Journal of Oil Palm Research Vol. 32 (3) September 2020 p. 488-496
DOI: https://doi.org/10.21894/jopr.2020.0045

OCCURRENCE, DISTRIBUTION AND FARMERS' KNOWLEDGE ON THE MANAGEMENT OF *Fusarium* WILT OF OIL PALM AMONG SMALLHOLDERS IN KALANGALA, UGANDA

OTUBA M AMUGOLI*; GABRIEL DDAMULIRA*; ALEX ASIIMWE*; KIMULI JOSEPH*; GERALD DDUMBA*; EDRINE MUTYABA* and IDD RAMATHANI*

ABSTRACT

Fusarium *wilt of oil palm is caused by* Fusarium oxysporum *f. sp.* elaeidis *and is particularly prevalent in Africa. This study was conducted in Kalangala district, the commercial oil palm cradleland in Uganda and it involved undertaking a survey among smallholder farmers to assess the occurrence, distribution, farmers' knowledge and management level of* Fusarium *wilt of oil palm. This was achieved by taking an inventory of all the plants in a given plot, noting the presence or absence of symptoms of* Fusarium *wilt and calculating the incidence in each given plot. This is the first time* Fusarium *is identified in oil palm plantations in Uganda and the results showed that infected oil palms were mainly found in Mugoye sub-county, Kagulube block. The highest average severity (3) was observed in Kagulube as compared to all other blocks (severity score 2). The highest percentage incidence (15%) was noted in Kagulube and the least (5%) in Bbeta East, Bbeta West and Bujjumba blocks. Despite the widespread occurrence of* Fusarium *wilt in Kalangala, management of the disease among farmers was inadequate. Urgent measures need to be undertaken to prevent spread of* Fusarium *wilt within and among farmers' fields.*

Keywords: *Fusarium* wilt, oil palm, Uganda.

Date received: 10 June 2019**; Sent for revision:** 2 July 2019**; Accepted:** 11 October 2019**; Available online:** 12 August 2020.

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.), the world's foremost oilseed crop, can annually produce 3.5 t of oil per hectare per year (Cochard *et al.,* 2001). The oil is extracted from its fruit's mesocarp and kernels before being processed as refined oil for food and a wide variety of other industrial products. The oil has been a traditional component of food in Africa for millennia and has continued to significantly contribute to nutrition, life style and household income in traditional and recent oil palm growing areas in Africa (Carrere, 2010). Also, national and regional demand for palm oil is very strong and is projected to grow in the future, creating a powerful incentive for the expansion of oil palm production (Ssemmanda and Opige, 2018), an aim strongly supported by government policy in Uganda. These opportunities encouraged the government of Uganda to initiate commercial oil palm production in Kalangala as the pioneer oil palm growing district in the country.

* Horticulture and Oil Palm Programme,
National Crops Resources Research Institute (NaCRRI),
P. O. Box 7084, 00256 Kampala, Uganda.
E-mail: mozes.otuba@gmail.com

Harvests from oil palm fields in Kalangala have boosted the income of farmers and contributed notably to the existing gap in demand for vegetable oil within the country and the region in general (MAAIF, 2015). Despite the significant economic benefits derived from oil palm production, intermittent increase in oil palm yields has been observed since 2008 when most oil palm plantation started fruiting. The reason for the low yield is attributed to unforeseen challenges such as outbreak of diseases like *Fusarium* wilt often expected at oil palm replanting.

Fusarium wilt is the most destructive disease of oil palm in Africa (Corley and Tinker, 2008). The disease can potentially cause the death of more than 70% of palms in plantations and eventually over 50% in yield losses if not effectively controlled (Cooper, 2011; Dumortier *et al.,* 1992; Rusli *et al.,* 2013). It is a cryptogamic disease, caused by a telluric fungus, *Fusarium oxysporum* f. sp. *elaeidis* (Foe) (Ascomycetes), specific to oil palm (Wardlaw, 1946). *Fusarium* wilt is prevalent in West and Central Africa, the centre of origin of oil palm (Corley and Tinker, 2016) suggesting an evolutional relationship between *Elaeis guineensis* and Foe (Rusli *et al.,* 2017). Once infested, Foe systematically colonises the vascular elements resulting in wilting in susceptible palms where plant defense responses involving the accumulation of gels, tyloses, gums, *etc*. are delayed (Cooper and Rusli, 2014; Paul, 1995). In mature palms, the symptoms manifest either as 'acute wilt' where the palms die rapidly or as 'chronic wilt' where the palms take several years to die or remain unproductive and stunted (Corley and Tinker, 2016). Fronds in palms with the acute symptoms maintain their erect position but dry up rapidly and die before snapping off in windy conditions. In the chronic cases, desiccated older leaves break near or at some distance from the rachis and the younger leaves progressively become chlorotic and reduced in size. Internally, the Foe-palm interaction results in a brownish-grey to black discolouration in susceptible oil palms. These symptoms were typically observed in Kalangala district, Uganda, threatening the development of an infant oil palm industry in the country.

