PRESENCE PERIOD AND SPATIAL DISTRIBUTION OF DOMINANT INSECTS ASSOCIATED WITH WATERMELON USING LLOYD'S INDEX OF PATCHINESS AND GREEN'S COEFFICIENT OF DISPERSION

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Abstract: The mean population densities of dominant insects (pest and beneficial) associated with watermelon (*Citrullus lanatus* Thunb.) in a field experiment conducted in 2016 early- and late-season were subjected to statistical models to determine the average relative length of their presence period (ARLPP) and spatial distribution pattern **(**using Lloyd's index of patchiness [m^*/m] and Green's coefficient of dispersion [C_x]**)**. The ARLPP ranged from 41.67 – 66.67% with pest species/taxa having overall slightly higher values of 62.50 and 59.38% on early- and late-crop, respectively vis-à-vis 59.52 and 54.76% for beneficial species. But for *Camponotus* sp. on the seedling stage of early-crop, all the other dominant insects had m^*/m values > 1 which indicates aggregated dispersion. Similarly, aside *Camponotus* sp. with C_x value of -0.050, all the other dominant insects had values that ranged from 0.001 – 0.466 indicating that the aggregation were weak since maximum clumping is 1. Even though the results from the dispersion models herein used corroborates previous results on this same study which used other models **(**variance to mean ratio [S^2/m], Taylor's power law [$S^2 = am^b$] and Iwao's patchiness regression [$m^* = \alpha + \beta m$]**)**, we recommend validation of the results on large field trials and with different varieties.
Keywords: Green's coefficient of dispersion, Lloyd's index of patchiness, Presence period, spatial distribution, Watermelon.

Introduction

Spatial distribution is an important ecological attribute of arthropod populations as it enables us to characterize them. It is a behavioral response of individuals of a species to the interactions of complex biological and environmental factors in a given habitat (Sevacherian and Stern, 1972; Steffy, 1979; Arbab and Bakry, 2016). Arthropods have been shown to follow three (3) dispersion/spatial distribution patterns: binomial (regular), poisson (random) and negative binomial (aggregated/contagious) (Southwood, 1978; Tirkey and Saxena, 2015). Describing the spatial structure of arthropod populations' vis-à-vis crop species/varieties is important in developing efficient and precise field sampling programs, field monitoring plans, density estimation strategies, population models and ultimately, pest management decisions (Iwao, 1970; Croft and Hoyt, 1983; Taylor, 1984; Tsai *et al.*, 2000; Khaing *et al*., 2002; Arbab and Backry, 2016).

Studies have shown that host plant species and/or varieties influences the distribution and colonization of arthropods (Pires *et al*., 2000; Peruyero and Jones, 2002; Sedaratian *et al.*, 2010; Moradi-Vajargah, 2011). Even though most arthropod species have been reported to exhibit aggregated pattern of distribution (Southwood and Henderson, 2000; Hamilton and Hepworth, 2004; Sedaratian *et al.*, 2010; Darbemamieh *et al.*, 2011; Moradi-Vajargah *et al.*, 2011, Soemargono *et al.*, 2011) and that, the degree of aggregation differ among populations and species (Root and Cappucino, 1992; Soemargono *et al.*, 2011), changes in resource availability and/or scale at which arthropods are viewed have been shown to influence changes/dynamism in the distribution patterns of arthropods (Pedigo and Buntin, 1994).

Dispersion indices enable a researcher to form a tentative view about an organism's spatial distribution pattern (Southwood, 1978) while, linear regression models like Taylor's power law and Iwao's patchiness regression models are commonly used in validating spatial distributions patterns (Wei *et al.*, 2013). However, it has been shown that using both regression models (eg., Taylor's and Iwao's) in validating spatial distribution of an arthropod is more advantageous as a species may vary from time to time such that different mathematical models fit better on different occasions (Iwao, 1970; Okrikata *et al*., 2019).

The spatial distribution pattern of a prey can determine the distribution pattern of its natural enemy hence, natural enemies and prey populations monitoring is an important component of integrated pest management (IPM) (Kalsi *et al.*, 2014). Information on spatial distribution pattern of prey and their natural enemy species has also been shown to be critical in assessing the potential of natural enemy species in checking prey populations (Slone and Croft, 1998; Darbemamieh *et al.*, 2011), establishing pest levels justifying control measures and, in choosing bio-control and other IPM techniques (Arnaldo and Torres, 2005; Kavallieratos *et al.*, 2005).

