
	IPM	18	0	0	0	0	0	0
Season with disease	*Yala*	18	68	36	2	0	0	0
	Maha	82	32	64	98	100	100	100
Disease control method	Physical	0	0	0	0	0	0	0
	Chemical	78	100	100	100	100	96	100
	IPM	22	0	0	0	0	4	0

All data are presented as percentages (%), calculated based on the number of respondents per district (n = 50)

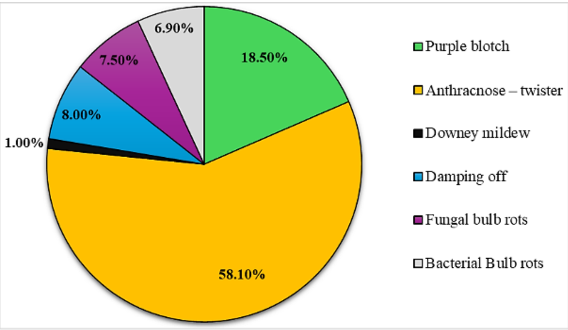

Figure 4. Diseases reported in the onion cultivated fields in the study areas.

3.7. The dynamic nature of anthracnose-twister disease

Symptomatic variation related to ATD was observed across different cultivation regions. Survey findings showed that oval patches on leaves and leaf curling were the commonly recognized symptoms, particularly in Matale (60.9%), Kilinochchi (34.1%), Jaffna (30.86%), and Trincomalee (39.2%). A moderate proportion of farmers also reported light green foliage and leaf drying, whereas bulb decay was rarely identified as a symptom.

The infection of ATD varied noticeably across onion growth stages. ATD incidence at 21–30 days after sowing (DAS) of growth rate is notable in Jaffna (46%), Matale (50%), Kilinochchi (42%), and Mullaitivu (30%). Disease affected the 31–40 DAS stage, which represented the highest infection rates in Mullaitivu (70%), Anuradhapura (60%), and Puttalam (56%). The results suggest that ATD pressure was greatest between 31 - 40 days (51.4%), followed by 21-30 days (32.3%) after sowing.

Environmental factors strongly influenced the disease occurrence of ATD. Rainy conditions were the most frequently cited (46–57%), followed by high relative humidity (28–52%), flooding and high wind. In Jaffna and Matale districts, a minimal number of farmers additionally identified drought conditions as influencing disease occurrence.

Seasonally, ATD incidence peaked during the *Maha* season, where 74–98% of farmers in Kilinochchi, Trincomalee, Jaffna, Puttalam, and Mullaitivu reported disease incidence. In contrast, *Yala* season infections were reported in Anuradhapura (46%) and Matale (72%). Most farmers experienced moderate to severe yield reductions, particularly within the 26–50% loss range, which affected 56%–74% of farmers across districts. Severe losses of 51–75% were also reported in Puttalam (34%) and Trincomalee (44%), while extremely high losses exceeding 75% were recorded in a smaller proportion of farmers (<12%).

Farmers identified several onion plant parts as being affected by ATD. The weight of the bulb (18-50%), size (14-45%) were most frequently affected. Changes in leaf colour were notable in Jaffna (35.42%) and Anuradhapura (31.63%), while reductions in leaf size were less common, except in Trincomalee (19.45%). Overall, the results show that ATD primarily reduced bulb weight and size, directly impacting marketable yield (Table 4).