The observation of *Fusarium* wilt in Kalangala has undermined the government impending plan to expand oil palm production to other suitable agro-ecologies in the districts of Mayuge and Buvuma. However, the extent to which *Fusarium* wilt has spread in Kalangala is not known. Also, there is an existing knowledge gap in identification of the disease among smallholder farmers. The aim of the present study was to establish the occurrence and distribution of *Fusarium* wilt among smallholder farmers in Kalangala as well as to assess the knowledge gap among farmers in the management of the disease.

MATERIALS AND METHODS

Survey Areas

The aforementioned study was conducted in Kalangala district, the main hub for oil palm production in Uganda. This district is an island on Lake Victoria lying between 0.6351°S and 32.5373°E below the equator. It receives an annual rainfall range of 1125 to 2250 mm and temperature ranges from 25°C-27.5°C making it typically a humid island characterised by mainly sand loamy soils (Government of Uganda, 2019).

Kalangala is administratively divided into seven sub-counties, namely; Kalangala Town Council, Bujjumba, Mugoye, Bufumira, Mazinga, Bubeke and Kyamuswa. However, for proper management of oil palm production, the production area has been apportioned into seven production blocks, namely; Bbeta East, Bbeta West, Bujjumba, Kalangala Town Council, Kayunga, Kagulube and Island blocks, and these have further been sub-divided into units. Three sub-counties, Kalangala Town Council, Bujjumba and Mugoye were considered in this study. These form the core oil palm production zones on Bugala Island where majority of the smallholder farmer fields are found. A field in Bufumira sub-county reported to have a typical *Fusarium* wilt symptomatic oil palm was also included in the survey. Within the three sub-counties, six blocks were targeted, namely; Bbeta East, Bbeta West, Bujjumba, Kalangala Town Council, Kayunga and Kagulube. The surveys were carried out in September 2018. A global positioning system (GPS) was used to record the coordinates of each prospecting site in order to develop a disease map for Bugala Island. A total of 123 farmers' fields were surveyed averaging about 1.01 ha (2.5 ac) each.

Identification of *Fusarium* Wilt Signs and Symptoms

The study targeted oil palm farmers in Kalangala district. The farmers were randomly selected for the survey from the smallholder farmer extension office, Kalangala Oil Palm Growers Trust (KOPGT). However, farmers with reports of a strange disease causing drying of palms were prioritised during the survey. In the field, plants were observed for signs and symptoms including desiccation of older fronds, bending at the rachis near the base of desiccated fronds, hanging downward of broken fronds, reduction in size and sometimes chlorosis of younger fronds, reduction in size of the crown and internal greyish-brown to black discolouration in the vascular elements as described by Corley and Tinker (2016). In fields observed with *Fusarium* wilt symptomatic plants, incidence and severity data were taken. Due to the localised tendency of *Fusarium* wilt, the incidence and severity data were

taken from 20 palms surrounding the *Fusarium* wilt symptomatic palm. This was considered a *Fusarium* wilt plot. Similar plots were randomly selected in fields without *Fusarium* wilt symptomatic palms. The *Fusarium* wilt plot was then critically assessed for both internal and external symptoms of *Fusarium* wilt. External symptoms were used to guide the dissection of palms for internal symptoms.

Determination of Incidence of *Fusarium* Wilt in Different Localities

The incidence of *Fusarium* wilt at each site was determined according to the formula used by Koussinou *et al.* (2019).

$$AI\ (\%) = \left(\frac{NPI}{NTPC}\right) \times 100$$

where:
AI (%) - average incidence.
NPI - number of infected palms observed in the *Fusarium* wilt plot.
NTPC - the total number of palms on the *Fusarium* wilt plot.