An indices related to the spatial distribution which is also important in characterizing a tax on in relation to its habitat/micro-habitat is the presence period. It is one of the indicators of the residency pattern of an arthropod and it defines the interval in which specimens of a given taxon/species are present in the habitat. The length of the presence period is influenced by a number of interacting factors such as trophic preferences, and availability and type of food (Matuszewski *et al*., 2010).

Understanding the spatial and residency distribution patterns of arthropods (pests and beneficials) has been shown to provide a basis for developing crop protection plans (Okrikata *et al.*, 2019). While, many literature shows dearth of information on spatial distribution of arthropods associated with watermelon (Souza *et al.*, 2012; Lima *et al.*, 2014; Alao *et al*., 2016); Okrikata *et al*. (2019) extensively described the spatial distribution of insect pests and beneficial associated with watermelon in Wukari using dispersion index (variance to mean ratio - S^2/m) and regression models (Taylor's power law and Iwao's patchiness regression models). However, since Mollet *et al.* (1984) recommends the use of more than one dispersion index and regression models to see if they agree with each other before drawing conclusions about the spatial pattern of a population, we attempt to close the gap here by using the Lloyd's and Green's indices of dispersion to assess the spatial pattern of the dominant insect pests and beneficial associated with watermelon (variety: Kaolack) at Wukari vis-a-viz its growth stage, while also highlighting the length of their presence period.

Materials and Methods

Study site

The field experiment was conducted during the planting season of 2016 (Sowing dates; May 4th and August 23rd; early and late sowing, respectively) in the teaching and research farm of Federal University Wukari, Taraba State (Latitude 7° 51'N and Longitude 9° 47'E). Wukari has an altitude of 187m above sea level, an average annual temperature of 26.8°C and, an average annual rainfall of 1205mm. The study area experiences a warm tropical climate characterized by wet and dry season. The wet season starts in April and ends in October with peaks in June and September. The textural class of the soil is Sandy loam, coarse textured (in the surface) and, well to moderately drained (Okrikata *et al*., 2019).

Field preparation and maintenance

The experimental land was ploughed and harrowed after which 20 sub-sampling plots each measuring, 5m long x 8m wide was demarcated. Plots were separated from each other by 1m interspace. Planting was done on raised beds (3 seeds/hole at a depth of about 2cm). The variety used was "Kaolack," the most widely cultivated variety in the region. The crop spacing was 2m between rows and 1m within row giving a plant population of 12 plants/plot in 3 rows of 4 plants/row and, a total plant population of 5,000 plants/hectare.

Thinning to 1 plant/stand was done at 10 days after planting. NPK (15:15:15) fertilizer was applied at the rate of 200kg/ha at 3 weeks after planting using the side band method. As a prophylactic treatment against fungi and insects during germination; the seeds were dressed with Imidacloprid 20% + Metalaxyl-M (20%) + Tebuconazole (2%) (Dress Force® 42 WS) at the labeled recommended rate of 10g/8kg before sowing. Manual weeding was done when necessary, and the field was left to natural infestation of arthropod pests and their natural enemies.

Arthropod sampling procedure

The sampling of arthropod species commenced at 70% emergence stage [2nd week after planting (WAP)] and thereafter at weekly intervals until fruit maturity. Arthropod species associated with the crop were sampled/collected between 4.00 and 6.00pm using a portable, knapsack shoulder-mounted, motorized suction sampler (Burkard Scientific Ltd., Uxbridge, UK.) (having a 10cm diameter inlet cone) swept through the 5m length middle row at an approximate walking speed of 1m/sec (sampling period; ≈ 5secs/sub-sampling plot). The arthropods collected were killed in ethyl acetate in a killing jar and then preserved in 70% ethanol. All insects collected were sent to the Insect Museum Centre of Ahmadu Bello University Zaria, Nigeria, for identification.

