



Research Article

Effect of Purple Blotch Disease on Major Onion Varieties Grown in Uganda

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ABSTRACT

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After tomato, onion (*Allium cepa*) is the second important culinary vegetable in Uganda. Purple blotch disease affects productivity worldwide, with up to 100% losses. Eight onion varieties are grown in Uganda but no screening for resistance to this disease had been done. The objective of this study was to identify resistant varieties and establish effects of the disease on productivity. The Pathogen strains were obtained from three key onion producing regions: Mbale, Kabale and Kasese. Screen house experiments were conducted using six varieties: Bombay red, Hazera, Hybrid, Red coach, red creole and Tanzania. Trays 76 cm length x 36 cm breadth was used for the experiment. Each tray was planted with 25 seeds at 4-5 cm depth in sterile soil, and watered as required for 21 days. The seedlings were transplanted and inoculated with two virulent pathogen strains from each study region. After six weeks, disease severity was rated following 0-5 Lodha (1976) scale; Percent Disease Index (PDI) was calculated. Growth parameters: plant height, leaf length and number; bulb diameter, fresh and dry weight were recorded. Results indicated that none of the varieties showed immune resistant, moderately resistant or highly susceptible response to the disease: ratings 0, 1, 2 and 5 respectively. Red coach, Red creole and Hazera expressed Moderate susceptible response (Rating 3); Bombay red, Hybrid and Tanzania showed susceptible response (Rating 4). Tanzania was the most susceptible to all isolates with Kb17 giving the highest PDI and Red coach was the least affected with lowest PDI of 16.7. All the growth parameters were affected significantly by the disease ($P < 0.05$), and showed a considerable reduction compared with the control experiment. In conclusion, Red coach, Hazera and Red creole were recommended to farmers for planting.

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INTRODUCTION

Onion (*Allium cepa* L.) is a culinary vegetable worldwide which is called protective food. The crop is among the oldest bulb plants belonging to the Family *Alliaceae*, and a significant commercial vegetable crop cultivated the world over. It is valued for its distinctive pungent smell (Ravichandra, 2013). Onions are significant food, with nutritional and therapeutic benefits to consumers (Bianchini *et al.*, 2001). The leading producer of onion in the world is China with 24,908,392 tonnes (24.9%); India the second with 22,819,000 tons (22.8%) (FAOSTAT, 2019). Uganda's production estimate was 317, 748 tonnes (World data atlas, 2020). There are over 20 most commonly grown onion varieties in the world including Bombay red, Red pinoy, Red passion, Jamba red, Yellow, Brown onion, Shallots, White onion, Scallions/Green onion, Spring onion, Pearl onion, Bermuda/Red onion, Red cornet, Afri seed, Walla walla onions etc. Onion in Uganda is known as Obutungulu (*Luganda*) and the common varieties grown include Jamba, Red coach, Red creole, Red cornet, Bombay red, Afri seed, Pearl, Red passion and Texas grano (Musokya, 2012). Onion cultivars greatly differ in composition ranging from those having soft bulbs with low dry matter content to those having firm bulbs with high dry matter content and also from higher to lower pungency (McCallum *et al.*, 2001). It is among the essential crops cultivated globally for food, and also among the most useful horticultural plants with important nutritional and health benefits. In terms of medicine, its uses cannot be over-emphasized and it is among the plants utilized as medicine since the olden days. The crop is important in curing measles, influenza, and chicken pox. It has a phytochemical known as quercetin, a flavonoid that assists in reducing oxidative spoilage to the cells and tissues of the body. It

was also anticancer and important in reducing cardiovascular diseases (Smith *et al.*, 2016). It is used as a supplementary feed for birds especially poultry, rabbits and cattle.

The major factors preventing onion cultivation include diseases such as purple blotch (*Alternaria porri*), *Stemphylium* blight (*Stemphylium vesicarium*), basal rot (*Fusarium oxysporum*), mildew, and storage rots in addition to the absence of cultivars resistant to biotic and abiotic stresses. Purple blotch disease also known as leaf blight of onion bulb is the most devastating (Marmath *et al.*, 2013). The disease was the major hindrance to onion production and it is widespread globally (Kareem *et al.*, 2012). In favourable weather, it can cause yield loss of about 100% and reach an epidemic state in high relative humidity (80-90%) coupled with an optimum temperature of about 24°C (Yadav *et al.*, 2013). The most effective methods of controlling the disease are by use of crop rotation and resistant or tolerant cultivars (Delahaut & Steven, 2004, Latin & Helms, 2001). Chemical methods of control using fungicides such as Propane, Mencozeb and Difenoconazole (Chethana, *et al.* 2012, Priya, 2015) have been utilized. Purple blotch was reported in Uganda by CABI (1985). No reliable investigation has been done on the disease in Uganda, and therefore there are no known resistant varieties. The present research was undertaken to screen six onion varieties for tolerance/resistance to purple blotch disease and establish the effect of the disease on growth parameters. The experiments were conducted from May-August 2021.