In each field, the number of diseased plants and the total number of plants grown was determined by simple enumeration. The incidence of the disease at the block level was calculated by averaging the total number of farmers' fields visited per block.

Determination of Severity of *Fusarium* Wilt in Different Localities

Modified from Koussinou *et al.* (2019), severity was assessed using a 1-5 scoring scale as described below.

1. No visible symptoms.
2. Symptoms on less than 25% of the plant (desiccation of older fronds).
3. Symptoms cover 50% leaf area (desiccation and breaking at some distance from the rachis of older fronds, younger fronds reduced in size).
4. Symptoms on entire leaf area (the above plus pencil like appearance towards the crown).
5. The above plus stunting, deformation and death of the plant.

Furthemore, a simple questionairre was administered among the farmers to assess their knowedge on identification and management of *Fusarium* wilt.

Statistical Analysis

Data on severity and incidence of *Fusarium* wilt was entered in GenStat (12th edition) statistical package, then an analysis of variance (ANOVA) was performed to compare the mean incidence of the disease in the units and blocks. When a significant difference was detected ($P<0.05$), the variance was complemented by the comparison of the averages using the Least Significant Difference (LSD) test for the formation of homogeneous groups. The map showing the distribution of *Fusarium* wilt in Kalangala Island was made using QGIS 2.6.0 software. Socio-economic data were coded and entered in an Excel sheet then transferred to SPSS statistical package (16th edition) to develop descriptive statistics involving means, mode, median, *etc*.

RESULTS AND DISCUSSION

Occurrence and Distribution of *Fusarium* Wilt in Uganda

Based on the observations from the fields (*Figure 1*) and analysis of the results, *Fusarium* wilt was found to occur in 20 out of the 123 (16.3%) fields surveyed (*Table 1*). More infected plots were observed in Mugoye (11 out of 20 *Fusarium* plots) as compared to Bujjumba (4) and Kalangala Town Council (4). *Fusarium* wilt was observed in all oil palm growing blocks except the Island block. Within units, Mulore-Senero, Kasekulo A and B did not have any infected oil palm. The outbreak of *Fusarium* wilt in Kalangala relates to the susceptibility of oil palm varieties being grown on both the nucleus and the smallholder farms. The varieties grown in Kalangala were all imported from Asia and West Africa and were not pre-evaluated for adaptability to Uganda conditions. As proposed by Rusli *et al.* (2017), some oil palm varieties vary in tolerance to *Fusarium* wilt with respect to the breeding and production locations. Also, the means through which *Fusarium* wilt of oil palm was introduced into Kalangala district are unknown. However, *Fusarium* wilt has globally spread through contaminated planting materials (Flood *et al.*, 1990). Dossa *et al.* (1991) noted that strains of Foe in South America were similar to those in West Africa, thus, concluding the disease had spread from West Africa possibly through seeds. Rusli *et al.* (2017) concluded that Foe has a monophyletic origin placing all the 21 strains of Foe studied into two evolutionary clades. The outbreak of *Fusarium* wilt in the first commercial farms in the country also suggests that the materials planted were susceptible to the disease. This lack of *Fusarium* tolerant materials in the country can further jeopardise the intended expansion of oil palm production to other suitable areas in the country. Appropriate measures including the use of clean and *Fusarium* wilt resistant materials should be adopted in Uganda as soon as possible for sustainable future oil palm production.

TABLE 1. PLOT OCCURRENCE, INCIDENCE AND SEVERITY OF *Fusarium* WILT IN DIFFERENT LOCALITIES IN BUGALA ISLAND, KALANGALA DISTRICT

Survey area	*Fusarium* wilt plots		
Sub-county			
Bujjumba	4		
Mugoye	11		
Kalangala T C	4		
Bufumira	1		
Total	20		
Blocks		Average severity	Incidence (%)
Bbeta East	2	2	5
Bbeta West	6	2	5
Bujjumba	2	2	5
Kalangala T C	5	2	8
Kayunga	4	2	7
Kagulube	1	3	15
Total	20	-	-
Units			
Bbeta	1	2	5
Bweza	1	2	5
Bumangi	1	2	5
Busanga	1	2	10
Kalaya	2	2	5
Kabaale	2	2	5
Kiizi	1	2	10
Kikwayu	2	2	5
Kizira	2	2	5
Mulore-Senero	-	-	-
Ssozi	2	2	10
Buswa	1	2	5
Kasekulo A, B	-	-	-
Kagulube	1	3	15
Lesenke	1	2	5
Naalya	2	2	5
Total	20	-	-

