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Epidemiology and Management of Onion Yellow Dwarf Disease in Sudan

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Abstract: The present study investigated the extent of Onion Yellow Dwarf disease (OYD) spread under two types of farming systems using the growing-on method of onion dry bulbs collected from four localities in four different States in Sudan. The study was also intended to assess the influence of isolation distance and wind direction in relation to source of infection on disease incidence and the subsequent plant vigour and bulb yield. In addition, the effect of insecticide spray and plant barrier around onion plots on disease development and virus dissemination were also investigated. These studies were carried out under the natural infection pressure prevailing in the area of experimentation. With regard to the influence of orientation of the test ridges in relation to source of infection (the infector line), OYD disease incidence (60 days after transplanting) was found to be significantly greater in ridges grown down-wind the infector line than in up-wind ridges. It was progressively declining with increasing distance from the infector line. Consequently, the plant vigour and bulb yield were found to be improved significantly in up-wind ridges and as the isolation distance was increased from the infector line. Although, spraying onion plants with Confidor® 200 (a pyrethroid insecticide) caused non-significant reductions of virus (OYDV) incidence, yet it significantly enhanced the plant height and bulb yield. The results also indicated that the plant barrier using corn plants constituted an effective hindrance against OYDV spread. The combination of the barrier and insecticide spray gave the lowest OYDV incidence compared to non-bordered/non-sprayed control plots.

Key words: *Allium cepa*, epidemiology, onion yellow dwarf, plant barrier, pyrethroid

INTRODUCTION

Onion (*Allium cepa* L.) is one of the oldest cultivated vegetables. It has been in cultivation for more than 4000 years (Tackholm and Drar, 1954; Darby *et al*., 1977). It is a member of the Family Alliaceae. Onion is attacked by many serious diseases; one of these is Onion Yellow Dwarf (OYD) disease that is caused by Onion yellow dwarf *potyvirus* (OYDV). In Sudan, the causal virus was isolated for the first time in 1982 (El Hassan and Morgan, 1992). OYD disease is usually very serious and often reaches an epiphytotic level that leads to considerable yield losses (Conci *et al*., 2003). The disease has been reported to cause an injurious and colossal effect on growth of onion plants and consequently on bulb or seed production. Yield losses have been reported to be heavy on dry bulb crop and grave on seed crop. The quality of the bulbs and seeds produced can be significantly affected by infection of mother plants with OYDV.

OYDV is a member of the Family *potyviridae*. OYDV is very restricted in its host range that is mainly limited to several species of *Allium* and *Narcissus*. The virus has a flexuous, rod-shaped particle reported to be between 720-833 nm and 13-16 nm in width (Bos *et al*., 1978). It produces pinwheel and scroll-shaped inclusion bodies that may be seen in ultra thin sections in the electron microscope (Edwardson, 1974). OYDV is transmitted in a non-persistent manner by *Myzus persicae* and several other species of the *Aphididae*. Aphids do not normally colonize onions but during migration, they may briefly land on a plant for feeding probes (Bos, 1976). The virus is maintained by vegetative propagation of infectious plants. OYDV may be transmitted by mechanical inoculation. It is not transmitted by contact between plants, nor by seed, or by pollen (Brunt *et al*., 1990; Abu Bakar, 1997). Leaves of infected onion plants lose their cylindrical shape and become flattened and crinkled. They bend over near the base causing the foliage to lie on the ground, so that the plant looks stunted. The leaves also develop yellowish striping giving the appearance of a parallel mosaic pattern and some leaves may turn almost entirely yellow (Chamberlain, 1954; Morgan, 1987; Gabbani, 2007).

Cultural practices play a crucial role in virus spread and therefore, are often manipulated to achieve some degree of control. Controlling inoculum sources within

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and around the field may offer a direct approach to virus control (Zitter and Simons, 1980). Volunteer crops are important in the perpetuation of virus diseases from one season to the next. Volunteer onions infected with OYDV may constitute, in certain areas, the main overwintering source of the virus. Thus, the incidence of the disease is reduced when the soil is appropriately cultivated or the infected volunteers are rogued before the new crop is planted or emerged (Louie, 1968).

The objectives of this work are: (1) investigate the extent of spread of OYDV in four localities in four different States representing the two main onion cropping systems in Sudan, (2) to study the up-and down-wind spread of OYDV in an epidemiological model under a natural infection pressure and (3) to assess the efficacy of a pyrethroid insecticide alone or integrated with a plant barrier (corn, practical and useful) in the control of OYDV.

