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REACTION OF OKRA (*ABELMOSCHUS ESCULENTUS* L. MOENCH) CULTIVARS TO OKRA LEAF CURL GENUS BEGOMOVIRUS IN MAIDUGURI, NIGERIA

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ABSTRACT
Field study was conducted to determine the reaction of ten okra (*Abelmoschus esculentus* L. Moench) cultivars namely; NH AE47-4, Clemson spineless, Jokoso, Ex Samara, Ex-Basawa, Yar Balla, Mai Malafa, Yar Syria, Kousko and Chalawa to Okra Leaf Curl Virus (OLCV) during the wet season of the year 2016 at the Teaching and Research Farm of the Department of Crop Protection, University of Maiduguri and the Demonstration Farm of Mohamet Lawan College of Agriculture. Randomized Complete Block Design (RCBD) was used for the experiment and the treatments were replicated three times. Among the 10 treatments, all the treatments were found susceptible to whitefly infestation leading to subsequent occurrence of the disease at both the locations. No significant variation was recorded at University of Maiduguri Farm among the test plants, whitefly population count, OLCV incidence and severity but significant difference was observed at Mohamet Lawan College of Agriculture Farm. The cultivars differed significantly in fruit yield recorded at both the locations. The lowest fruit yield was recorded on cultivar Jokoso (119.30 kg/ha) and the highest fruit yield per ha was recorded on cultivar Yar Syria 604.87 kg/ha). Reaction of the cultivars to OLCV disease showed that cultivar Chalawa was moderately resistant (MR), NH AE-47-4, Klemson spineless, Jokoso, Ex Basawa, Yar balla were moderately susceptible to the virus at Mohamet Lawan College of Agriculture. Based on the results of the study, cultivar Yar Syria and Klemson Spineless should be adopted for okra production, after cross breeding with resistant cultivar and could be useful in resistance breeding program to the virus.
Key Words: *Okra, OLCV, Whitefly, Cultivar, and Locations.*

INTRODUCTION

Okra (*Abelmoschus esculentus* (L) Moench), is a fruit vegetable crop that belongs to the Malvaceae family, which is widely grown all over tropical, subtropical and warm temperate regions of the world (Lamont, 1999; Saifullah and Rabbani, 2009). Okra is valued for its edible green seed pods, leaves and fibrous stems (Bamire and Oke, 2003). The leaves and seeds are considered as traditional medicine (Gul *et al*., 2011). The fruit is a popular vegetable which contains abundant vitamins, pectin, and minerals (Oyelade *et al*., 2003). The seeds of okra contain edible oil of more than 14% and the protein content varies from 15% to 26% (NARP, 1993). The seed oil of Okra is rich in unsaturated fatty acids (Savello *et al*., 1980), which is important for human nutrition. The pods of okra contain a substance which is used as blood volume expander (Onunkun, 2012). The fibres of okra are used in making game traps, sponges and fishing lines (Osawaru and Dania-Ogbe, 2010).

The world okra production, as of 2013, was estimated at 8.6 million tons with India leading the production by 70% (6.3 million tons produced on over 0.35million hectares of land) followed by Nigeria (15%), Pakistan (2%), Ghana (2%), Egypt (1.7%) and Iraq (FAOSTAT, 2015). World production of okra as fresh -fruit vegetables is estimated at 6 million ton/year. An estimated 500,000 to 600,000 tons of Okra is produced annually in West and Central Africa which is about 5% of total world production of okra (Siemonsma and Hamon, 2004).