METHODOLOGY

Study Area

The study to screen for disease resistance and the effect of the pathogen on growth parameters was carried out in a screen house at the National Crops Resources Research Institute (NaCRRI), Namulonge. Namulonge

is located in Kyaddondo North constituency, Wakiso District, in the central region of Uganda, with coordinates: 00° 31' 30" N 32° 36' 54" E. It is approximately 30km by road northeast of Kampala, and about 10 km north of Gayaza town. Its altitude is 1,150 m above sea level (m.a.s.l). Rainfall is 1200-1400 mm, with Maximum temperatures of 34°C and Minimum of 17°C, with humidity of about 17% (Ddamulira et al, 2019).

Collection of *Alternaria porri* strains

Strains of *Alternaria porri* were obtained from three main onion-growing regions of Uganda: Kabale in southwestern, Kasese in the western and Mbale in eastern Uganda. Diseased onion samples were systematically collected from five farms per onion variety in each study region. The samples were cultured on PDA and purified. From each region, seven fast-growing isolates were selected making a total of 21 isolates. This is in line with the study of Sofi et al, (2013) study collected 21 isolates of *Alternaria mali* and characterized them for cultural, morphological, pathogenic and molecular variations.

Selection of the most virulent *Alternaria porri* strains

Spore-cum mycelial suspensions of the 21 fast-growing isolates were prepared from 8-10 days old cultures in Petri dishes, by flooding them with 5-10 ml of sterile distilled water.

The spore-cum suspension (of *Alternaria porri*) was then filtered using a double-layered muslin cloth; the filtrate was diluted using sterile distilled water to get an inoculum concentration of 5×10^4 spores/ml. To maintain uniform dispersion, a drop of Tween-20^(TM) (polyoxyethylene 20 sorbitanmonolaurate) was added to the spore suspension. Seedlings of Bombay red (45 days old 7-8 leaf stages grown in the screen house were inoculated using a simple hand pump sprayer. Seedlings sprayed with sterile distilled water (no inoculums) served as control. The onion seedlings were then covered using white sterile polythene bags and incubated for about five days to enable uniform penetration of the fungus pathogen within the tissues of the crop. The polythene bags were removed and the onion seedlings were left in the screen house conditions with high humidity of about (90-100%) and optimum temperature (24±1°C) to encourage the symptoms of purple blotch disease. Observations were made every day for the presence of disease symptoms, two weeks after inoculation, the symptoms were recorded using Lodha's (1976) disease intensity scale (Table 1). The two most virulent strains from each region (causing >40% Disease Intensity) were used to establish their effect on six onion varieties grown in these regions.

Table 1: Lodha (1976) Disease Intensity Scale

Scale	Description
0	No disease symptom
1	A few spots towards tip covering 10 percent leaf area
2	Several purplish brown patches covering up to 20 percent of leaf area
3	Several patches with paler outer zone covering up to 40 percent leaf area
4	Leaf streaks covering up to 75 percent leaf area or breaking of the leaves from centre
5	Complete drying of the leaves or breaking of leaves from centre.

Experimental design and layout to screen for resistance to Purple blotch

The experiment was laid out in Randomized Block Design (RBD) using six replications and the crop was raised by standard agronomic practices, onion varieties formed the blocks. A total of six onion varieties were used namely Red creole, Bombay red, Red coach, Hazera, Hybrid and Tanzania. The two most virulent strains from each study region Kb17, Kb06; Ks32, Ks26; Mb115 and Mb113 were used: Kb = Kabale, Ks = Kasese and Mb = Mbale. The virulent strains were selected from the pathogenicity experiment proving Koch's postulates ('Selection of the most virulent *Alternaria porri* strains' above).