MATERIALS AND METHODS

Field experiments were conducted at the Demonstration Farm of the Faculty of Agriculture, University of Khartoum (Latitude 15°:40'N, Longitude 32°:32' E, 280 m above sea level). This locality lies in the semi-arid region with tropical climate and has considerable seasonal variations in both rainfall and temperature.

Survey of onion yellow dwarf disease: A study was conducted in 2008 to determine the extent of OYDV spread in four localities in the States of River Nile, Khartoum, Gezira and Kassala. One thousand onion bulbs (250 bulbs from each locality) were randomly collected from at least three different farmers in each locality after harvest of the previous season's crop. All bulbs were planted in the field (Feb. 2008) in 4 different plots (6.0×5.5 m) designating the four States. Disease diagnosis was based on visual examination of the characteristic foliage symptoms developing in plants three weeks after planting (a hand lens was used to detect the characteristic fine yellow strips appear in the initial stage of infection).

Aphid trapping and incidence of OYDV: The aim of aphid trapping was to find out the correlation between aphid populations and incidence of OYDV in the field of onion where the experiments were conducted. The assessment of aphid populations started in 2008, February and finished at the beginning of April of the year 2008. Aphid populations were sampled by means of circular yellow water pan traps.

Effect of isolation distance, wind direction and insecticide spray on onion yellow dwarf disease incidence: Infected onion plants (120 plants) showing typical OYDV

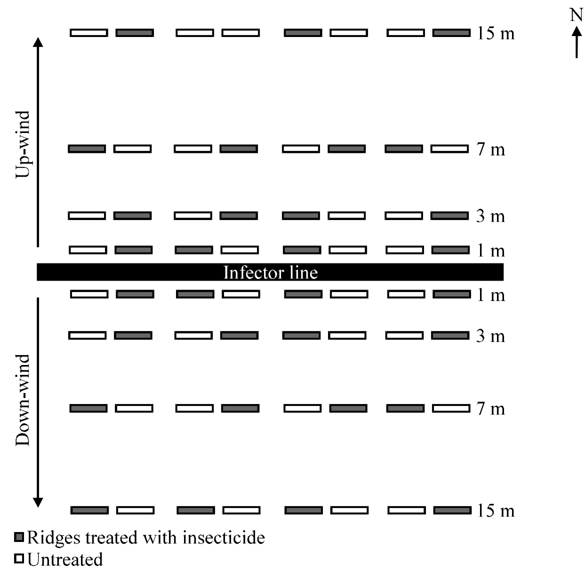

Fig. 1: Diagram representation of the layout of experiment (1)

symptoms were collected from a field of seed crop and transplanted in the middle of the experiment field as an infector line (source of OYDV). Healthy (i.e., were planted in a glass house before the start of aphid flight) onion seedlings (cv. Saggai) were transplanted in parallel ridges located down-wind and up-wind the infector line and spaced at 1, 3, 7 and 15 m, respectively on both directions. There were eight ridges for each isolation distance oriented as shown in Fig. 1. Four randomly selected ridges at each isolation distance were sprayed with the insecticide Confidor® 200 at weekly intervals to a total of ten applications. The four remaining ridges were left untreated. The experiment was left for natural infection pressure and the incidence of OYDV was recorded weekly for each treatment distance depending on visual examination of the characteristic foliage symptoms as shown before.

Effect of plant barrier and pyrethroid treatment on OYDV infection: The treatments consisted of the following plots replicated four times: plots bordered on four sides with one row of corn (*Zea mays*) plants and sprayed at weekly intervals with Confidor® 200. Plots bordered on four sides with corn plants but were not sprayed. Plots treated with Confidor® 200 but without plant barrier. Plots left untreated as control (left without barrier and not sprayed). An infector line (consisting of 20 plants) was planted on the lee side of all treatments replications at 1 m distance from the plots. The incidence of OYDV was recorded weekly depending on visual symptomatology.

RESULTS

Survey of onion yellow dwarf disease: The present study unravelled the current situation of OYDV spread in four different localities in central and eastern Sudan which are practicing two different farming systems of onion production. The areas under late winter farming and at the same time practicing seed onion production (River Nile and Khartoum States) recorded remarkably high disease incidences (64 and 71%, respectively), whereas areas generally practicing no seed onion production and the main season of dry bulb production is autumn (autumn season is known to have little or no vector activity, like in Kassala and Gazira), displayed very low, if any, OYDV infection levels (0 and 4%, respectively).