Data analysis

Determination of dominant insect species

Taxa/species with frequency of occurrence (FO) ≥ 25 % and, relative abundance (RA) ≥ 1 % were regarded as dominant as detailed in Okrikata *et al*. (2019). The dominant insect taxa were identified as *Aulacophora africana* (Weise), *Aphis gossypii* (Glove), *Asbecesta nigripennis* (Weise), *A. transversa* (Allard), *Bactrocera cucurbitae* (Coq.), *Bemisia tabaci* (Genn.), *Epilachna chrysomelina* (Fab.) and *Monolepta nigeriae* (Bryant) [pestiferous taxa] and; *Apis mellifera* (L.), *Camponotus* sp., *Crematogaster* sp., *Cardiochiles niger* (H & W.), *Cheilomenes sulphurea* (Oliv.), *Pheidole* sp. and *Rhynocoris nitidulus* (Fab.) [beneficial taxa]. These were categorized into feeding guilds/ecological associations as also detailed in Okrikata *et al*. (2019).

Determination of presence period

The average relative length of the presence period (ARLPP) was computed using the model described by Salman *et al*. (2018) as:

$$RLPP \ = LPP \ x \ 100/LSI$$

Where:
RLLP = relative length of presence period.
LPP = length of presence period.
LSI = length of sampling interval.

Determination of spatial distribution using Lloyd's index of patchiness and Green's coefficient of dispersion

The index - variance to mean ratio (S^2/m), and regression models - Taylor's power law ($S^2 = am^b$) and Iwao's patchiness regression ($m^* = \alpha + \beta m$) were used to determine the spatial patterns of the dominant insects (pest and beneficial) associated with watermelon at Wukari as detailed in Okrikata *et al*. (2019). However, since the use of different indices of dispersion and linear regression models were recommended for use by Mollet *et al*. (1984) to ascertain spatial patterns, we herein report two indices of dispersion ie., Lloyd's index of patchiness and Green's coefficient of dispersion in relation to the stages of growth of the crop.

Lloyd's index of patchiness

The Lloyd's index of patchiness (m^*/m) is the ratio of mean crowding (m^*) to the mean density (m). The mean crowding (m^*) was calculated using the formula described by Lloyd (1967) and Southwood (1978):

$$m* = m + (S2/\mathrm{m}) - 1$$

Where;
S^{2-} Variance

When the Lloyd's index (m^*/m) = 1 (Random dispersion),
= >1 (Aggregated/Clumped dispersion),
= <1 (Regular/Uniform dispersion).

Green's coefficient of dispersion

The degree of aggregation of each dominant taxa/species was measured by Green's coefficient of dispersion (Green, 1966):

$$Cx \ = \left(\frac{S2}{\mathrm{m}}\right) / \ (\sum \mathrm{x} - 1)$$

Where; C_x – Green's coefficient of dispersion,
$\sum x$ – Total number of arthropod taxa/species.

When C_x = 0 (Random dispersion)m
= >0 – 1 (Aggregated dispersion where, 1= Maximum clumping).

Table 1. Presence periods of dominant insects associated with watermelon at Wukari in the early- and late-season of 2016

Species	Ecological Association	Average relative length of presence period (%)	
		Early-sown Crop	Late-sown Crop
Pest			
Aulacophora africana Weise	Phytophagous[a]	66.67	66.67
Aphis gossypii Glove.	Phytophagous	50.00	66.67
Asbecesta nigripennis Weise	Phytophagous	66.67	66.67
Asbecesta transversa Allard	Phytophagous	66.67	58.33
Bactrocera cucurbitae Coq.	Phytophagous, Pollinator	50.00	41.67
Bemisia tabaci Genn.	Phytophagous	66.67	50.00
Epilachna chrysomelina Fab.	Phytophagous	66.67	66.67
Monolepta nigeriae Bryant	Phytophagous	66.67	58.33
Beneficials			
Apis mellifera L.	Pollinator	50.00	41.67
Camponotus sp.	Predator	66.67	66.67
Crematogaster sp.	Predator	66.67	66.67
Cardiochiles niger H & W.	Parasitoid	58.33	41.67
Cheilomenes sulphurea Oliv.	Predator	58.33	58.33
Pheidole sp.	Predator	66.67	66.67
Rhynocoris nitidulus Fab.	Predator	50.00	41.67

[a]Phytophagous – includes defoliators, flower feeders, fruit feeders and sap suckers

Indices of dispersion

The Lloyd's index of patchiness (m^*/m) which has no upper limits indicates that all the arthropods have aggregated dispersion ($m^*/m > 1$) [except, *Camponotus* sp. (m^*/m = 0.500) indicating uniform dispersion at the seedling stage of the early-sown crop] across the growth stages (Tables 2a and 2b). Therefore, like the variance to mean ratio (S^2/m) reported by Okrikata *et al*. (2019), the Lloyds index of patchiness (m^*/m) indicates that the dominant insects were largely clumped in dispersion across the various growth stages.