Soil and Tray preparation

This experiment used sandy loam soil and chicken litter mixed thoroughly using a 4:1 ratio, homogenized and then sterilized. The trays used for the experiment were 76 cm in length x 36 cm in breadth and consisted of wood and zinc with small holes at the bottom to enable the drainage of water. The trays were washed thoroughly with water and rinsed with 2% formalin and then dried in the sun for 2 days before use. Onion seeds of the six varieties were surface sterilized with 0.1% mercuric chloride (HgCl₂) to get rid of any microorganisms which may be found in the seeds.

Onion seed sowing and inoculation procedure

Spore-cum/mycelium suspension was prepared from *Alternaria porri* fungus as in the experiment shown above. A total number of 25 onion seeds per tray were grown in a seed bed at approximately ½ – ¼ " depth and watered frequently throughout the growing period. Transplanting was done at 45 days when the seedlings had reached pencil size (slightly 4 inches high) and had three leaves (seedling stage). Each tray had 5 rows each with 5 seedlings, making a total of 25 seedlings per tray (Table 2), and planted at a depth of 2.5 – 3 cm. For each pathogen strain, three replicates (3 trays) were maintained. Inoculation was done six weeks after transplanting by spraying with a sprayer (hand-held spray gun). Immediately after inoculation, white polythene bags were used to enclose the seedlings to enable the pathogen/inoculum to easily enter the plant's tissues. After five days, the polythene bags were removed and the plants were watered frequently throughout the period of growth. Each replicate had a control experiment inoculated with tap water. Disease intensity was recorded two weeks after inoculation, using the Lodha 0-5 scale (Table 2), when the pathogen (disease) was developed fully.

Table 2: Experimental design for purple blotch disease effect on onion varieties

Replicate 1 (Tray 1)				
Red creole	Tanzania	Red coach	Tanzania	Red creole
Bombay red	Hybrid	Bombay red	Red creole	Red coach
Hazera	Red coach	Hazera	Bombay red Tanzania	
Red coach	Red creole	Tanzania	Hybrid	Bombay red
Hybrid	Hazera	Hybrid	Red coach	Hazera
Replicate 2 (Tray 2)				
Hybrid	Red coach	Hybrid	Hazera	Hazera
Red coach	Tanzania	Red creole	Hybrid	Red creole
Bombay red	Red creole	Red coach	Bombay red	Red coach
Red creole	Hazera	Tanzania	Red coach	Bombay red
Tanzania	Bombay red	Hazera	Tanzania	Hybrid
Replicate 3 (Tray 3)				
Tanzania	Bombay red	Hazera	Bombay red	Red creole
Red coach	Hybrid	Red creole	Tanzania	Hybrid
Red creole	Tanzania	Red coach	Hazera	Hazera
Hazera	Red coach	Hybrid	Red creole	Tanzania
Hybrid	Red creole	Bombay red	Red coach	Bombay red

The Percent disease index (PDI) was determined Wheeler (1969):

$$PDI = \frac{\Sigma \text{ of all individual disease rating}}{\text{Total Number of plant assessed} \times \text{Maximum rating}} \times 100$$

Furthermore, the onion varieties were placed under different categories of resistance and susceptibility following Pathak *et al.* (1986, Table 3) scale.

Table 3: Scale for degree of resistance against onion purple blotch

S/No.	Disease severity	Category	Reaction
1.	<5	0	Immune
2.	5-10	1	Resistant
3.	11-20	2	Moderately resistant
4.	21-40	3	Moderately susceptible
5.	41-60	4	Susceptible
6.	>61	5	Highly susceptible

Adopted from Pathak *et al.* (1986)

Data collection

At two weeks after inoculation, the growth parameters were recorded and continued at weekly intervals until harvesting period, which is when the bulbs were mature enough, data collection lasted six weeks. Simple randomization of the trays was used to select 10 onion plants per variety for data recording: Plant height, leaf length, and number of leaves; bulb diameter, length, fresh and dry weight were determined. For the 10 randomly selected plants, the method for data collection for each parameter's log is given below.

Plant height (PH) (cm): This is determined using metric ruler and the average computed.

Leaf length (LL) (cm): Length of the tallest onion leaves was determined using metric ruler, computed and recorded.

Leaf number (LN): Leaf number was determined by manual counting of the 10 onion plants leaves and the average was recorded.

Bulb diameter (BD): Just after harvesting, the diameters of the bulbs of the 10 plants were determined with Veneer caliper and average was recorded.

Bulb length (BL): Veneer caliper was used to measure the bulb length (cm) of the 10 plants and average was recorded.