Effect of vector population on OYDV spread: The correlation between the number of alate aphids and the incidence of OYDV in onion fields during the year 2008 is illustrated in Fig. 2. The aphids flight started in the first week of February, its population increased progressively and then peaked during February 18th to March 11th. The greatest peak of aphid populations occurred during the week ending March 4th. No alatae were caught in the yellow water traps in the week ending April 15th. The disease incidence progressed gradually with time in a sigmoid pattern in response to the increase in aphid populations and activity. It was not until three weeks after aphid populations had reached the peak (877 aphids per trap), the incidence of OYDV increased from 2.8% on March 4th to 18.3 and 24.3% on March 25th and April 8th, respectively.

Effect of wind direction, isolation distance and insecticide spray on onion yellow dwarf disease development: Under natural infection pressure, the effect of isolation distance and wind direction orientation of the test ridges from the source of infection (the infector line) on the spread of OYDV was found to be significantly greater in ridges grown down-wind the infector line than in up-wind ones (Table 1). The virus incidence was also found to be progressively declining with increasing distance from the infector line and the opposite was also true. Onion plants grown furthest (15 m) up-wind the infector line had the lowest OYDV incidence (5.6%) (assessed 60 days after transplanting) while those grown closest (1 m) down-wind had the highest incidence (38.4%) (Table 2). In comparison, the up-wind records were constantly lower than the down-wind data. Thus, the infection gradient was shallow down-wind the infector line compared to the steeper gradient in up-wind direction (Fig. 3).

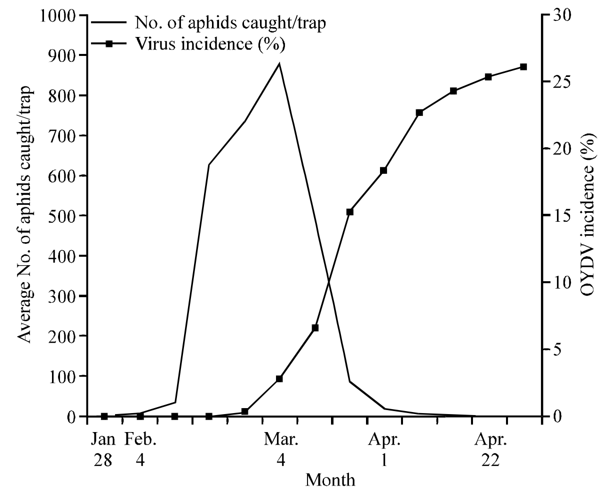

Fig. 2: A disease progress curve of OYDV infection correlated to weakly catches of alate aphids during Jan. 28-Apr. 22, 2008

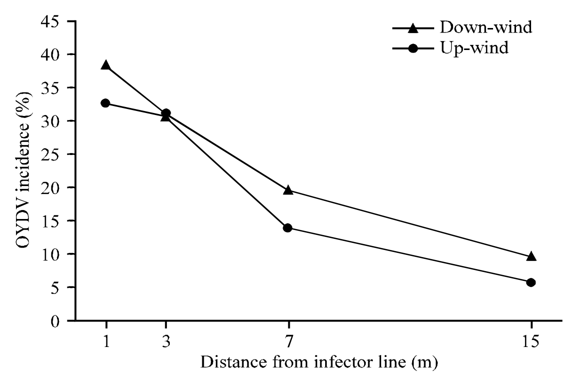

Fig. 3: Infection gradients of onion yellow dwarf virus (OYDV) in test ridges oriented down-wind and up-wind an infector line 60 days after transplanting

The effect of isolation distance of test ridges from OYDV source on total and marketable bulb yield was found to be significant (Table 3). Onion plants grown 15 m up-wind the infector line gave the greatest total bulb yield (3201.9 g ridge^{-1}), followed by those grown at 7 m up-wind (2988.8 g ridge^{-1}) and 15 m down-wind (2944.3 g ridge^{-1}); whereas those located 1 m down-wind produced significantly the least total bulb yield (1833.1 g ridge^{-1}). The inverse relationship between the isolation distance from the infector line and the effect on total bulb yield was evidently clear and it appeared to be more profound on down-wind ridges. Similar results were also recorded for the marketable bulb yield. Significant differences were detected in the yields of large-sized bulbs by ridges spaced at different isolation distances,

Table 1: Effect of orientation of test ridges in relation to the infector line on OYD disease development