However, the yields of okra are usually below the actual productivity and have also decreased over the years (Asare-Bediako *et al*., 2014). Insect pests and plant viruses are among the major factors contributing to the reduction of yield of okra worldwide (Obeng-Ofori, 2003). Okra plant is susceptible to at least 19 plant viruses with okra leaf curl virus (OLCV) and okra mosaic virus (OMV) being the major diseases (Bi-Kusi, 2013; and has been reported in several countries including Nigeria (Askira, 2012), Ghana (Bi-Kusi, 2013), Ivory Coast (N'Guessan *et al*., 1992) and Saudi Arabia (Ghanem, 2003)**.** OLCV disease causes leaf wrinkle, curling of leaf, distortion of vein, yellowing of leaf, stunted growth and reduction of yield (Askira, 2012). The symptoms of okra leaf curl virus disease usually start appearing 4 to 6 weeks after planting which is the age at which plants are most prone to the disease and proceeds to a stunted growth with fewer pods, thickening of the vein, later the leaf texture becomes rough and warty and the leaves begin to curl (Atiri and Fayoyin, 1989).

Whitefly-transmitted geminiviruses are economically important pathogens that cause enormous losses of crops in subtropical and tropical region of the World. The magnitude of loss caused by this disease in the North Eastern Nigeria is not ascertained. The danger posed by OLCV disease to global okra production calls strategical action to identify durable resistant cultivars. There is an urgent need to identify available okra land races for resistance to OLCV disease with a view to identifying cultivars, which are highly resistance to the disease. The objective is therefore to;

i. evaluate okra cultivars for resistance to okra leaf curl virus in Sudan Savanna region of Nigeria and

ii. determine the frequency of occurrence and severity of okra leaf curl virus in Maiduguri.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at Teaching and Research Farm of Faculty of Agriculture, University of Maiduguri; 11˚80 N and 13˚21 E; and Teaching and Research Farm of Mohamet Lawan College of Agriculture, Maiduguri, 11˚85 N and 13.20 E Borno State during 2016 wet season. Maiduguri is located at Sudan savanna region of North

Eastern Nigeria at about 350m above sea level. The mean annual rainfall and temperature is about 650mm and 32℃, respectively.

Experimental materials

Ten okra cultivars were used for the experiments, they include; 'NHAE 47-4' obtained from National Horticultural Research Institute, Ibadan, 'Klemson spineless', 'Jokoso', 'Kousko', 'Chalawa' from the seed unit of Borno State Agricultural Development Program and 'Ex-Samara', 'Ex-Basawa', 'Yar Balla', 'Maimalafa' and 'Yar Syria' from the Institute of Agricultural Research, Samaru, Zaria all in Nigeria.

Experimental design and field layout

The land was cleared, ploughed, harrowed and leveled manually using a hoe and rake. The experiment was laid out in a Randomized Complete Block Design (RCBD) consisting of 10 treatments, and each treatment was replicated three times making a total of thirty plots. The total land area of the experiment was 379.5 m^2. Each plot was measured 3m × 3m ($9m^2$), with 1m between replication and 0.5 m between each plot. The experimental area consisted of sandy-loam soil was ploughed harrowed and divided into 30 plots. Planting was done at the month of July when the rain is well established. The plots consisted of 30 okra plants at a spacing of 100cm X 30cm giving a total plant population of 30 okra plants per plot. Okra seeds were planted at the depth of 2-3 cm. NPK 15:15:15 fertilizer was applied at the rate of 100kg N ha^{-1}, 100kg P ha^{-1} and 100kg K ha^{-1}. Row method of fertilizer application was employed at 3 weeks after planting and weeding was done using hoe as the need arose.

Sampling of white-fly's infestation associated with okra plants

Adults of whitefly population were counted on topmost expanded leaves of five plants on the underside surface of the leaf in each experimental plot at two weeks after sowing and continued at two weeks' intervals. Whitefly counting was done in the early morning hours when the environment is cooler and whiteflies are relatively immobile than later in the day.