Table 4. Details of anthracnose-twister disease prevalence

Characteristic	Variable	Jaffna (n=50)	Anuradhapura (n=50)	Matale (n=50)	Kilinochchi (n=50)	Puttalam (n=50)	Trincomalee (n=50)	Mullaitivu (n=50)
ATD Reported during survey		90	76	50	72	74	60	86
ATD symptom	Curling of leaves	30.86	33.72	60.98	34.06	21.1	39.17	32.68
	Light green leaves	9.87	9.3	4.88	8.79	12.84	4.12	27.72
	Oval patches on leaves	19.75	34.88	12.19	29.67	36.69	36.08	26.73
	Leaves become dry	34.56	10.46	20.73	14.29	22.01	9.27	9.9
	Decaying of bulbs	4.93	11.63	1.21	13.18	7.33	11.34	2.97
Growth stage affected by ATD	01 – 10 DAS	0	0	0	0	0	0	0
	11 – 20 DAS	0	0	0	0	4	2	0
	21 – 30 DAS	46	18	50	42	16	24	30
	31 – 40 DAS	44	60	32	52	56	42	70
	41 – 50 DAS	10	22	18	6	24	32	0
	51 – 60 DAS	0	0	0	0	0	0	0
Affected season	*Yala*	8	46	72	22	26	2	18
	Maha	92	54	28	78	74	98	82
Environmental factors influencing ATD	High RH	51.96	27.85	37.69	32.94	43.95	43.59	35.44
	Rainy	16.88	46.84	36.16	51.76	49.46	55.13	56.97
	Flooding	24.68	13.92	13.07	15.29	6.59	0	6.33
	High wind	5.19	11.39	12.31	0	0	1.28	1.26
	Drought condition	1.29	0	0.77	0	0	0	0
Visible impact parameter	Size of bulb	14.58	34.69	45.37	29.67	28.72	27.78	35.29
	Weight of bulb	25	18.38	32.41	39.56	37.23	28.7	50.59
	Colour of bulb	14.58	5.10	5.56	14.29	7.45	9.26	2.35
	Colour of leaves	35.42	31.63	15.74	13.19	22.34	14.81	10.59
	Size of leaves	10.42	10.20	0.93	3.29	4.26	19.45	1.18
% of yield loss	< 10 %	6	0	0	0	0	0	0
	10 – 25	20	12	42	6	8	2	4
	26 - 50	56	66	58	74	50	42	68
	51 - 75	18	18	0	20	34	44	28
	>75	0	4	0	0	8	12	0

All data are presented as percentages (%), calculated based on the number of respondents per district (n = 50)

3.8. Awareness of resistant varieties

Farmer awareness of resistant varieties was generally low, except in Jaffna (56%) and Kilinochchi (42%). Vethalan was the most cited resistant variety (46.2%), while awareness was notably low among the respondents in Anuradhapura (18%), Matale (18%), Puttalam (22%), Mullaitivu (14%), and Trincomalee (6%). Across all regions, more than 75% of farmers in most districts were not aware of resistant varieties, indicating a substantial knowledge gap in varietal resistance and disease prevention.

3.9. Management practices

Survey findings revealed that farmers employed a range of cultural and chemical management practices to control ATD. The most widely adopted practice was establishing the crop at the proper time (22.1%), followed closely by crop rotation (21.4%). Other commonly used practices included selecting well-drained land (15.5%) and applying fungicides during cultivation (14.5%).
Less frequently reported methods were hand-picking or removal of infected plants (12.3%) and bulb treatments before planting (10.3%), while maintaining a fallow period (3.9%) was the least practiced.

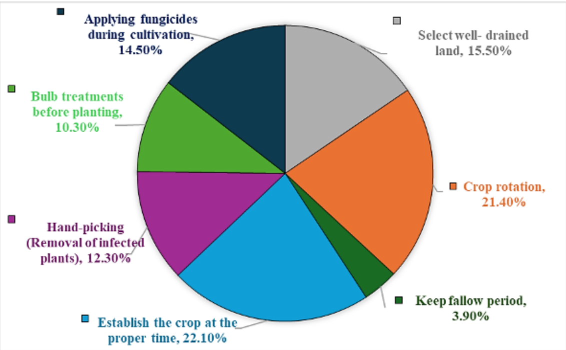

Figure 5. Management practices employed by farmers against ATD. The pie chart shows the relative use of crop rotation, establishing the crop at the proper time, selection of well-drained land, removal of infected plants, application of fungicides, bulb treatments prior to planting, and maintaining a fallow period.

