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EFFECTS OF FEEDING BY WHITEFLY *BEMISIA TABACI* (GENN.) ON BRINJAL AND ITS MANAGEMENT USING *CITRUS AURANTIUM* EXTRACTS

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ABSTRACT

This study examined the extent of damage caused by *Bemisia tabaci* (Genn.) on brinjal and the effects of citrus extracts in managing the menace using randomized block design during the 2022 and 2023 cropping seasons. The variety examined was highly susceptible with plants in T_3 being the most affected. Citrus extracts differed significantly ($p \leq 5\%$) with its essential oil (30 ml/ l) being the most effective. The extracts are recommended to be incorporated in *B. tabaci* management practicesof brinjal.

Key words: Leaf damage, brinjal, cost-effective, ecofriendly *Bemisia tabaci,* sap sucking pests, *Citrus aurantium*, pest control, susceptible, infestation, management, Nigeria

Brinjal (*Solanum melongena* L.) is an important vegetable (Anjorin et al., 2013; Chapman, 2019; Naem and Ugur, 2019). *Bemisia tabaci* is highly destructive insect pest that feeds on the phloem sap of vegetable plants, causing a range of damaging effects including reduction in plant transmission of harmful viruses (Sani et al., 2020; Ugwu et al., 2021). They also release honeydew, which lead to the development of sooty mold that blackens the leaves and affect the crop photosynthetic ability (Solanki et al., 2018; Perring et al., 2018). There is heavy reliance on synthetic pesticides for *B. tabaci* control, but the use of these chemicals posed a great health and environmental hazards and can lead to development of resistance (Shah et al., 2019; Abubakar et al., 2022). The development of safer and cost-effective alternatives for managing *B. tabaci* is therefore of utmost importance. Plant-based extracts have emerged substantial in this regard as they have been proven effective in reducing the density *B. tabaci* on various agricultural crops (Hussein et al., 2017; Kumar et al., 2019; Farina et al., 2022). There is little information on the extent of damage due to *B. tabaci* infestation, and the use of citrus extracts for its management, specifically on the green round brinjal cultivar, in Kebbi State, Nigeria. Previous studies have focused more on the effects on the physiological and biochemical parameters, neglecting the cumulative effects of infestation on plant growth (Li et al., 2013; De Lima Toledo et al., 2021). Understanding the level of leaf damage caused is crucial and these along with plant based products of evaluated will provide cost-effective strategies. This study therefore aims to assess the extent of damage due to *B. tabaci* infestation on the green round brinjal cultivar and to evaluate the potential of *C. aurantium* essential oil extracts for its management.

MATERIALS AND METHODS

This study was carried out in the Agricultural Research Farm of the Kebbi State University of Science and Technology, Aliero, Kebbi State, Nigeria 12° 13' 19.88"N 4° 22' 46.67'E from December to May, during the 2022 and 2023 cropping seasons. The variety used was the green round brinjal cultivar, being the most cultivated in the area for which seeds were procured from Afrimash Company Limited, Ibadan, Nigeria. The seedlings were raised using portable sunken nursery beds Ghosh (2022). Randomized block design (RBD) consisting of four plots and treatments (T1= 15, T2= 30, T3= 45 and T4= control with 0 whiteflies/ plots) replicated four times was used to assess the damage caused. Each plot measuring 1x $1m^2$ (covered with mosquito nets) with 0.5 m space between the plots was transplanted with three seedlings at 60x 60 cm spacing. The required number of *Bemicia tabaci* for each plot was counted as they were caught from the vegetables using aspirator and released into the demarcated plots. The damage assessment was done following the method of (Anjorin et al., 2013; Oso and Borisade, 2017). The RBD was also used to determine the efficacy of the *C. aurantium* extracts against *Bemisia tabaci* on the crop under field conditions. The trial consists of ten (10) experimental plots measuring 3x 3m^2, separated by 0.5 m and replicated three times. Twenty five (25) seedlings were transplanted in each plots at 60x 60 cm spacing and the recommended agronomic practices were followed (Rahman et al., 2015). The plant materials (citrus fruits) and essential oil (100% pure steam distilled) were procured from local markets. The aqueous extract was prepared following (Al-Manhel and Niamah (2015); fermented botanicals extract (FBE) was prepared by adopting Khadem et al. (2022); while the essential oil emulsion was prepared following Kumar et al. (2019). All the treatments (T_1 -T_3: citrus aqueous extract at 100, 150 and 200 ml/ l, T_4-T_6: citrus fermented extract at 100, 150 and 200 ml/ l, T_7 to T_9: citrus essential oil at 10, 20 and 30 ml/ ℓ, and T_{10}: Normal tap water at 1.2 l/ plot) were sprayed thrice on the leaves (covering upper and lower surfaces of the leaves) at an interval of two weeks using 15 ℓ Knapsack sprayer (MT-107, China). The data analysis was done in OPSTAT software using ANOVA and means separated using critical difference C D, p=5%.