Disease incidence

Okra Leaf Curl Virus (OLCV) infected okra plants were monitored from one week after germination until the end of growing season. Data was taken on incidence of the disease from 5 tagged plants in each plot. The number of plants showing the visible symptoms of OLCV was expressed as percentage of the total number of plants per plot and computed as follows:

Disease incidence (%) = $\frac{Number\ of\ infected\ plants\ per\ plot}{Total\ number\ of\ plants\ per\ plot} \times 100$

Disease severity index

The severity of OLCV was assessed on 5 tagged plants at weekly intervals from 14-80 days after sowing in the okra fields using a visual scale of 1-7 developed by Alegbejo, (1995) Where; No visible disease symptom(s) =1, Top leaves curled and slight stunting of plants =3, All leaves curled and slight stunting of plants=5 and Severe curling of leaves, stunting of plants and proliferation of auxiliaries branches =7. The disease severity indices (DSI) were calculated using the formula:

DSI= $\frac{\sum n}{N \times 7} \times 100$

Where: $\sum$n = sum of all disease rating, N= Total number of rating and 7= Maximum disease grade

Reaction of okra cultivars to OLCV

Reaction of okra cultivars to OLCV were determined using the scale outlined below (Alegbejo, 1995). This was based on the mean of the percentage of OLCV severity at 8 weeks after Emergence (WAE). The disease reaction was classified as; where;

1.0-15.9 %	Resistant (R)
16.0- 25.9%	moderately resistant (MR)
26.0- 36.9%	moderately susceptible (MS)
37.0% and above	highly susceptible (HS)

Data Analysis

All data collected was subjected to statistical analysis of variance (ANOVA) based on Randomized complete block design using the statistical package statistic 8.0. Difference between means was determined using Honestly Significance Difference (HSD) test at 5% level of probability.

RESULTS

Effect of Whitefly Population, Incidence, Severity Index of OLCV and Fruit Yield of Okra during 2016 Rainy Season at Teaching and Research Farm, University of Maiduguri

The whitefly population count was statistically insignificant among test plant at 4, 6 and 8 WAE, though the population increases as the WAE increase. The least whitefly population count was observed on variety Maimalafa at 2 and 4 WAE while higher whitefly population was recorded on Ex Basawa, but statistically insignificant with the other test cultivars. There was no significant variation ($p \leq 0.05$) in the vector population at 8 WAE, however the highest population was observed on cultivar Yar Balla while the least was on Ex Basawa (Table 2).

It was further observed that the disease incidence was statistically not significant among the test plant at 6 and 8 WAE though tends to increase. The highest and lowest percentage incidence was recorded on cultivar Kousko and Maimalafa, respectively. Moreover, an incidence of as high as 90% was recorded on Jokoso but statistically insignificant with the rest of the cultivars while NH AE47-4 records the least. There was no pair wise significant difference recorded among the occurrence of disease severity among the cultivars screened but there is an increase in the trend of the infection as the test plants grow older. The lowest and highest severity index was observed on cultivar Mai Malafa and Kousko, respectively at 6WAE and 8WAE. However, a high severity index was recorded on Kousko and Jokoso at 8 WAE.A significant variation was recorded between the yield of cultivars of okra at Teaching and Research Farm, University of Maiduguri. Yar Syria produce the highest yield kg/ha of fresh fruit yield while Jokoso produce the lowest yield per hectare. No significant difference was observed among the yield of Klemson spineless and Yar Syria; NH AE47-4, Ex Samara 5, Ex Basawa, Yar Balla, Mai malafa and Chalawa. Among the ten okra cultivars evaluated for resistance to OLCV, cultivar NH AE47-4 and Klemson spineless were found to be moderately susceptible, however, Jokoso, Ex Samara5, Ex Basawa, Yar Balla, Maimalafa, Yar Syria, Kousko and Chalawa were highly susceptible to the Okra leaf curl virus (Table 2).