Orientation of test ridges	OYD disease incidence (%) at 30 days	60 days	90 days from transplanting	Plant growth: Plant height (cm)	No. of leaves/ plant	Final bulb yield (g ridge^{-1}): Total bulb yield
Down-wind	3.86^a	24.61^a	28.05^a	42.84^a	9.41^a	2423.91^b
Up-wind	1.71^b	20.70^b	24.06^b	45.25^a	10.13^a	2819.36^a
LSD 5%	0.99	2.47	2.17	2.68	0.70	157.89
LSD 1%	1.33	3.32	2.92	3.61	0.94	212.64

Values followed by the same letter (s) within a column do not differ significantly according to Duncan's Multiple Range Test at the 5% level

Table 2: Effect of isolation distance from OYDV source on disease incidence and plant growth

Isolation distance from infector line (m)	OYDV incidence (%) at 30 days	60 days	90 days from transplanting	Plant growth: Plant height (cm)	No. of leaves/plant
Down-wind					
1	7.81^a	38.44^a	40.31^a	38.88^c	9.86^b
3	4.70^b	30.63^b	34.06^b	41.19^c	8.81^b
7	1.91^c	19.69^c	23.13^c	43.25^{abc}	9.00^b
15	1.00^c	9.69^{de}	14.69^d	48.06^a	9.94^b
Up-wind					
1	5.01^b	32.50^b	37.50^{ab}	42.81^{bc}	9.81^b
3	1.01^c	30.94^b	34.69^b	43.50^{abc}	9.44^b
7	0.40^c	13.75^d	15.31^d	47.13^{ab}	9.75^b
15	0.40^c	5.63^e	8.75^e	47.56^{ab}	11.50^a
LSD 5%	1.97	4.93	4.33	5.37	1.40
LSD 1%	2.65	6.64	5.84	7.23	1.89

Values followed by the same letter (s) within a column do not differ significantly according to Duncan's Multiple Range Test at the 5% level

Table 3: Effect of isolation distance from OYDV source (i.e., infector line) on final onion bulb yield

Isolation distance from infector line (m)	Final bulb yield (g/ridge): wt. of large-sized bulbs	wt. of medium-sized bulbs	Marketable yield	Total bulb yield
Down-wind				
1	380.63^e	1277.50^{cd}	1658.13^e	1833.13^e
3	856.25^d	1505.63^{ab}	2361.88^d	2435.00^d
7	943.75^{cd}	1475.00^{bc}	2418.75^{cd}	2483.13^{cd}
15	1168.75^{bc}	1683.75^a	2852.50^b	2944.38^{ab}
Up-wind				
1	1275.00^b	996.25^e	2271.25^d	2325.00^d
3	1275.00^b	1412.50^{bcd}	2361.88^d	2761.88^{bc}
7	1725.00^a	1225.00^d	2950.00^{ab}	2988.75^{ab}
15	1587.50^a	1581.25^{ab}	3168.70^a	3201.88^a
LSD 5%	280.64	198.70	316.13	315.79
LSD 1%	377.94	267.60	425.73	425.28

Values followed by the same letter (s) within a column do not differ significantly according to Duncan's Multiple Range Test at the 5% level. Large-sized bulbs≥60 mm in diameter, Medium-sized bulbs = 35-59 mm in diameter. Marketable bulb yield = weight of large-sized bulbs+medium-sized bulbs

indicating an inverse relationship which was also more evident on the down-wind direction. The closest ridge to the infector line on the down-wind side gave significantly the least large-sized bulb yield (380.6 g ridge^{-1}). Significant differences were also detected on the yields of medium-sized bulbs produced by ridges spaced at different isolation distances from the infection source. Greater yields of medium-sized bulbs were produced by ridges located at 15 m on either sides of the infector line (down-wind 1683.8 g ridge^{-1}, up-wind 1581.3 g ridge^{-1}), whereas the least yield (996.3 g ridge^{-1}) was obtained by the ridge spaced 1 m up-wind the virus source (Table 3).

Application of insecticide (Confidor® 200) had no significant effect on OYDV incidence assessed 30, 60 and 90 days after transplanting. Virus incidences recorded in the above mentioned dates were, respectively 2.78, 21.56 and 25.63% in the treated ridges and 2.79, 23.75 and 26.48% in the control ridges (Table 4).