RESULTS AND DISCUSSION

Symptoms related to *B. tabaci* infestation were observed especially those symptoms that led to leaf damage (%) with the treatments differing significantly from week 3 to 12 during the 2022 and 2023 cropping seasons. The highest effects (85.80 and 88.00%) were recorded with plant in T_3 at week 12 while the least (0.3 and 0.2%) were recorded with plant in T_1 at week 2 and 3, respectively during 2022 and 2023. Based on the visual rating scale, all treatments were under scale 1 (0-20%), 4 weeks after infestation. At week 8, plant in T_1 showed the least effects falling in scale 1 while those T_3 recorded the highest effects being on scale 3 during the 1st and 2nd year trials. The severity increased at week 12 after infestation, with plants in T_2 and T_3 being the most affected falling in scale 5 (81-100%) (Table 1). These findings demonstrated that *B. tabaci* feeding negatively affects the brinjal leaves morphology causing various infestation symptoms including leaf chlorosis, distortion, stunting, leaf holes, yellowing, darkening, honey dew deposition and sooty mold development. These symptoms development were observed to be gradual with leaf wilting and yellowing being the early symptoms while honey dew deposition and leaf darkening as the later symptoms. It was observed that plants in T_3 were the most affected with those in T_1 being the least affected while those in the control plots (T_4) remained healthy. This signified that the effects observed were density dependent. Similarly, the cumulative effects and the leaf damage (%) were observed to be very low during the first thirty days after infestation. However, at sixty days it becomes severe with most of the leaves in the treated plots becoming crumbled, dehydrated, and nutrients deficient. Previous studies showed that *B. tabaci* infestations had led to various symptoms similar to what has been reported herein (Li et al., 2013; Abubakar et al., 2022; farina et al., 2022).

Table 1. Effect of *B. tabaci* infestation and leaf damage (%) in brinjal

Treatments	Data record periods												
	48 hr	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12
2021/ 2022													
T1	0.0a	0.0a	0.3a	0.0b	0.8b	1.6c	3.1b	6.0c	11.0c	22.0c	37.9c	43.9c	69.2c
T2	0.0a	0.0a	0.5a	1.6a	5.2a	4.0b	5.7b	12.7b	26.4b	40.1b	65.2b	64.8b	80.0b
T3	0.0a	0.0a	1.4a	4.4a	7.7a	7.9a	10.3a	29.3a	44.4a	63.9a	76.2a	84.1a	85.8a
T4	0.0a	0.0a	0.0a	0.0b	0.5b	1.0c	0.3b	0.1b	0.9d	1.1d	0.9d	2.3d	2.2c
C.D	0.0	0.0	0.0	2.9	3.2	1.9	1.0	1.4	2.5	5.6	4.8	5.4	2.5
SEM±	0.0	0.0	0.5	0.2	0.1	0.6	0.3	0.4	0.8	1.7	1.5	1.7	0.8
2022/ 2023													
T1	0.0a	0.0a	0.0a	0.2b	1.3b	2.6b	5.3c	6.8c	12.3b	25.4c	40.5c	49.2c	66.6b
T2	0.0a	0.0a	0.0a	0.7a	6.2a	4.0b	8.1b	15.8b	23.6b	43.4b	59.3b	69.4b	81.3a
T3	0.0a	0.0a	0.0a	1.4a	9.2a	9.7a	15.1a	27.9a	46.8a	69.8a	81.1a	85.4a	88.0a
T4	0.0a	0.0a	0.0a	0.0b	0.3b	1.3c	1.0d	1.1d	2.2c	2.9d	2.2d	4.4d	3.8c
C.D	0.0	0.0	0.0	0.7	1.3	2.6	1.2	3.0	16.1	9.8	5.3	4.6	8.9
SEM±	0.0	0.0	0.0	0.2	0.4	0.7	0.4	0.8	4.9	3.0	1.6	1.4	2.7