Effect of Whitefly population, Incidence, Severity Index of OLCV and Yield on Okra during 2016 Cropping Season at Teaching and Research Farm, Mohamet Lawan College of Agriculture

The population of whitefly vector recorded at 2 WAE does not vary significantly among the test plants but varied significantly at 4 and 6 WAE. The highest and lowest whitefly vector population was observed on Ex Basawa and Klemson spineless though statistically insignificant with that of Yar Syria and Kousko. However, there was no variation among the vector population of NH AE47-4, Jokoso, Ex Samara-5, Yar Balla, Maimalafa and Chalawa. It was further observed that Ex Samara 5 and Ex Basawa recorded the highest and lowest whitefly, respectively. There was no significant variation recorded for whitefly population among NH AE47-4, Klemson spineless, Jokoso, Yar Balla, Maimalafa, Yar Syria, Kousko and Chalawa. There were no significant ($p \leq 0.05$) variations in the disease incidence at 6 and 8 WAE, though the highest disease incidence was recorded on Klemson Spineless and Chalawa at 6WAE while the lowest disease incidence was on NH AE47-4. The highest disease incidence was recorded on Maimalafa and Kousko at 8WAE; however cultivar NH AE47-4 records the lowest mean disease incidence although not statistically significant. It was further observed the disease severity of the test cultivars do not differ significantly ($p \leq 0.05$) at both 6 and 8 WAE though the highest and lowest severity was observed on Klemson spineless and NH AE47-4; Kousko and Chalawa respectively. There was statistically significant variation ($p \leq 0.05$) of fresh fruit yield of Okra cultivars. The highest and lowest fresh fruit yield per hectare was found on Klemson Spineless and NH AE47-4, respectively although no significant variation was observed on Jokoso, Ex Samara 5, Ex Basawa, Yar Balla and Chalawa. Also, no significant variation was found among Maimalafa, Yar Syria and Kousko.Chalawa was observed to be moderately resistant to the infection at the Demonstration Farm, Mohamet Lawan College of Agriculture. Although it was also observed that Jokoso, Ex Basawa and Yar Balla were moderately susceptible while Kousko, Yar Syria, Maimalafa, Ex Samara5 and Klemson spineless were highly susceptible (Table 3).

DISCUSSION

The economic impact of OLCV is difficult to determine due to the influence of many factors such as local environment in which okra is grown, stage of the plant at which infection occur, the virus strains or variants, parameters of crop selected for evaluation, and the host plant-virus –vector interaction (Barret *et al*., 2008).Large population of whitefly (*Bemisia tabaci* Genn) was noticed during the moderate stage of the crop. None of the okra cultivars were found completely free from attack of whitefly. The infestation of whitefly was first observed in the 3rd week of emergence in both the locations. All the cultivars were found susceptible to whitefly infestation, though the population varied with cultivar and environment. The least whitefly population was observed on variety Maimalafa while higher populations were recorded on variety Ex Basawa at University of Maiduguri Teaching and Research Farm while the results obtained at Demonstration Farm Mohamet Lawan college of Agriculture indicates the higher population on Ex Samara, though the lower population was recorded on Ex Basawa. This is in agreement with the findings of (Chartterjee *et al*., 2019) where he observed whitefly population vector at 2 – 3 weeks after planting and the pest load varied with the cultivars. Nataraja *et al*, (2013) found the susceptibility of okra to sucking pests and whitefly under field condition on various okra cultivars. The cumulative average population of whitefly vector and the associated occurrence of the disease incidence and severity were observed in both the locations. Similar results were also reported by (Ghanem, 2003) who reports 70% of plants showing severe leaf curl symptoms. The infections of the virus were observed when there is a presence of whitefly vector population than in the early weeks of planting. The observed variation in the disease severity and incidence could be due to different host genotypes, OLCD isolates and biotypes of the species of the vector present. Similar reasons were assigned to the variation Tomato yellow leaf curl virus (TYLCV) among tomato genotypes tested by (Azizi *et al*, 2008). Plant characteristics also known to affect vector population hence disease severity and incidence as observed at Mohamet Lawan College of Agriculture Farm. Asare-Bediako (2017) found the changes in host environment and disease ecology are key to creating novel transmission pattern.