Severity and % Incidence of *Fusarium* Wilt in Kalangala

The results at P≤0.05 showed that there was a significant difference in the average severity within blocks and no significant difference among units. The highest severity scores were recorded in Kagulube block (*Table 1*). Kagulube recorded the highest severity score among units. There was no significant difference in percentage incidence within the surveyed sub-counties, blocks and units at P≤0.05. The highest percentage incidence within blocks (*Figure 2*) and units (*Figure 3*) was recorded in Kagulube (15%). Severity and incidence were not dependent on the age of the oil palms despite most fields being less than 10 years of age (*Figure 4*). Unlike outbreaks in South America and other parts of Africa that occur from second plantings (Franqueville and Renard, 1990), *Fusarium* wilt in Kalangala appeared in the first planting of commercial oil palm plantations. Measures to prevent spread to other newly established or yet to be established fields should be undertaken. These range from a change in policy to regulate the use of planting materials, adoption of *Fusarium* wilt resistant planting materials to manipulation of management practices to suppress *Fusarium* wilt in infested areas.

Disease Identification

Fusarium wilt is a newly identified oil palm disease in Kalangala. Disease identification in the fields was dependent on observation of typical *Fusarium* wilt symptoms as described by Corley and Tinker (2016). Both chronic (*Figure 5*) and acute (*Figure 6*) symptoms were observed in Kalangala. *Fusarium* wilt was initially observed on quite a number of plants in the nucleus farm and later on small scale farmers' fields. However, 68.3% of the respondents were not aware of the disease, the majority of the farmers or the caretakers (61.8%) could not identify the diseases on their oil palm plantations and neither could 59.3% distinguish between nutritional deficiencies and disease infection. The few (19% of the respondents) who were aware of the disease had basic information on how it is spread from one palm to another or from field to field. Among the diagnostic symptoms observed in the field, none was easily identified by either farmers or caretakers (*Table 2*).

TABLE 2. SUMMARY OF RESPONDENTS' ABILITY TO IDENTIFY *Fusarium* WILT FROM OBSERVATION OF SYMPTOMS

Symptom	Yes	No
Desiccation of older fronds	21.1	78.9
Bending at the rachis or near the base of the fronds. Fronds hanging downward	6.5	93.5
In immature palm, development of a bright lemon yellow colour in the middle to upper canopy	11.4	88.6
Yellowing or drying out of leaves at the same level	4.9	95.1
Internal greyish-brown to black discolouration in the vascular elements	17.9	82.1
The drying of all fronds	10.6	89.4