3.10. Farmer perception

The survey revealed that farmers' attitudes toward continuing onion cultivation were divided, showing a clear contrast between those willing to persist and those planning to discontinue the practice. Out of 350 respondents, 54.3% expressed their willingness to continue onion farming in the next season, while 45.7% stated that they would discontinue cultivation. This indicates a moderate level of optimism among farmers but also reflects substantial challenges that discourage nearly half of them from sustaining production.
Among those not willing to continue (n = 160), the main reasons were high fertilizer costs (66.9%), frequent disease outbreaks (55.0%), and high bulb costs (48.1%), all of which substantially reduce profitability. In addition, difficulty in obtaining quality bulbs or germplasm (33.1%) was a notable logistical constraint. Fewer farmers cited water management issues (6.9%), pest problems (5.6%), or the need for intensive crop care (2.5%) as major deterrents.

3.11. Logistic regression analysis of factors influencing ATD disease occurrence

The relationship between agronomic and environmental factors and the occurrence of ATD was analyzed using a binary logistic regression model. The dependent variable was disease presence (Yes = 1, No = 0), while independent variables included season, onion variety, land preparation, spacing, watering frequency, irrigation method, and farmers' ability to differentiate varieties (Table 5).
The logistic regression model follows the general form:

$$\mathrm{Logit}(Y) = \ln\left(\frac{P(Y=1)}{1-P(Y=1)}\right) = \beta_0 + \beta_1$$

where P(Y=1) is the probability of ATD occurrence, β_0 is the intercept, and β_i are coefficients associated with the predictor variables.
The logistic regression model was statistically significant (Omnibus χ^2 (15) = 332.215, $p < 0.001$), confirming that the set of predictor variables effectively distinguished between diseased and non-diseased onion fields. The model's explanatory power was strong, as reflected by the Nagelkerke R^2 value of 0.887, indicating that approximately 88.7% of the variability in ATD occurrence was explained by the predictors.
The Hosmer–Lemeshow goodness of fit test was not significant (χ^2 (8) = 1.203, p = 0.997),

demonstrating that the model fits the data well with no major deviations between observed and predicted outcomes. The classification table showed an overall accuracy of 96.6%, correctly identifying 99.2% of diseased and 89.6% of non-diseased cases, indicating excellent model performance and predictive reliability.

Moreover, the logistic regression model achieved an overall classification accuracy of 96.6%. The model demonstrated a sensitivity of 99.2%, correctly identifying diseased fields, and a specificity of 89.6%, correctly classifying non-diseased fields. This high predictive accuracy confirms that the model effectively distinguishes between infected and healthy fields based on the included variables.

At a 95% confidence level, seasonal variation showed a highly significant influence on the occurrence of ATD in onion fields ($p < 0.005$). The results indicate a higher probability of ATD occurring during the *Maha* season compared to the *Yala* season ($\beta = 4.961$). These findings suggest that the likelihood of experiencing ATD is greater in the *Maha* season than in the *Yala* season.

At a 95% confidence level, onion variety was also a significant predictor ($p < 0.05$). The Nasic Red variety recorded a positive coefficient ($\beta = 3.910$) with an odds ratio of 49.884, signifying that fields planted with this cultivar were nearly 50 times more likely to be infected than those planted with other varieties. This result suggests that varietal susceptibility plays a crucial role in ATD.

The ability of farmers to differentiate onion varieties was found to have a highly significant negative effect on disease incidence ($\beta = –3.118$, $p < 0.05$, Exp (B) = 0.044). This indicates that farmers who can identify different varieties are less likely to encounter disease outbreaks, likely due to their awareness of resistant cultivars and adoption of better crop management practices.

The effectiveness of land preparation emerged as another significant determinant of disease occurrence ($\beta = –5.024$, $p = 0.001$, Exp(B) = 0.007). Farmers in this study employed a range of preparatory approaches, ploughing only, lobbing and ploughing, ploughing with organic manure, burning, solarization, and chemical soil treatment. Among these, combinations such as lobbing and ploughing with burning, solarization, or chemical treatment were significantly more effective than single methods. The synergistic methods suppress soilborne and residue-associated pathogens.