Effect of plant barrier and pyrethroid application on OYD disease development: The results on the efficacy of plant barrier and insecticide application (Confidor® 200) in controlling OYDV are presented in Table 5. Although, there were no significant differences between treatments at 30 days after transplanting, incidence of OYDV was

Table 4: Effect of pyrethroid application (Confidor® 200) on OYD disease development

	OYDV incidence % assessed 30, 60 and 90 days after transplanting			Plant growth		Final bulb yield (g/ridge)
Insecticide treatment	30	60	90	Plant height (cm)	No. of leaves/ plant	Total bulb yield
Sprayed	2.78^{a}	21.56^{a}	25.63^{a}	45.41^{a}	9.63^{a}	2940.78^{a}
Non-sprayed (control)	2.79^{a}	23.75^{a}	26.48^{a}	42.69^{b}	9.91^{a}	2302.50^{b}
LSD 5%	0.99	2.47	2.17	2.68	0.70	157.89
LSD 1%	1.33	3.32	2.92	3.61	0.94	212.64

Values followed by the same letter (s) within a column do not differ significantly according to Duncan's Multiple Range Test at the 5% level

Table 5: Effect of plant barrier (corn plants) and pyrethroid application (Confidor® 200) on OYDV incidence

	OYDV incidence (%) at 30 days from transplanting				OYDV incidence (%) at 60 days from transplanting		
	Pyrethroid application				Pyrethroid application		
Barrier treatment	P_1(%)	P_0(%)	Barrier mean (%)	Barrier treatment	P_1 (%)	P_0 (%)	Barrier mean (%)
B_1	2.88	2.50	2.69^{a}	B_1	8.75	9.63	9.19^{a}
B_0	4.38	4.25	4.31^{a}	B_0	11.50	13.63	12.57^{b}
Spray mean	3.63^{a}	3.38^{a}		Spray mean	10.13^{a}	11.63^{a}	
LSD 5% (barrier) = 2.61				LSD 5% (barrier) = 3.31			
LSD 5% (insecticide) = 1.77				LSD 5% (insecticide) = 2.45			

Values followed by the same letter (s) within a column do not differ significantly according to Duncan's Multiple Range Test at the 5% level. B_1 = Test plots were bordered with corn plants, B_0 = Test plots were left without plant barrier, P_1 = Test plots were sprayed with pyrethroid insecticide (Confidor® 200), P_0 = Test plots were not sprayed with pyrethroid

Table 6: Effect of plant barrier (corn plants) and pyrethroid application (Confidor® 200) on number of leaves and total bulb yield growth in onion plots exposed to onion yellow dwarf virus (OYDV) natural infection pressure

	No. of leaves/plant				Total bulb yield (g/plot)		
	Pyrethroid application				Pyrethroid application		
Barrier treatment	P_1	P_0	Barrier mean	Barrier treatment	P_1	P_0	Barrier mean
B_1	9.75	7.25	8.50^{a}	B_1	4437.5	2825.0	3631.3^{a}
B_0	8.50	6.75	7.63^{a}	B_0	3825.0	2712.5	3268.8^{a}
Spray mean	9.13^{a}	7.00^{b}		Spray mean	4131.3^{a}	2768.8^{b}	
LSD 5% (barrier) = 2.28				LSD 5% (barrier) = 1097.72			
LSD 5% (insecticide) = 2.05				LSD 5% (insecticide) = 827.46			

Values followed by the same letter (s) within a column do not differ significantly according to Duncan's Multiple Range Test at the 5% level. B_1= Test plots were bordered with corn plants, B_0= Test plots were left without plant barrier, P_1= Test plots were sprayed with pyrethroid insecticide (Confidor® 200), P_0= Test plots were not sprayed with pyrethroid

lesser in onion plants which were both bordered with corn and sprayed with Confidor® 200 compared to non-bordered and non-sprayed ones. At 60 days after transplanting, onion plants bordered with corn recorded significantly lower incidence mean (9.19%) compared to the non-bordered plants (12.57%). The combined treatment of the barrier and insecticide spray recorded the lowest virus incidence (8.75%), while the non-bordered/non-sprayed treatment (control) had the highest incidence (13.63%).

A significant difference was obtained between means of spray treatments concerning number of leaves per plant. Sprayed and non-sprayed plants gave 9.13 and 7.00 leaves/plant, respectively. The combination of corn barrier and pyrethroid spray produced the greatest number of leaves per plant (9.75). Furthermore, the combined effect of both treatments produced the greatest total bulb yield (4437.5 g $plot^{-1}$) (Table 6).