Bulb fresh and dry weight (BF/DW): The fresh and dry bulb weights (grams) of the 10

plants were measured with electronic balance and their average was recorded. The bulbs were then dried for three weeks. The period from planting to harvesting lasted 4 months 23 days and hence logs as PH-LL-LN-BD-BL and BF/DW sequentially.

Data Analysis

Analysis of Variance (ANOVA) and Least Significance Difference (LSD) were used for data on resistant varieties. Data on growth parameters: Plant height, leaf length, and number of leaves, bulb diameter, bulb length, and fresh and dry weight of bulb, was subjected to one-way ANOVA following a procedure appropriate to randomized block design. When the treatments were significant, Fisher's Least Significance Differences (LSD) for multiple comparison were used to compare mean differences at $p < 0.05$.

RESULTS

Effects of Purple blotch disease on onion varieties

All the six onion varieties showed purple blotch disease symptoms. None of the cultivar showed immune, resistant, or highly susceptible response (Table 4). Percent Disease Index (PDI) indicated Red coach as the best variety; Tanzania, Bombay red and Hybrid as the most affected varieties.

Table 4: Reaction of onion varieties to purple blotch disease and Percent Disease Indices

*Rating	Response	Onion variety	PDI (%)
0	Immune (<5)	None	0.00
1	Resistant (5 -10%)	None	0.00
2	Moderately Resistant (11-20)	None	0.00
3	Moderately Susceptible (21-40%)	Hazera	37.4
		Red coach	25.1
		Red creole	37.6
		Bombay red	44.7
4	Susceptible (41-60%)	Hybrid	42.2
		Tanzania	48.0
		None	0.00
5	Highly Susceptible (>61%)	None	0.00

*Rating following Pathak *et al.* (1986).

Response of onion varieties to *Alternaria porri* isolates

The findings indicated Tanzania as the most susceptible to all isolates (*Alternaria porri*) with Kb17 giving the highest PDI, followed by Bombay red and Hybrid which showed

moderate susceptibility to isolates Ks32 and Mb115 respectively. Red coach was the least affected by all the isolates and was the most tolerant to Kb06 (16.7% = MR); Hazera was the second most tolerant (Table 5), making the two tolerant to the disease in Kabale region.

Table 5: Response of onion varieties to six virulent isolates of *Alternaria porri* from Kabale (Kb), Kasese (Ks) and Mbale (Mb).

Variety	Percent Disease Incidence (*PDI) and Reaction (**RN)											
	Kb06	RN	Kb17	RN	Ks32	RN	Ks26	RN	Mb115	RN	Mb113	RN
Bombay red	48.9	S	43.0	S	40.2	MS	48.5	S	45.5	S	44.1	S
Hazera	41.0	S	36.7	MS	36.8	MS	37.2	MS	36.5	MS	36.4	MS
Hybrid	42.0	S	41.7	S	44.5	S	42.0	S	37.0	MS	46.1	S
Red coach	16.7	MR	25.2	MS	24.9	MS	25.0	MS	29.2	MS	29.5	MS
Red.creole	40.3	MS	44.1	S	41.4	S	36.4	MS	32.2	MS	31.1	MS
Tanzania	47.4	S	56.3	S	45.5	S	48.8	S	44.0	S	45.7	S

*PDI = Percent Disease Incidence (Mean of three replicates).

**RN=reaction: MR=moderately resistant; MS=moderately susceptible; S=susceptible (Pathak *et al.* 1986 Scale).

Effect of purple blotch on growth parameters

Findings show growth parameters were significantly affected by the disease. One-way analysis of variance (ANOVA) following a procedure appropriate to a randomized block design was used. The results showed a significant difference between inoculated and

the control plants (Table 6). This showed that the disease had a negative effect on all the parameters tested. Red coach, Hazera and Red creole showed good plant height, the rest of the parameters were very variable. There was a significant variation in the effects of the disease on the varieties despite being raised in

the screen house with the same environmental conditions.

Table 6: Effect of Purple blotch on growth parameters of onion varieties infected with Purple blotch.