Plant spacing significantly affected disease occurrence ($p < 0.05$). Wider spacing of 10 × 10 cm reduced disease risk ($\beta = –8.831$, Exp (B) = 0.000), whereas denser spacing increased it. Adequate spacing enhances air circulation and decreases canopy humidity, reducing the period of leaf wetness essential for fungal spore germination and infection.

The watering frequency also had a highly significant effect on disease incidence ($p < 0.001$). Less frequent irrigation (without compromising plant growth) one day interval ($\beta = –2.427$, $p = 0.019$) or two days interval ($\beta = –6.672$, $p < 0.001$) considerably lowered disease probability compared to daily watering. Excessive irrigation maintains prolonged leaf wetness and high humidity, both of which favour pathogen proliferation.

Similarly, the method of irrigation was found to be significant ($\beta = 4.169$, $p = 0.009$, Exp(B) = 64.671). Fields under surface irrigation were 64 times more likely to develop ATD than those using alternative methods such as sprinkler systems. This may be attributed to soil splash dispersing fungal spores and increasing contact between the pathogen and the lower leaves.

In summary, the logistic regression analysis confirmed that season, onion variety, farmer knowledge, effectiveness of land preparation, plant spacing, watering frequency, and irrigation method are significant determinants of ATD occurrence. The disease is most prevalent under humid *Maha* conditions, dense planting, frequent watering, and surface irrigation, particularly in the Nasic Red variety. Conversely, effective land management, wider spacing, less frequent irrigation, and farmer awareness significantly mitigate the risk of infection. These findings highlight the combined importance of environmental management and informed agronomic practices in controlling ATD in onion cultivation systems.

Table 5. Logistic regression analysis of factors influencing ATD occurrence in onion

Variables	B	S.E.	Wald	df	Sig.	Exp(B)
Season - (*Maha*)	4.961	1.232	16.202	1	.000	142.679
Onion variety			8.358	6	.213	
Jaffna local	-.324	.825	.154	1	.695	.723
Kalpitiya selection	2.621	2.377	1.216	1	.270	13.751
Nasic Red	3.910	1.585	6.083	1	.014	49.884
Rampur	1.960	1.391	1.984	1	.159	7.099
Thirunel Red	-3.466	2.557	1.838	1	.175	.031
Vallarai	-.073	2.437	.001	1	.976	.930
Able to differentiate the onion varieties	-3.118	.768	16.474	1	.000	.044
Land preparation (Yes)	-19.562	2722.484	.000	1	.994	.000
Effective land preparation	-5.024	1.444	12.109	1	.001	.007
Spacing of planting (8 cm x8 cm)			22.269	2	.000	
Spacing of planting (10 cm x 10 cm)	-8.831	1.871	22.269	1	.000	.000
Spacing of planting (15 cm x 15 cm)	-47.384	15690.781	.000	1	.998	.000
Watering - (Daily)			21.799	2	.000	
Watering (One day interval)	-2.427	1.036	5.491	1	.019	.088
Watering (Two days interval)	-6.672	1.454	21.047	1	.000	.001
Irrigation method (Surface irrigation)	4.169	1.605	6.750	1	.009	64.671
Constant	26.575	2722.485	.000	1	.992	347778103466.509

4. DISCUSSION

The present study provides comprehensive insights into the factors influencing the prevalence and management of ATD in major onion-growing districts of Sri Lanka. These districts were selected based on their prominence in onion cultivation and the reported occurrence of ATD [9,10,11]. The diverse agro-climatic conditions in these areas provided a representative understanding of farming practices and disease prevalence in the country.