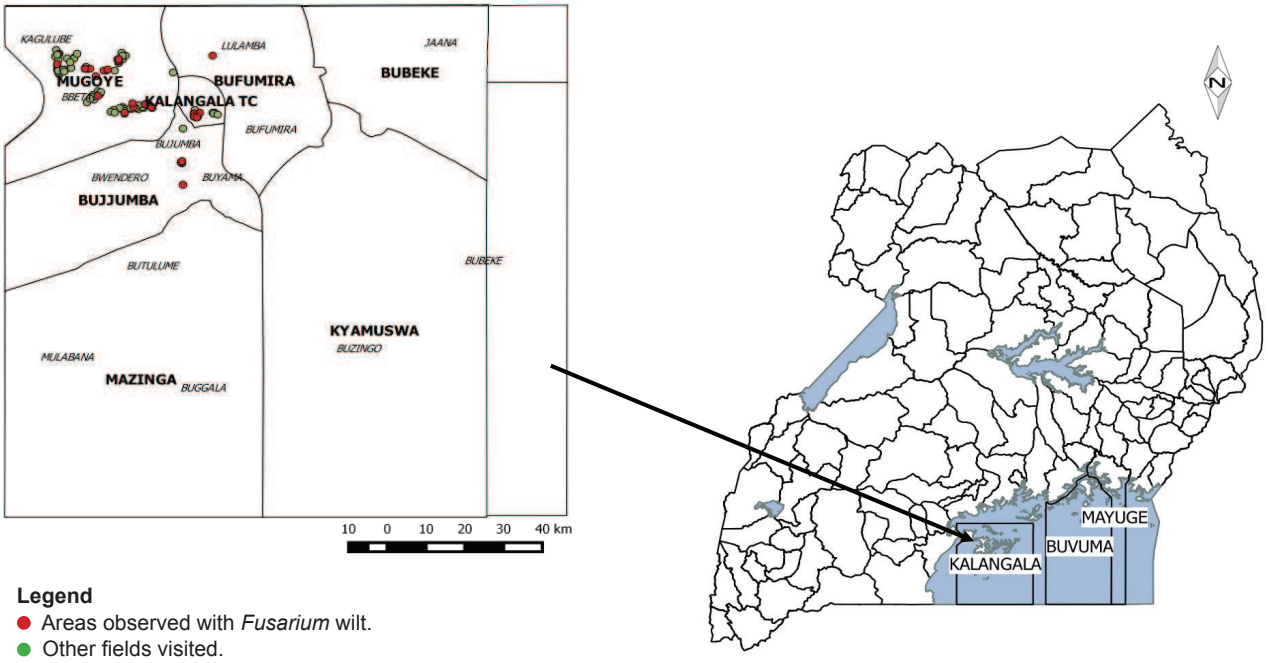

Figure 1. Map of Uganda showing areas studied for occurrence of Fusarium *wilt in Kalangala district and other districts imminent for oil palm production.*

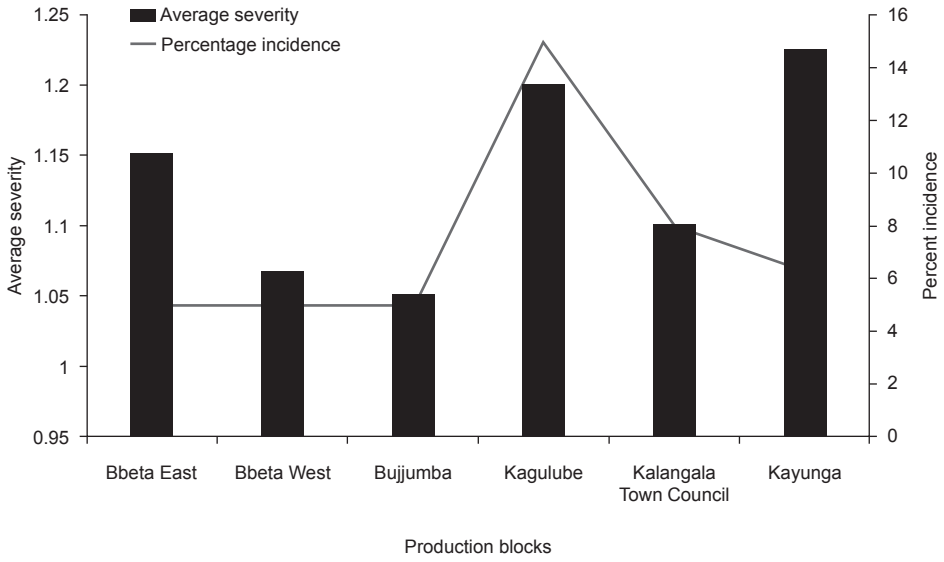

Figure 2. Mean severity and percentage incidence score of Fusarium *wilt of oil palm among the production blocks on Bugala Island, Kalangala district.*

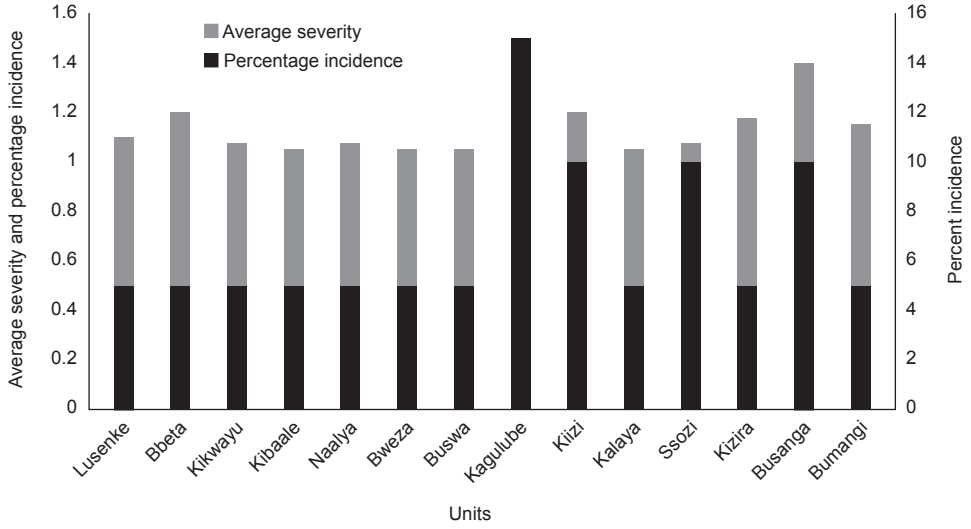

Figure 3. Mean severity and percentage incidence score of Fusarium *wilt of oil palm among the different production units on Bugala Island, Kalangala district.*