It was further revealed that all the okra cultivars were found to be susceptible to OLCV, although variation in the levels of incidence and severity were evident during the trial period. An incidence of 93% was observed on cultivar Jokoso at the University of Maiduguri Teaching and Research Farm. This finding is in agreement with the work of Asare-Bediako (2017) who observed that all the okra genotypes tested in both rainy and dry seasons were susceptible to the infection. The study also revealed that all the okra cultivars screened in both the locations were susceptible to OLCD and severe symptoms of the infection were observed in both the locations. This was also reported by (Ghanem, 2003) where he observed from his study of okra cultivars both at green house and commercial field in Saudi Arabia with a severe symptom of the OLCV disease. Such symptoms induced by whitefly have been described on cotton in Egypt (Biggare *et al*, 2001), on okra in Pakistan (Mansoor *et al*, 2001). As such, cultivar Mai Malafa, NH AE 47-4, Ex Samara and Kousko with relatively mild symptoms of the infection at Mohamet Lawan College of Agriculture farm but records relatively higher at the University of Maiduguri Farm during the trial period. This implies that their mode of resistance was not stable though influenced by the prevailing environmental condition and the presence of the whitefly vector and its corresponding virus isolates or variants. This is due to the interaction of the host plant and the vector and as well as the environment (Barrett *et al*, 2008). Changes in the host-environment and disease ecology are the key to creating favorable environment for transmission pattern. The role of environmental factors such as temperature and humidity in virus survival and transmission, seasonality in abundance and distribution of the whitefly vector could account for relatively higher disease incidence and severity during the trial season. Among the okra cultivars with mild disease incidence and severity symptoms of OLCD had the highest mean number of fruits and yield per hectare. This suggests that cultivar Klemson spineless, and Yar Syria and Kousko were tolerant to OLCD infection, on the contrary, Ex Basawa, Yar Balla, Mai Malafa, and Chalawa even though demonstrated severe symptom though indicating that they were also tolerant to OLCD infection. The yield was higher at University of Maiduguri Teaching and Research Farm than College of Agriculture were obtained by the cultivars. Similar results were obtained by Mishra *et al*. (2001), Marthin and Rhodes (1999) that pod weight of okra varied among different varieties of okra. Thus, OLCD resistance in the cultivars is not complete but can be influenced by the environmental factors. However, cultivar Maimalafa with relatively low vector population but with high disease incidence, while Jokoso with relatively high vector population records the highest percentage disease incidence and relatively high disease severity though statistically insignificant from all the cultivars screened.

CONCLUSION

The present study documents that OLCD is a serious threat to okra production in Maiduguri and happen to occur in all okra growing areas. It poses a serious threat to okra production. Among the various varieties screened, NH AE-47, and Klemson spineless were found to be moderately susceptible to the infection while Jokoso, Ex Samara 5, Ex Baswa, Yar Balla, Mai Malafa, Yar Syria, Kousko and Chalawa were Highly Susceptible at University of Maiduguri Teaching and Research Farm. Similar trend were observed at Mohamet Lawan College of Agriculture with NH AE 47, being Moderately Susceptible and Chalawa Moderately Resistant. The sero-distribution of the pathogen in the study area show functional interaction with varying efficiencies possibly leading to new begomovirus recombination and pseudo-recombinants with component from different host crop formed which may overcome plant resistance and increase the host range of the begomoviruses already existing in the study area. Thus there is a need to come up with further studies on the spread of OLCV, host range as well as molecular characterization of begomovirus to identify the currently circulating OLCV isolates complex as well as possible emergence of new strains with their extended or alternative host characteristics in Maiduguri.

Table 1: Variety Characteristics

Cultivars	Height (CM)	Fruit Type	Maturity Duration days	Varietal Type
NH AE47-4	45	Dark green and spiny	40-50	Resistant to Mosaic Virus
Klemson spineless	55-60	Light green and long	-	High Yield potential
Jokoso	40-50	-	40-50	Susceptible to OLCD
Ex Samara	-	-	-	Improved local (High yield)
Ex-Basawa	-	-	-	Improved local (High yield)
YarBalla	-	-	-	-
Mai Malafa	-	-	-	Local variety
Yar Syria	-	-	-	Local variety
Kousko	45	Long pod	50-55	-
Chalawa	-	-	-	Local variety