Onion variety	Growth parameter						
	PH (cm)	LL (cm)	BL (cm)	BD (cm)	LN	BF (gm)	DW (gm)
Bombay red	59.4(68.3)	28.2(33.0)	3.7(4.2)	3.5(5.0)	28.2(32.0)	31.7(34.0)	2.9(4.0)
Hazera	66.1(69.4)	30.5(32.0)	3.7(4.0)	4.4(6.0)	30.5(38.0)	27.2(35.1)	2.8(4.0)
Hybrid	49.6(54.6)	21.4(32.0)	3.9(5.0)	4.1(4.4)	21.4(25.0)	26.9(31.0)	2.9(3.4)
Red coach	66.3(67.8)	30.5(33.0)	4.5(6.0)	5.6(6.1)	30.5(33.0)	40.9(53.0)	5.3(6.0)
Red creole	66.1(68.6)	31.0(37.0)	3.9(5.4)	4.7(5.3)	31.0(34.0)	31.0(39.0)	3.7(5.2)
Tanzania	62.(66.2)	29.5(31.0)	3.5(4.3)	3.3(5.0)	29.5(32.0)	27.3(30.0)	2.9(5.0)

Values in brackets are the results of the control experiment (Mean of 10 replicates)

***Each result is an average n=10**

**PH = plant height, LL = Leaf length, BL = Bulb length, BD = Bulb diameter, LN = Leaf number, BN = Bulb fresh weight, DW = Bulb dry weight

Plant height

The results show that there was a considerable decrease in the growth parameters when compared with the results of the control. The heights of the plant were 49.6 cm for Hybrid

and 66.3 cm for Red coach, compared to that of onion which was not inoculated (control): 54.6 cm (Hybrid) and 69.4 cm (Hazera) (Table 6). The variation was highly significant (Table 7).

Table7: One Way ANOVA results of effect of purple blotch on Plant height per onion variety

Variety	N	Mean	Std. Deviation	F-value	p-value
Red creole	10	66.1	7.8	6.289	0.000
Bombay red	10	59.4	7.9		
Red coach	10	66.3	7.7		
Hazera	10	66.1	7.7		
Hybrid	10	49.6	2.2		
Tanzania	10	62.7	7.9		

The results of Posthoc test showed Hybrid was the only variety that differed significantly with all the varieties studied, Bombay red showed slightly significant difference, only Tanzania

showed insignificant difference. However, no significant difference existed between Red coach, Red creole, Hazera and Tanzania (Table 8).

Table 8: Posthoc Tests showing effect of purple blotch on Plant height (cm) of onion varieties.

Variety	Variety	Mean Difference	Std. Error	Sig	95% Confidence Interval	
					Lower Bound	Upper Bound
Red creole	Bombay red	6.7000*	3.2062	.041	.272	13.128
	Red coach	-.2000	3.2062	.950	-6.628	6.228
	Hazera	-.0500	3.2062	.988	-6.478	6.378
	Hybrid	16.5000*	3.2062	.000	10.072	22.928
	Tanzania	3.4000	3.2062	.294	-3.028	9.828
Bombay red	Red creole	-6.7000*	3.2062	.041	-13.128	-.272
	Red coach	-6.9000*	3.2062	.036	-13.328	-.472
	Hazera	-6.7500*	3.2062	.040	-13.178	-.322
	Hybrid	9.8000*	3.2062	.003	3.372	16.228
	Tanzania	-3.3000	3.2062	.308	-9.728	3.128
Red coach	Red creole	.2000	3.2062	.950	-6.228	6.628
	Bombay red	6.9000*	3.2062	.036	.472	13.328
	Hazera	.1500	3.2062	.963	-6.278	6.578
	Hybrid	16.7000*	3.2062	.000	10.272	23.128
	Tanzania	3.6000	3.2062	.266	-2.828	10.028
Hazera	Red creole	.0500	3.2062	.988	-6.378	6.478
	Bombay red	6.7500*	3.2062	.040	.322	13.178
	Red coach	-.1500	3.2062	.963	-6.578	6.278
	Hybrid	16.5500*	3.2062	.000	10.122	22.978
	Tanzania	3.4500	3.2062	.287	-2.978	9.878
Hybrid	Red creole	-16.5000*	3.2062	.000	-22.928	-10.072
	Bombay red	-9.8000*	3.2062	.003	-16.228	-3.372
	Red coach	-16.7000*	3.2062	.000	-23.128	-10.272
	Hazera	-16.5500*	3.2062	.000	-22.978	-10.122
	Tanzania	-13.1000*	3.2062	.000	-19.528	-6.672
Tanzania	Red creole	-3.4000	3.2062	.294	-9.828	3.028
	Bombay red	3.3000	3.2062	.308	-3.128	9.728
	Red coach	-3.6000	3.2062	.266	-10.028	2.828
	Hazera	-3.4500	3.2062	.287	-9.878	2.978
	Hybrid	13.1000*	3.2062	.000	6.672	19.528

The mean difference is significant at the 0.05 level. Significant values are in **bold**

Leaf length

The results of the inoculated onions showed the highest leaf length was observed in Red creole (31.0 cm) while the lowest in Hybrid

with 21.4 cm. In contrast, the highest leaf length in control results was (37.0 cm) (Red creole) and lowest was recorded in Hybrid (21.4 cm). The results show significant variation ($P < 0.05$) (Tables 6).