Means with same common letter in same column not significantly different from each other ($p < 0.05$). Keys: DAS = Days after the spray, % = Percentage, C.D = Critical difference, SEM = Standard error means, W = week, hr = hour; for T_1 to T_{10} refer Materials and Methods

The effects of *C. aurantium* extracts against the *B. tabaci* during the two year trials are presented in Table 2. The results differed significantly in both the cropping seasons. The maximum effects (15.5 and 15.3 *B. tabaci*/ leaf) were recorded with the essential oil (30 ml/ l) followed by fermented extracts (200 ml/ l) (17.8 and 16.1 *B. tabaci*/ leaf) while the least were found in aqueous extracts (100 ml/l) (29.8 and 31.3 *B. tabaci*/

Table 2. Effect of citrus extracts against the *B. tabaci* on brinjal

Treatments	*B. tabaci* number/leaf 2022					*B. tabaci* number/leaf 2023				
	1st spray									
	1DAS	3DAS	5DAS	7DAS	15DAS	1DAS	3DAS	5DAS	7DAS	15DAS
T1	40.7 a	34.0 b	31.9 b	26.5 b	29.8 b	36.8 a	32.5 a	31.8 a	29.8 a	31.3 a
T2	36.8 b	31.7 b	28.2 b	23.5 c	24.7 b	32.6 b	27.9 a	26.2 b	23.9 a	22.8 b
T3	35.6 b	28.8 c	24.4 c	23.6 c	25.0 b	32.5 b	28.2 a	27.1 b	24.3 a	21.0 b
T4	33.5 b	26.9 c	25.9 c	20.6 c	22.0 c	29.1 c	27.9 a	25.6 b	23.2 a	21.6 b
T5	30.6 c	23.2 d	21.3 d	18.4 d	18.8 c	28.4 c	23.0 b	21.2 c	19.7 b	16.9 c
T6	29.3 c	21.5 d	19.3 d	17.7 d	17.8 c	27.6 c	22.9 b	20.5 c	17.1 b	16.1 c
T7	37.7 b	34.1 b	30.1 b	28.9 b	27.9 b	33.7 b	27.5 b	22.7 b	21.3 b	23.9 b
T8	35.0 b	29.7 c	26.7 c	24.8 c	24.7 b	30.7 b	25.1 b	22.8 b	19.9 b	18.7 b
T9	29.5 c	26.8 c	24.1 c	23.8 c	15.5 d	26.6 c	22.9 b	21.4 c	16.6 b	15.3 c
T10	41.7a	40.8 a	39.0 a	37.3 a	36.7 a	39.5 a	33.4 a	34.2 a	30.2 a	33.4 a
SEM±	1.3	0.9	1.0	1.3	1.5	1.5	1.9	1.5	2.4	2.2
C.D (p=0.05)	3.9	2.9	2.9	3.8	4.5	4.4	5.6	4.5	7.3	6.7
	2nd spray									
T1	21.2 b	15.6 b	10.6 b	14.1 b	15.1 b	25.8 b	19.5 b	16.7 b	17.0 b	14.1 c
T2	25.8 b	12.2 c	9.9 b	13.8 b	14.0 b	20.5 b	16.2 b	14.5 b	12.5 b	11.3 d
T3	20.9 b	10.2 c	9.1 b	8.9 c	9.3 c	19.2 c	15.9 b	11.8 c	9.4 c	7.4 e
T4	16.7 c	10.3 c	7.7 b	5.7 d	6.8 d	19.7 c	17.4 b	13.3 c	12.2 b	17.5 b
T5	15.6 c	6.1 d	8.9 b	4.2 d	7.9 c	14.0 d	11.1 d	9.0 d	7.5 c	7.4 e
T6	14.2 c	4.6 d	5.4 c	6.9 d	7.4 c	13.5 d	9.7 d	6.3 d	5.7 c	6.9 e
T7	24.6 b	13.4 b	14.4 b	11.6 b	15.6 b	21.3 b	17.1 b	16.1 b	14.3 b	12.3 c
T8	23.5 b	10.2 c	10.7 b	10.8 b	9.6 c	16.4 c	14.4 c	12.0 c	10.1 c	10.4 d
T9	16.0 c	9.3 c	5.4 c	3.2 c	6.4 d	12.6 d	8.2 d	6.7 d	5.5 c	4.7 f
T10	37.1 a	34.5 a	32.2 a	36.4 a	24.8 a	31.4 a	27.7 a	32.4 a	28.9 a	28.5 a
SEM±	1.2	0.9	1.3	0.8	0.8	1.8	1.1	0.8	1.9	0.7
C.D (p=0.05)	3.7	2.6	3.8	2.4	2.6	5.4	3.2	2.5	5.6	2.1
	3rd spray									
T1	8.3 b	8.7 b	7.8 b	9.8 b	8.7 c	12.7 b	11.5 b	10.5 b	6.8 c	10.1 b
T2	5.2 c	6.8 c	5.3 c	4.9 c	3.6 d	10.5 b	8.5 b	7.5 b	7.4 c	6.6 c
T3	7.8 c	3.4 d	5.2 c	6.3 c	8.5 c	5.1 c	3.7 d	3.8 c	2.8 d	3.4 d
T4	5.4 c	7.5 b	4.9 c	2.2 d	4.7 d	10.4 b	7.8 c	8.2 b	12.4 b	5.8 c
T5	3.5 d	1.7 d	3.4 c	2.6 d	3.4 d	8.7 b	6.5 c	5.0 c	6.8 c	6.8 c
T6	3.3 d	2.6 d	2.0 d	2.9 d	3.7 d	5.3 c	4.0 d	3.4 c	2.5 d	2.2 d
T7	11.4 b	5.6 c	8.4 b	9.1 b	12.2 b	11.2 b	9.4 b	7.4 b	7.4 c	7.8 b
T8	5.1 c	4.5 c	5.3 c	3.3 d	5.9 d	8.9 b	7.6 c	5.9 c	3.1 d	2.7 d
T9	5.7 c	1.4 e	3.1 d	1.6 d	3.3 d	3.6 c	2.5 d	3.4 c	2.1 d	1.9 d
T10	33.5 a	26.7 a	25.8 a	24.3 a	26.6 a	29.7 a	31.4 a	32.1 a	31.5 a	33.0 a
SEM±	1.1	0.6	0.7	0.6	0.8	1.4	1.2	1.0	0.9	0.8
C.D (p=0.05)	3.3	1.8	2.0	1.7	2.3	4.3	3.5	3.1	2.7	2.4