Aggregation has been shown to infer a presence of a disproportionately large number of arthropods on some plants (Taylor *et al*., 1978). Arthropods have been shown to feed in colony and the largely aggregated distribution pattern indicated by this analysis suggests that the presence of an individual arthropod at a particular point enhances the possibility of a nearby presence of another arthropod of same species (Ahmadi *et al*., 2005; Sedaratian *et al*., 2010; Okrikata *et al*., 2019) and this could be because large numbers of eggs were laid at selected sites and young larvae/nymph feed together.

The variance to mean ratio is the simplest and most fundamental index of dispersion which forms a basis for making a tentative opinion on dispersion patterns (Myers, 1978; Taylor, 1984). However, like the Lloyd's index, it has no upper/maximum limits and thus cannot be used to make comparison. That Green's coefficient has an upper limit (which is 1) and thus can be used for comparison, places it at an advantage in this respect. This is even more so as Taylor (1984) revealed that, though the simplest, the variance-to-mean ratio was the most unsuitable in his study.

Table 2a. Lloyd's index of patchiness (m^*/m) and Green's coefficient of dispersion (C_x) of dominant insects associated with early-sown watermelon at Wukari in the early- and late-season of 2016

Species	Seedling Stage		Vegetative stage		Flowering stage		Fruting stage	
	m^*/m	C_x	m^*/m	C_x	m^*/m	C_x	m^*/m	C_x
Pest								
A. africana	1.628	0.032	1.484	0.016	1.368	0.008	2.991	0.042
A. gossypii	-	-	2.219	0.031	2.329	0.022	2.503	0.025
A. nigripennis	1.633	0.032	1.479	0.012	1.402	0.007	1.820	0.014
A. transversa	1.781	0.039	1.607	0.015	1.282	0.005	1.639	0.018
B. cucurbitae	-	-	6.900	0.160	1.075	0.001	4.056	0.052
B. tabaci	3.100	0.033	2.744	0.031	3.120	0.036	4.200	0.055
E. chrysomelina	1.185	0.009	1.043	0.001	1.361	0.006	2.457	0.024
M. nigeriae	1.696	0.035	1.402	0.010	1.109	0.002	2.214	0.020
Beneficials								
A. mellifera	-	-	3.393	0.061	1.353	0.006	3.587	0.043
Camponotus sp.	0.500	-0.050	3.351	0.062	2.166	0.020	2.800	0.034
Crematogaster sp.	2.123	0.062	3.104	0.058	2.962	0.033	4.708	0.064
C. niger	-	-	3.047	0.053	1.864	0.015	2.865	0.031
C. sulphurea	-	-	2.566	0.040	1.172	0.003	2.915	0.032
Pheidole sp.	1.656	0.035	1.889	0.022	1.507	0.008	1.827	0.014
R. nitidulus	-	-	4.291	0.086	1.466	0.008	4.505	0.061

The Green's coefficient of dispersion (C_x) which has an upper limit of 1 indicating maximum clumping, was consistently > 0 [except, for *Camponotus* sp. on the seedling stage of the early-sown crop (C_x = -0.050)]. The C_x ranged from -0.050 to 0.160 and, 0.002 to 0.466 across all the growth stages on the early- and late-sown crops, respectively. This indicates that all the dominant arthropods were weakly aggregated (Tables 2a and 2b). On both the early- and late-sown crop, the index also shows that the beneficial arthropod species were slighted more aggregated than the pest species (Tables 2a and 2b). The overall weak aggregation observed may be attributed to the size of the field used for the experiment. Hence, a further trial is recommended on a much bigger field. The relatively low level of pest species aggregation observed in this study may be as a result of the influence of predatory and/or parasitoidal activities of natural enemy species.