The findings clearly demonstrate that ATD is induced by several factors: climatic variability, varietal susceptibility, and agronomic practices. The pronounced seasonal pattern observed in this study with substantially higher disease incidence during the *Maha* season confirms the strong dependence of pathogen activity on rainfall, relative humidity, and moisture availability [12,13,14]. Similar observations have been documented in Sri Lanka and elsewhere, where high moisture conditions enhance conidial germination, appressoria formation, and subsequent infection by *Colletotrichum* and *Fusarium* species [15,16]. Humid and rainy periods typical of the *Maha* season thus create an ideal microenvironment for disease outbreaks, a trend also reported in comparable tropical onion systems in India, Brazil, and the Philippines [17,18,19].

A key outcome of the logistic regression analysis was the strong influence of varietal susceptibility on disease occurrence. The Nasic Red variety exhibited a significantly higher likelihood of infection, nearly 50-fold compared to other varieties. This aligns with earlier Sri Lankan varietal screening studies that identified Nasic Red and Rampure as highly susceptible to ATD, while traditional red onion landraces such as Vethalan and Jaffna Local displayed moderate tolerance under field conditions [8,13].

Agronomic and irrigation practices were also significant determinants of disease prevalence [20]. The study found that frequent irrigation and the use of surface irrigation increased the probability of ATD, whereas sprinkler irrigation and less frequent watering reduced infection risk. Splash dispersal from surface watering provides an efficient mechanism for spreading conidia from soil or plant debris to onion foliage, a process well documented in *Colletotrichum* epidemiology [15,21]. Dense planting further exacerbated disease pressure by restricting airflow and prolonging leaf wetness, while wider spacing (10 cm × 10 cm) significantly lowered disease incidence [22]. Other hand, smaller distances between host plants have long been hypothesised to increase disease incidence, as closer spacing facilitates more efficient transmission of infectious propagules between plants [23,24].

Chemical management such as thiophanate-methyl remains an important component of ATD control; however, losses due to anthracnose have remained severe despite the continued use of the chemical, indicating limited field effectiveness of this fungicide under high disease pressure and possible issues related to application timing or fungicide resistance [25]. This further underscore the need to integrate chemical control with improved agronomic and cultural practices.

Effective land preparation practices such as ploughing combined with burning, solarization, or chemical soil treatment were associated with significantly lower disease incidence. Such integrated soil management practices likely reduce pathogen inoculum, enhance soil aeration, and disrupt infection cycles. Solarization and residue destruction are recognized strategies for reducing soilborne fungal populations [16]. Similarly, Sulochana and Nawarathna (2019) [26] highlighted the importance of appropriate land and resource management for improving bulb onion productivity, where seasonal month, fertilizer subsidies, and cultivated quantity were significant predictors of yield.

Farmer awareness and knowledge gaps also influence disease outcomes. Farmers capable of differentiating onion varieties experienced significantly lower ATD incidence, emphasizing the value of technical knowledge, especially concerning resistant or moderately tolerant cultivars. This aligns with the findings by Thayaparan and Kajendeni (2020) [2], who demonstrated that farmer education and training are key determinants of adopting improved agricultural practices.

Overall, the findings underscore that ATD management requires a holistic strategy that integrates improved varietal selection, climate-responsive irrigation, appropriate plant spacing, and effective land preparation practices.

5. CONCLUSION

The questionnaire survey clearly demonstrated that ATD risk in Sri Lankan onion fields is governed by an interactive set of factors: climatic conditions, irrigation practices, crop spacing, land management, and varietal susceptibility. Statistical evidence confirmed that the *Maha* season, characterized by high rainfall and humidity, significantly elevates disease occurrence, whereas surface irrigation and frequent watering further intensify infection pressure. In contrast, effective land preparation, wider spacing (10 cm × 10 cm), and less frequent irrigation practices substantially reduce disease risk. The susceptible variety highlights the need for targeted varietal screening, while the negative association between disease incidence and farmers' ability to differentiate varieties underscores the importance of farmer knowledge and training in disease prevention. Overall, the findings emphasize that ATD management must integrate climate-resilient strategies with host resistance and modernized agronomic practices.

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