Table 9: Effect of purple blotch on Leaf length (cm) per onion variety

Variety	N	Mean	Std. Deviation	F-value p-value	
Red creole	10	31.0	4.3		
Bombay red	10	28.2	5.0	8.14	0.000
Red coach	10	30.5	3.8		
Hazera	10	30.5	3.7		
Hybrid	10	21.4	1.3		
Tanzania	10	29.5	4.8		

Posthoc test showed that only Hybrid had significant difference ($p < .000$) with all the varieties studied (Table10).

Table10. Posthoc Tests showing effect of purple botch on Leaf length (cm) of onion varieties

Variety	Variety	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	Bombay red	2.7500	1.7914	.131	-.842	6.342
	Red coach	.5000	1.7914	.781	-3.092	4.092
Red creole	Hazera	.4500	1.7914	.803	-3.142	4.042
	Hybrid	9.5500*	1.7914	.000	5.958	13.142
	Tanzania	1.4500	1.7914	.422	-2.142	5.042
	Red creole	-2.7500	1.7914	.131	-6.342	.842
	Red coach	-2.2500	1.7914	.215	-5.842	1.342
Bombay red	Hazera	-2.3000	1.7914	.205	-5.892	1.292
	Hybrid	6.8000*	1.7914	.000	3.208	10.392
	Tanzania	-1.3000	1.7914	.471	-4.892	2.292
	Red creole	-.5000	1.7914	.781	-4.092	3.092
	Bombay red	2.2500	1.7914	.215	-1.342	5.842
Red coach	Hazera	-.0500	1.7914	.978	-3.642	3.542
	Hybrid	9.0500*	1.7914	.000	5.458	12.642
	Tanzania	.9500	1.7914	.598	-2.642	4.542

	Red creole	-4.500	1.7914	.803	-4.042	3.142
	Bombay red	2.3000	1.7914	.205	-1.292	5.892
Hazera	Red coach	.0500	1.7914	.978	-3.542	3.642
	Hybrid	9.1000*	1.7914	.000	5.508	12.692
	Tanzania	1.0000	1.7914	.579	-2.592	4.592
	Red creole	-9.5500*	1.7914	.000	-13.142	-5.958
	Bombay red	-6.8000*	1.7914	.000	-10.392	-3.208
Hybrid	Red coach	-9.0500*	1.7914	.000	-12.642	-5.458
	Hazera	-9.1000*	1.7914	.000	-12.692	-5.508
	Tanzania	-8.1000*	1.7914	.000	-11.692	-4.508
	Red creole	-1.4500	1.7914	.422	-5.042	2.142
	Bombay red	1.3000	1.7914	.471	-2.292	4.892
Tanzania	Red coach	-9.9500	1.7914	.598	-4.542	2.642
	Hazera	-1.0000	1.7914	.579	-4.592	2.592
	Hybrid	8.1000*	1.7914	.000	4.508	11.692

In bold = Mean variation significant at 0.05 level.

Effect of purple blotch on bulb length and diameter per onion variety

The results show that bulb length for the varieties inoculated ranged from 3.5-4.5 cm as compared to un-inoculated (control) 4.3-6.0 cm

which indicated a significant variation. Red coach had the highest bulb length (5.6 cm) and lowest (3.5 cm) recorded in Bombay red (Tables 6).

Table 11: Effect of purple blotch on bulb length and diameter per onion variety

Varieties	Bulb length (cm)	Bulb Diameter (cm)
Red creole	3.9±0.7	4.7±0.9 ^{ab}
Bombay red	3.7±0.7 ^a	3.5±1.4 ^{acd}
Red coach	4.5±0.6 ^{abc}	5.6±0.7 ^c
Hazera	3.7±0.7 ^b	4.4±0.8 ^d
Hybrid	3.9±0.8	4.1±0.8
Tanzania	3.5±0.7 ^c	3.3±1.2 ^b
Total	3.9±0.7	4.3±1.2

Values are expressed as mean ± standard deviation. Values in the same column with the similar superscript show significant mean differences at 0.05 levels when compared with each other. Statistical comparisons were performed using Analysis of Variance (ANOVA) and Least Significance Difference (LSD) posthoc tests.