Means with same common letter in same column not significantly different from each other ($p< 0.05$). Keys: DAS = Days after the spray, % = Percentage, C.D = Critical difference, SEM = Standard error means; for T_1 to T_{10} refer Materials and Methods leaf) at 15 days after the 1st spray. The essential oils (15 ml/ l) remained the most effective (6.4 and 4.7 *B. tabaci*/ leaf) while the aqueous extract was the least effective recording (15.6 and 14.1 *B. tabaci*/ leaf) 30 days after 2nd spray. Similar results were recorded after the 3rd spray with the essential oil (30 ml/ l) being the most effective (3.3 and 1.9 *B. tabaci*/ leaf) while the aqueous extract (100 ml/ l) remained the least effective with (12.2 and 10.1 *B. tabaci*/ leaf) 45 days after the 3rd spray. The biopesticide properties of *C. aurantium* like other aromatic plants have been attributed to the presence of some bioactive compounds like limonene, α-pinene and β-myrcene, which have been found to have insecticidal effects (Showler et al., 2019; Langsi et al., 2020; Sun et al., 2020; Kumar et al., 2021). The *C. aurantium* extracts have different degree of effectiveness depending on the type of extract (aqueous, fermented or essential oil), number of sprays, and dosage used. The essential oils were more effective while the aqueous extracts were the least, and all the extracts were observed to have higher effects with the increase in dosage. The results indicate that most of the treatments were more effective during first five days, and later tends to decrease (15 days) after each spray. Several report from the previous works (Pumnuan et al., 2017; Kumar et al., 2019) have demonstrated the effectiveness of essential oils to cause 42.8 to 100% *B. tabaci* mortality. The effectiveness of fermented botanical extracts against the sap-sucking pests had been reported (Nzanza and Mashela, 2012; Baloc et al., 2013; Ayub et al., 2021). Tembo et al. (2018); Okolo and Iludum (2019) and Fabrick et al. (2020) have revealed the effects of the aqueous plant extracts against sap-sucking pests.

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AUTHOR CONTRIBUTION STATEMENT

All authors contributed equally.

CONFLICT OF INTEREST

No conflict of interest.

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