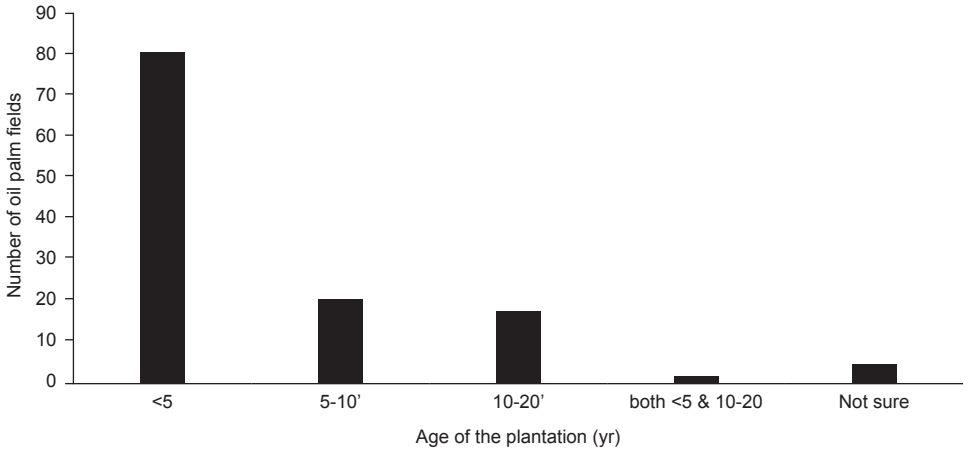

Figure 4. Age ranges of farmers' oil palm fields visited during the study.

Figure 5. External symptoms of chronic Fusarium *wilt observed in Kalangala. Initial wilting followed by desiccation of the fronds and breaking and hanging downwards at a short distance from the palm trunk.*

Figure 6. External symptoms of acute Fusarium *wilt observed in Kalangala. Rapid wilting followed by desiccation of the fronds while maintaining their erect position.*

Figure 7. Internal discolouration typical of Fusarium *wilt infected oil palms. Note the speckled distribution of blocked vascular elements across the frond.*

The inability of farmers to clearly identify *Fusarium* wilt through observation of symptoms makes management of the disease impracticable. This can also encourage the spread of the disease since caution to prevent spread is hardly taken by farmers in the course of routine management of their fields. Farmers, therefore, need to get acquainted with symptoms of *Fusarium* wilt to ease diagnosis, prevention and later effectively manage the disease. Despite the poor correlation between internal and external symptoms in the identification of *Fusarium* wilt (Buchanan, 1999), external symptoms can be used to effectively identify the disease as used in this study. A subsequent study will target characterisation of the Foe in Kalangala in relation to strains identified in other parts of the continent. Currently, occurrence and distribution of *Fusarium* wilt are critical in the management of *Fusarium* wilt in Kalangala district and surveillance is on-going to monitor the disease dynamics.

Field Management in Kalangala District

Farmers growing oil palm in Kalangala district are contracted by the Oil Palm Uganda Limited (OPUL) and it is the sole supplier of seedlings to the farmers. The contracted farmers therefore in turn supply OPUL with harvested fruits from their fields for palm oil extraction. However, there was a great variation in agronomic practices applied by farmers in their respective fields. At least 59% of the farmers applied fertilisers two to three times in a year. The other 31% deemed it expensive or applied fertiliser at least once a year. Oil palm requires continued nourishment with nitrogen, phosphorus, potassium, and magnesium (NPK-Mg) to maintain high vegetative growth, yield production, suppression of some biotic infestations, *etc*. (Tang *et al.*, 1999). For example, potassium in fertilisers or cover crops exhibits high Foe suppressive properties (Ntsefong *et al.*, 2012; Ollagnier and Renard, 1976). Regular K fertiliser application can, therefore, control *Fusarium* wilt outbreaks in oil palm plantations. Also, despite the limited growth of cover crops by farmers in Kalangala, encouraging farmers to grow K rich cover crops like *Brachiaria* or routinely apply NPK-Mg can maintain higher yields under *Fusarium* wilt infestation.