Again the degree of aggregation of both pests and beneficials were observed to be generally slightly higher on the early- than on the late-sown crop (Tables 2a and 2b). Some of these variations observed in the spatial distribution pattern may be as a result of changes in the density of the arthropod populations as spatial behavior has been shown to be density dependent and to vary with season (Steffy, 1979; Darbemamieh *et al.*, 2011). Factors such as pest/natural enemy interactions, microclimate and reproductive behaviour have also been shown to influence aggregation (Southwood, 1978; Steffy, 1979).

Table 2b. Lloyd's index of patchiness (*m*/m*) and Green's coefficient of dispersion (C_x) of dominant insects associated with late-sown watermelon at Wukari in the early- and late-season of 2016

Species	Seedling Stage		Vegetative stage		Flowering stage		Fruting stage	
	m/m*	C_x	*m*/m*	C_x	*m*/m*	C_x	*m*/m*	C_x
Pest								
A. africana	2.570	0.082	2.715	0.043	1.710	0.012	3.318	0.039
A. gossypii	-	-	5.920	0.088	1.906	0.015	1.830	0.014
A. nigripennis	4.742	0.211	1.555	0.014	1.140	0.002	2.470	0.024
A. transversa	2.605	0.084	1.805	0.020	1.394	0.007	1.123	0.025
B. cucurbitae	-	-	3.613	0.067	1.819	0.014	4.180	0.054
B. tabaci	-	-	7.643	0.175	1.742	0.012	1.628	0.011
E. chrysomelina	5.260	0.239	2.128	0.029	1.904	0.015	1.630	0.011
H. armigera	-	-	5.288	0.111	2.667	0.028	2.372	0.023
M. nigeriae	2.563	0.083	1.700	0.018	1.262	0.004	3.893	0.038
Beneficials								
A. mellifera	-	-	17.909	0.466	1.551	0.009	4.409	0.058
Camponotus sp.	2.637	0.088	3.028	0.052	3.850	0.049	5.044	0.070
Crematogaster sp.	1.053	0.003	2.135	0.029	2.835	0.159	5.213	0.075
C. niger	-	-	3.186	0.056	1.465	0.008	4.674	0.066
C. sulphurea	1.788	0.134	1.974	0.025	1.144	0.002	3.138	0.037
Pheidole sp.	1.462	0.024	1.503	0.013	1.508	0.009	1.814	0.014
R. nitidulus	-	-	7.128	0.159	2.264	0.021	4.241	0.055

Darbemamieh *et al.*, 2011 reported that, dispersion indices are easy to calculate and their results, simple; making them to be a convenient decision making tool for management programs. However, Mollet *et al.*, 1984 recommended the use and comparison of results of different dispersion indices alongside regression models before drawing conclusions on an arthropod dispersion pattern. The current results buttresses the inference drawn from the use of vaiance to mean index of dispersion and regression models – Taylor's and Iwao's (Okrikata *et al*. 2019) which shows that the dominant insects associated with watermelon at Wukari were largely spatially aggregated.

The changes in the distribution pattern of the major species observed in relation to sowing period in this study may be attributed to not only the cumulative effect of changes in population density in relation to weather factors but also, the suitability of host plants either for food or oviposition, and also the impact of natural enemy species as suggested by Pedigo and Buntin, 1994. Variation in the density of arthropod populations has been shown to cause changes in dispersion patterns (Southwood, 1978). The assertion that true randomness is rare (Steffy, 1979) is also buttressed by the present result as the dominant insects largely tended towards clumpiness and not randomness. However, aware that differences in crop varieties influences the attractiveness/preference by arthropods (Okrikata *et al.*, 2020), and consequently spatial characteristics, a further study to assess different varieties of watermelon is thus recommended. This is even more so as research has shown that, though an inherited trait, spatial characteristics can be influenced by different environmental factors (Nestle *et al.*, 1995; Okrikata *et al*., 2019).

Conclusion

The overall average relative length of presence period of the dominant insects associated with watermelon at Wukari were > 50% and slightly higher with respect to pest vis-à-vis beneficial species; and early- vis-à-vis late-crop. Lloyd's index shows that aside *Camponotus* sp. which tended towards uniform dispersion at the seedling stage of the early-crop, the other dominant species were aggregated in dispersion. Similarly, Green's index revealed that overall; the dominant insects were weakly aggregated.

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