Bulb diameter

The inoculated plants of the bulb diameter ranged from 3.3-5.6cm which also differed from the control results 5.0–6.1cm showing significant variation (Tables 6). Posthoc tests indicate no significant variation in bulb diameter for all species.

Leaf number

The results indicated significant difference between leaf numbers in all the varieties investigated ($P < 0.05$). The highest number of leaves (7.4, 7.2 and 7.0) was recorded in Bombay red, Hazera and Red coach varieties respectively. Hybrid recorded the lowest leaf number (Tables 6).

Table 12: Effect of purple blotch on leaf number per onion variety

Variety	N	Mean	Std. Deviation	F-value	p-value
Red creole	10	6.6	0.8		
Bombay red	9	7.4	0.7	3.217	0.013
Red coach	10	7.0	1.1		
Hazera	10	7.2	0.8		
Hybrid	10	6.0	0.5		
Tanzania	10	6.6	1.3		

Fresh and dry bulb weight per onion variety

The results indicate that both fresh and dry bulb weight were significantly affected by all the varieties ($P < 0.05$). Red coach showed the

highest bulb (40.9 g) and (5.3 g) for fresh and dry weight, Hybrid showed the least weight 26.9 g and 2.9 g for fresh and dry weight as seen below.

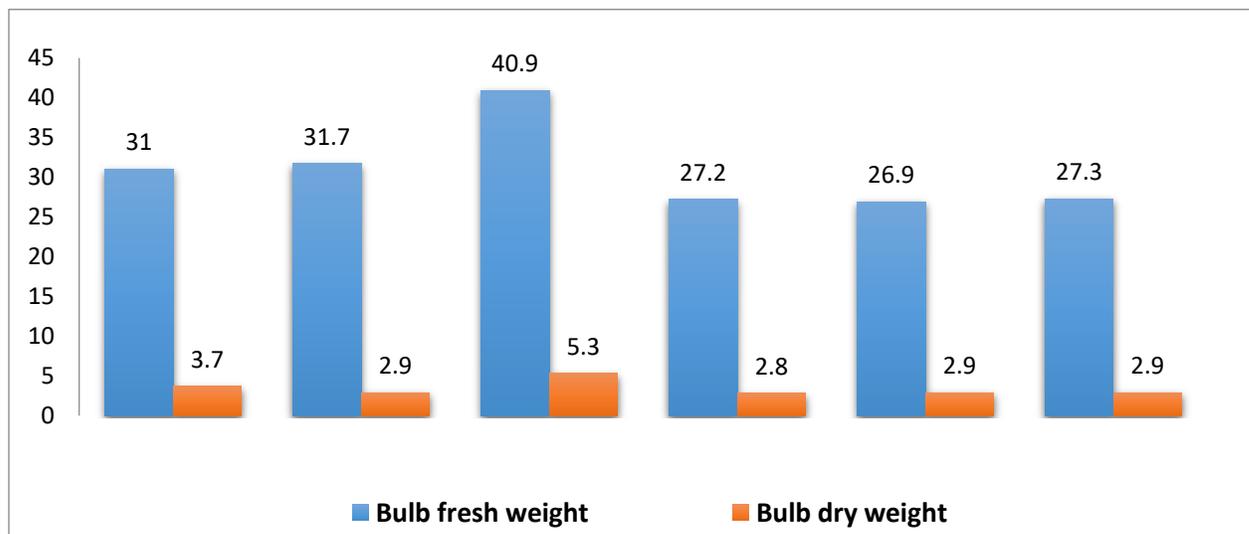


Fig.1: Effect of purple blotch on fresh and dry bulb weight per onion variety.

DISCUSSION

Reaction of onion varieties to purple blotch

Out of the six varieties screened, three were susceptible to the disease, and the other three were moderately susceptible. The most affected variety was Tanzania (susceptible) while the least affected was Red coach (moderately susceptible). This is in line with Awuah *et al.* (2009), who indicated variation in reaction: Malawi variety was the least susceptible, Red creole was moderately susceptible, and Bawku red was highly susceptible to onion bulb rot disease and produced smaller bulbs. Behera *et al.* (2013) tested 22 onion cultivars at Kalyani, West Bengal, and none of them showed immune response to the disease. Alam *et al.* (2007) examined six local garlic varieties and not even one reported high tolerance to purple blotch. Kavitha *et al.* (2017), reported varieties exhibiting moderate tolerance to the disease (purple blotch). Purple blotch is among the major fungal diseases that have devastating effect on onion worldwide irrespective of the variety, which may be the reason why all the varieties studied showed signs of infection by the disease.