Farmers in Kalangala (83%) did not apply any pesticides for management of oil palm pests and diseases in their fields except a few who applied Ant-killer, Cypermethrin, and Duducyper to manage termites and ants. However, the unsupervised application of these insecticides especially against ants is harmful to useful insects such as oil palm pests predators, parasitoids and pollinators. This with time can lead to a catastrophic upsurge of pest populations due to lack of natural enemies or development of resistance of pests to inappropriately applied pesticides. Severe pest infestations in oil palm can reduce plant defenses against diseases like *Fusarium* wilt, thus, leading to more death of palms from Foe attacks. Pruning was done by the majority of farmers (64%) at least twice a year. However, disinfection of tools was not done both between plants and fields. Contaminated pruning tools can significantly spread *Fusarium* wilt from one plant to another. Only 3% of the farmers disinfected their tools mostly by cleaning in soapy water after a day's work. These poor management practices can also be attributed to the fact that the majority of the oil palm fields are managed by unskilled caretakers on behalf of distant owners. The caretakers lack basic knowledge in modern agriculture and poorly implement recommended management practices.

Social, Ecological and Economic Aspects of Oil Palm Production in Kalangala

In Kalangala, majority (52%) of farmers own between 1.01 to 2.02 ha (1 to 5 ac) of land and their land is generally relatively flat (81% of the fields).

About 48% of the farmers possess fields with oil palm populations ranging from 58 to 200 oil palms and the only source of planting materials / seedlings is OPUL through the farmers' association, KOPGT. Most of the fields (82% of the fields) in Kalangala under the farmers' control were young (less than 5 years old). Despite planting of oil palm in Kalangala starting way back in 2004, the majority of the farmers' fields were planted in 2007 (30%), 2010 (20%) and 2012 (25% of the respondents). Most of the land was occupied by natural forest (86%) before it was cleared for planting oil palm. However, a few farmers had initially planted coffee, banana, cassava, and other food crops before they abandoned these projects in favour of oil palm production. Within the natural forests that existed, a few farmers (28% of the respondents) reported the occurrence of wild palm and these were mostly burnt after clearing (64%). However, a few farmers (9%) left the wild palms on the ground within their fields.

CONCLUSION

The objective of this study was to assess the occurrence, distribution of *Fusarium* wilt and farmers' field management practises against *Fusarium* wilt of oil palm. It is evidenced from this study that the disease is wide-spread in the district and urgent containment measures need to be undertaken to curb its spread in farmers' fields. The disease was mainly found in Mugoye sub-county within the blocks of Kagulube, Bbeta West and Kayunga. Farmers within these blocks needed urgent sensitisation and training on best practises in *Fusarium* wilt control. Generally, it was observed that oil palm farmers lacked knowedge in the diangosis of the disease and its management. This was attributed to the fact that the crop was new in the area and majority of the field owners employed caretakers with limited knowedge to manage their fields. We recommend that an increased connection between KOPGT and the oil palm research team should be developed. The outcome should be multiple practical training of KOPGT extension staff and farmers on the most suitable *Fusarium* wilt management measures. Furthermore, we recommend that KOPGT takes the initiative of clearing all infected oil palms from the farmers' fields since the farmers currently have no capacity to contain the spread. For new plantings, the authorities in collaboration with the Uganda oil palm research team should consider the adoption of *Fusarium* wilt resistant materials widely used in West and Central Africa. These should, however, be evaluated for adaptability and suitability to local conditions for successful control of *Fusarium* wilt of oil palm in Uganda.

REFERENCES

Buchanan, A G (1999). *Molecular Genetic Analysis of* Fusarium *wilt Resistance in Oil Palm*. Ph.D thesis. University of Bath. p. 6.3.5, 13.4.2.1, 13.4.2.9.

Carrere, R (2010). Oil palm in Africa: Past, present and future scenarios. *WRM Series on Tree Plantations, 15*: 3.