Source: Seed Units and stores

Table 2: Effect of Whitefly Population, Incidence, Severity Index of OLCV and Fruit Yield of Okra during 2016 Rainy Season at Teaching and Research Farm, University of Maiduguri

Cultivars	**White Flies Population**			**Disease (%)**	**Severity**	**Disease (%)**	**Incidence**	**Host Reaction**	**Yield (Kg/ha)**
	4WAE	6WAE	8WAE	6WAE	8WAE	6WAE	8WAE	1-7	
NH AE47-4	1.06	1.00	2.46	22.00	39.00	26.66	53.33	MS	213.97[bc]
Klemson Spineless	1.60	1.26	2.93	27.66	37.00	46.66	66.66	MS	559.57[ab]
Jokoso	1.13	1.00	2.66	27.00	50.33	46.66	93.33	HS	119.30[c]
Ex Samara	0.33	0.86	3.13	22.00	46.66	26.66	80.00	HS	164.53[bc]
Ex-Basawa	1.06	1.53	2.20	27.66	43.00	46.66	73.33	HS	164.60[bc]
Yar Balla	0.60	1.00	3.53	22.00	43.00	26.66	86.66	HS	292.17[bc]
Mai Malafa	0.00	0.53	3.06	18.00	43.00	13.33	86.66	HS	308.57[bc]
Yar Syria	0.26	1.46	3.20	23.66	48.33	33.33	86.66	HS	604.87[a]
Kousko	1.13	1.40	2.80	30.33	52.00	73.33	80.00	HS	386.80[ab]
Chalawa	0.93	1.20	2.26	29.66	41.00	53.33	80.00	HS	201.63[bc]
CV	2.56	1.43	1.50	21.78	33.59	69.52	49.34	-	228.47
SE±	0.71	0.40	0.42	6.07	9.37	19.39	13.77	-	63.746

Column means followed by the same letter(s) are not significantly different from one another at p≥0.05 level of probability using Tukey HSD

WAE- Weeks After Emergence

Table 3: Effect of Whitefly population, Incidence, Severity Index of OLCV and Yield on Okra during 2016 Cropping Season at Teaching and Research Farm, Mohamet Lawan College of Agriculture

Cultivars	**Whitefly Population**			**Disease (%)**	**Severity**	**Disease (%)**	**Incidence**	**Host Reaction**	**Yield Kg/ha**
	4WAE	6WAE	8WAE	6WAE	8WAE	6WAE	8WAE		
NH AE47-4	0.46	1.40ab	1.53ab	16.00	29.33	6.66	33.33	MS	90.47[c]
Klemson Spineless	0.60	1.06b	1.80ab	25.66	35.33	33.33	66.66	HS	403.23[a]
Jokoso	0.60	1.60ab	1.73ab	20.00	33.00	20.00	53.33	MS	148.10[c]
Ex Samara	0.13	1.46ab	3.20a	19.66	37.00	13.33	53.33	HS	119.30[c]
Ex-Basawa	0.26	2.40a	1.20b	20.00	33.33	20.00	60.00	MS	98.70[c]
Yar Balla	0.40	1.53ab	1.46ab	22.00	35.00	26.66	66.66	MS	156.33[c]
Mai Malafa	0.26	1.40ab	2.93ab	18.00	54.33	13.33	93.33	HS	279.70[b]
Yar Syria	0.46	1.06b	1.73ab	22.00	43.00	26.66	86.66	HS	279.70[b]
Kousko	0.26	0.86b	2.40ab	18.00	58.00	13.33	93.33	HS	320.87[b]
Chalawa	0.93	1.66ab	1.53ab	24.00	25.66	33.33	40.00	MR	168.73[c]
CV	0.87	1.22	1.82	14.45	32.97	41.99	66.54	-	80.56
SE±	0.24	0.34	0.51	4.03	9.19	11.71	18.56	-	22.47

Column means followed by the same letter(s) are not significantly different from one another at p≥0.05 level of probability using Tukey HSD

WAE- Weeks After Emergence

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