Effects of Purple blotch disease on onion varieties

All the six onion varieties showed purple blotch disease symptoms. None of the cultivar showed immune, resistant, or highly susceptible response following Pathak *et al.* (1986) scale. This is contrary to the study conducted by Mathur *et al.*, (2006) who describe onion cultivar. RO 59 resistance to purple blotch.

Response of onion varieties to six purple blotch isolates

Red coach and Hazera were the least affected (tolerant) by all the isolates, though the latter registered susceptible response to isolate Kb06. The results are in line with Tripathy *et al.* (2013) who studied onion cultivars from

Odisha India for purple blotch tolerance showed 4 cultivars such as NRCWO-3, NRCWO-4, NRCRO-3 and VG-19 resistant to the disease. However, the virulent isolates were Kb06 and Kb17 from Kabale region while the least virulent was Mb115 from Mbale region. This is in line with Garg *et al.* (2013) who showed that inoculating the plants using high concentration of inoculums usually leads to change of disease severity from resistant to susceptible when plants were inoculated artificially.

Effect of purple blotch on growth parameters

Inoculated and the control experiments showed a considerable difference in the results, and indicating a negative effect on all the parameters tested. Also there was a significant variation among the effects of the disease on the varieties. The variation may be attributed to genetic makeup of the varieties which could not be influenced by the environment. Similar findings by Lancaster *et al.* (1996) showed purple blotch affected the crop from above soil surface leading to its total destruction and considerable yield loss, thus the effect on all varieties alike.

Plant height

Plant height was significantly affected according to variety with Red coach, Red creole, Hazera and Tanzania being least affected, meaning the disease had a significant impact on the test plants. The variation may be attributed to different genetic makeup of cultivars. The result is in accordance with Yemane *et al.* (2014) who showed significant differences in the height of plants among onion cultivars.

Leaf length

The highest leaf length was observed in Red creole (31.0 cm) while the lowest was in Hybrid (21.4 cm). This is in line with Yemane *et al.* (2014) who reported variable leaf length

between Adama Red, Melkam and Bombay Red.

Leaf number

There was a significant variation in the leaf number for the six varieties examined, Bombay red, Hazera and Red coach had the highest number, and Hybrid recorded the lowest. Mollah *et al.* (2015) and Rao *et al.* (2013), indicated variation in leaf numbers among onion varieties.

Bulb diameter, fresh and dry weight

These parameters varied significantly across onion varieties. Red coach had the highest diameter, and both fresh and dry bulb weights; Bombay red had the lowest bulb diameter; and Hybrid had the lowest fresh and dry bulb weights. Yemane *et al.* (2014) reported significant differences in both fresh and dry bulb weight across varieties.

CONCLUSION

All onion varieties grown in Uganda are affected by purple blotch disease. However, the varieties, Red coach, Hazera and Red creole were the least affected by the disease. The virulent isolates were Kb06 and Kb17 from Kabale region while the weakest was Mb115 from Mbale region. Hybrid variety was highly affected by isolates of Kasese and Mbale but less affected by isolates in Kabale region. All growth parameters were significantly affected by the disease. Therefore, choosing cultivars with high yield and tolerant to purple blotch in paramount in improving onion production in the country. It is also recommended that farming communities should plant onion varieties resistant to purple blotch, and suitable to their region. Red coach, Hazera and Red creole are

recommended for wider cultivation in all the regions. Farmers in the three regions should be discouraged from growing Tanzania variety because it is prone to the disease (*Alternaria porri*). Red coach, Hazera and Red creole could be used as parent in onion improvement programmes aimed at developing purple blotch resistant varieties. More research work is needed in area of effective method of purple blotch disease control in Uganda.

ETHICAL CLEARANCE

The authors report that this was not necessary as experiments involving investigations on humans or animals were not carried out.

DECLARATION

No conflict of interest declared by the authors and they are in charge of writing the manuscript.

STATEMENT OF CONTRIBUTION

Writers listed on this paper, were fully involved in the authentication, data generation, examination, and evaluation of manuscript among others, especially the second and third authors for their editing and corrections.

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