Cochard, B; Adon, B; Kouame, R K; Durand-Gasselin, T and Amblard, P (2001). Advantages of improved commercial palm oil (*Elaeis guineensis* Jacq.) seeds. *OCL-Oléagineux, Corps Gras, Lipides, 8(6)*: 654-658.

Cooper, R M (2011). *Fusarium* wilt of oil palm: A continuing threat to Southeast Asian plantations. Paper presented at the Seminar / Dialogue Sustainable Agriculture - An Insight into *Ganoderma.* 24 February 2011, Kuala Lumpur, Malaysia.

Cooper, R M and Rusli, M H (2014). Threat from *Fusarium* wilt disease of oil palm to South-east Asia and suggested control measures. *J. Oil Palm Res. Vol. 26(2)*: 109-119.

Corley, R H V and Tinker, P B (2008). *The Oil Palm*. John Wiley & Sons. 592 pp.

Corley, R H V and Tinker, P B (2016). Diseases of the oil palm. *The Oil Palm*. 5th edition. Chichester: Wiley Blackwell. p. 399-437.

Dossa, C; Pando-Bahuon, A; Renard, J L and Boisson, C (1991). Détermination des groupes de compatibilité végétative chez des souches africaines de *Fusarium oxysporum* isolées de palmiers à huile fusariés (Determination of vegetative compatibility groups in African *Fusarium oxysporum* strains isolated from vascular wilt-infected oil palms). *Oléagineux, 46(4)*: 145-147.

Dumortier, F; Van Amstel, H and Corley, R H V (1992). *Oil Palm Breeding at Binga, Zaire, 1970-1990*. Unilever Plantations, London. 404 pp.

Flood, J (2006). A review of *Fusarium* wilt of oil palm caused by *Fusarium oxysporum* f. sp. *elaeidis*. *Phytopathology, 96(6)*: 660-662.

Flood, J; Mepsted, R and Cooper, R M (1990). Contamination of oil palm pollen and seeds by *Fusarium* spp. *Mycological Research, 94(5)*: 708-709.

Franqueville, H D and Renard, J L (1990). Improvement of oil palm vascular wilt tolerance:

Results and development of the disease at the R. Michaux plantation. *Oléagineux, 45(10)*: 399-405.

Government of Uganda (2019). Kalangala district local government. Overview. https://kalangala.go.ug/lg/overview, accessed on 23 July 2019.

Koussinou, C K L; Adandonon, A and Nodichao, L (2019). Distribution and incidence of *Fusarium* wilt in oil palm in Benin. *J. Applied Biosciences, 135*: 13831-13839.

MAAIF (2015). Status of the vegetable oil development project in Kalangala district. Press Release. Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), Entebbe.

Ntsefong, G N; Ebongue, G N; Paul, K; Martin, B J; Hermine, N B and Gervais, B E (2012). Control approaches against vascular wilt disease of *Elaeis guineensis* Jacq. Caused by *Fusarium oxysporum* f. sp. *elaedis*. *J. Biol. Life Sci., 3(1)*: 160-72.

Ollagnier, M and Renard, J L (1976). Effect of potassium on the resistance of oil palm to *Fusarium* disease. *Oleagineux, 31(5)*: 203-208.

Paul, T C (1995). Fusarium *wilt of Oil Palm: Studies on Resistance and Pathogenicity.* Doctoral dissertation, University of Bath. 219 pp.

Rusli, M H; Wheals, A E; Sharma, S; Seman, I A and Cooper, R M (2017). Disease epidemiology and genetic diversity of *Fusarium oxysporum* f. sp. *elaeidis*, cause of *Fusarium* wilt of oil palm (*Elaeis guineensis* Jacq.). *J. Oil Palm Res. Vol. 29(4)*: 548-561.

Rusli, M H; Idris, A S; Wheals, A E and Cooper, R (2013). Detection of *Fusarium* wilt in oil palm by polymerase chain reaction methods. *MPOB Information Series No. 533*: 2 pp.

Ssemmanda, R and Opige, M O (2018). *Oil Palm Plantations in Forest Landscapes: Impacts, Aspirations and Ways Forward in Uganda.* Wageningen, The Netherlands: Tropenbos International. 55 pp.

Tang, M K; Nazeeb, M and Loong, S G (1999). An insight into fertiliser types and application methods in Malaysian oil palm plantations. *The Planter, 75(876)*: 115-137.

Wardlaw, C W (1946). *Fusarium oxysporum* of the oil palm. *Nature, 158*: 712.