DISCUSSION

The high levels of OYDV infection in Khartoum and River Nile States could be ascribed mainly to the cropping pattern followed at these localities since late winter crops coincide with abundant and high activity of aphids vector flight in presence of a primary source of infection represented by strips of infected seed crop. On the other hand, the low level or absence of infection in bulbs collected from autumn crops grown in Gezira and Kassala State could be attributed to absence or scarcity of the primary source of infection and/or limited vector activity, if not complete absence of the vector responsible for secondary virus spread.

The study demonstrated that the aphid flight started in the first week of February and the greatest peak of aphid populations occurred during the week ending March 4th. The rapid decrease in numbers of alatae after

11th March is attributed to the onset of warm temperatures. The virus incidence assessed concomitantly with aphid population counts indicated that the incidence of OYDV progressed exponentially from 2.8 to 18.3% in response to aphid flight with a time lag of three weeks which seems to represent the incubation period. Such results are in agreement with previous study which recorded that increments of OYDV incidence appeared to correspond to increases in the counts of individual aphid species caught on yellow water pan traps (Salih, 1990).

The effect of isolation distance and wind direction orientation of the test ridges from the infector line on the spread of OYDV was found to be significantly greater in ridges grown down-wind the infector line compared with those grown up-wind. The plausible explanation for this may reside in the fact that at wind speeds that are above the flight speeds of aphids, the insects would be carried in the direction of the wind or at a tangent to it (Johnson, 1969). So, wind may facilitate aphids movement while the up-wind movement of aphids is somewhat hindered. The high incidence of virus noticed down-wind is understandable. However, several investigators have observed that under controlled conditions in a flight chamber, some aphids may fly against the wind until they are carried against screens in the chamber or out of the experimental arena (Kring, 1967). This explains the data on OYDV incidence observed in this study even at 15 m up-wind the infector line. On the other hand, the improved plant vigour and consequently the significant increase in bulb yield can be ascribed to the profound reductions in infection levels with increased isolation distances from the inoculum source and this is conceivable since the virus has a crippling effect on diseased plants.

The results revealed that spraying onion plants with Confidor® 200 (a pyrethroid insecticide) caused non-significant reductions of OYDV incidence. This could be due to the inefficiency of insecticidal spray in controlling viruliferous aphids carrying non-persistent viruses because the restlessness of the sprayed prey will make it accomplishes several brief probe-feeds before the final knock-down (Haim and James, 1990). Conversely, the insecticide treatment significantly improved the plant vigour and onion bulb yield. This could be explained through the non-specific effect of the insecticide on the general insect pest status.

The experiment on the efficacy of plant barrier and insecticide application in controlling OYDV indicated that the plant barrier using corn was an effective check against the virus dissemination which significantly reduced the disease incidence (assessed 60 days after transplanting), whereas non-bordered plots had the highest incidence. The combination of the barrier and insecticide spray was superior and reduced OYDV incidence by ~36% compared to non-bordered/non-sprayed control plots. Such results are in agreement with earlier findings of Salih (1990) who reported that corn barrier alone or combined with oil spray will be useful in controlling OYDV. Other workers reported similar results indicating the effectiveness of using non-host crops as barriers in reducing spread of many insect-transmitted viruses (Simons, 1957, 1960). The plausible explanation of these results resides on the fact that incoming viruliferous aphids loose the non-persistently transmitted virus during their brief probes on a plant barrier. The contribution of the insecticide in enhancement of the plant vigour was noticeably higher than the influence of the plant barrier and this could again be attributed to the specific and non-specific effect of the insecticide on the viruliferous aphids and the general insect pest situation. Consequently, the bulb yield was significantly improved.

CONCLUSION

Two significant perspectives emerge from the study. Firstly, OYDV in Sudan appears to be manageable by sanitation since the cropping pattern, manipulations of source of infection and vector avoidance can bring about profound reductions in disease incidence and consequently significant enhancement of plant growth and crop yield. Secondly, it appears that Kassala area which is one of the main onion producing regions of Sudan, and other small areas in the different States resembling Kassala in the farming system can serve as infection-free zones to help eliminate the virus.

The major future prospective stems from the fact that OYDV in Sudan possesses a weak epiphytotic cycle and therefore can easily be eliminated. Using Kassala area as a national focal point for production of virus-free bulbs will constitute the nucleus for clean seed production and certification programs. This national project is envisaged to eliminate OYDV from the country in few to several years.

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