EVALUATION OF GLOBAL AND LOCAL INDICATOR OF SPATIAL AUTOCORRELATIONS OF KENAF IN EXPERIMENTAL PLOTS IN SOUTH WESTERN NIGERIA

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ABSTRACT

A study was conducted to assess spatial variations in experimental plots through the global and local indicator of spatial autocorrelation of kenaf. Field data obtained from experiment conducted at both Ilora and Ikenne outstations of the Institute of Agricultural Research and Training, Ibadan, Nigeria in 2006 were used to investigate spatial variability in experimental plots. The descriptive statistics showed that sample mean (μ) from different tessellated plots of the experimental sites were biased estimators which might have been probably caused by spatial variations in the experimental sites. Also, the global Moran I and Moran I scatter plots showed that these can be used as a measure of variation between the plots. Generally, the selected spatial autocorrelation indicators were found to be consistent with some other spatial statistical analytical tools.

KEYWORDS: ***Hibiscus cannabinus*; experiments; spatial autocorrelation indicator; Nigeria.**

INTRODUCTION

Three types of spatial relationship have been established for plots in any experimental site viz. randomness (where the plots distribution in terms of the response variables are haphazard), clustered (where points are concentrated in one or more areas forming groups) and scattered (when the points are distributed evenly) (2, 4). These give the general indications of the variations of experimental sites which always based on some tools otherwise known as indicator of spatial autocorrelation. There are three spatial autocorrelation indicators for measuring spatial variations in spatial statistics. These are variogram, global and local indicator of spatial autocorrelation, (1,3). Moran *I* is a measure of spatial autocorrelation. Spatial autocorrelation exists when a

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systematic spatial variation in the values of a given variable is suspected. It is about proximity in space (1) and is defined as the relationship among values of a variable that comes from the spatial arrangement of the areas in which these values occur. Let x_i be the set of data for variable *j* whose treatment response are obtainable in an experimental field, autocorrelation seeks to establish relationship between the x_i at different parts of the experimental field for the variable *j*. Spatial statistics (especially spatial autocorrelation indicators) have been widely and extensively explored in ecology and geography while its use in agriculture is also gaining prominence.

Works on spatial statistics in agriculture abounds (3, 8, 9). The need for an assessment of global and local indicator of spatial autocorrelations cannot be overstressed because these are measures/estimates of spatial variations of any experimental site. While global Moran *I* measures spatial pattern in an entire plots, the local indicator of spatial autocorrelation measures the spatial pattern in patches. Also, it provides the basis for accuracy and reliability of results of spatial statistical analysis from experimental field. One of the fundamental concerns of spatial analysis is to find patterns in spatially referenced data which lead to the identification of types of spatial autocorrelation or association. Thus, spatial autocorrelation indicator provides insight into the interpretation of spatially referenced data. This work is, therefore, justified from the need to assess spatial pattern types in experimental plots *vis – a - vis* interpreting spatially patterned data from such experimental plots. Such interpretation to add reveals the regional effects in any experimentation. Its goal was to compare the use of autocorrelation indicator in the study of ecology and geography with that of agricultural field. One of the distinguishing feature of present study as against the previous (ecology and geography as against agriculture) is the environment of operation. While the former exists in a natural environment, the latter is based on an artificially influenced environment.

The objective of the study was to assess spatial variations in experimental plots through global and local indicator of spatial autocorrelation. This study would be useful in search of interpolant in spatial statistics which is a function used to predict ***z*** – values (data values) associated with irregularly located (*x,y*) points (sites).

MATERIALS AND METHODS

For this study data were obtained from two experiments carried out at both Ikenne and Ilora Out-stations of the Institute of Agricultural Research and Training, Ibadan, Nigeria between June and September 2006. In both these experiments effect of fertilizer and insecticides on Kenaf was evaluated. Ikenne falls within the forest zone ($27^0.48^!$N and $3^0.52^!$) of the country while Ilora is located in the intermediate guinea savanna ($126^0.52^!$N and $3^0.41^!$). Both experiments were carried out in split plot design with the main plot factor being the spraying regime (S_1 = 300kg NPK+100kg Furadan + 2 pre-flowering insecticide sprays and S_2 = 600g NPK + 200kg Furadan + 4 pre-flowering insecticide sprays). The varieties (V_1 = Cuba 108, V_2 = Ifeken 400 and V_3 = local cultivar) were the sub-plot factor. Data on stem girth and plant height were collected at interval of two weeks commencing from four weeks after planting and relative to their spatial address. Plant height and stem girth are two of growth indicators in plant morphology. This was repeated five times (that is 4, 6, 8, 10 and 12 weeks after planting).

The data obtained were subjected to descriptive statistics. The sample mean, $\bar{x}$ for any parameter *h* at any of the site *g* were compared with their population mean, μ to test for biasness. Also, the data were investigated for global indicator of spatial autocorrelation using Moran's I (5). Moran I is defined as,

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Where *n* is number of the areas, x_i is attribute value in area *i*, x_j is mean values of the neighbouring plots, $\bar{x}$ is mean spatial variability effects in the study region, w_{ij} is the spatial weight matrix.

Spatial variability effects are the values of variables after the effects of treatments must have been removed. It is obtained through the relationship;

$$\bar{x}_{(s)} = x_i - {x_i}/{x_{(s)}}$$

where $\bar{x}_{(s)}$ = spatial variability effects, x_i = value of the variable (s) for plot *i*, $x_{(t)}$ = the mean values of plots of same treatment. The sum of the treatment effects for plots of the same treatment is expected to be equal to 1. Also, the local indicator of spatial autocorrelation (LISA) which compares the local value to that of its neighbour was also computed. Moran I for the local indicator is given by the following relationships;

$$I = \frac{(x_i - \bar{x})\sum_{i=1}^{n} w_{ij}(x_i - \bar{x}_{(s)})}{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n}}$$

x_i is the attribute value in area i and $\bar{x}_{(s)}$ =sample mean value(for the spatial variability effects) in the study region and it is uniform for all variables as well as sites. Also, scatter plot map which indicate the relationships between the different plots for the different parameters and sites were also drawn using spatial weight matrix. Similar to traditional correlation calculation, the Moran I values go from -1 to +1. The statistical package employed was SYSTAT version 9.

RESULTS AND DISCUSSION

Descriptive statistics

Let $\bar{x}$ be the sample mean, *g* the site (Ilora/Ikenne) and *h* be the variable of interest, the sample mean for Ikenne $\bar{X}_{gh}$ are as follows;

$$height, Ilora \begin{bmatrix} 100.968 & 73.893 & 83.448 & 131.812 & 141.060 & 75.736 \\ 64.028 & 46.984 & 126.168 & 136.256 & 139.672 & 118.052 \\ 89.316 & 71.108 & 122.820 & 99.068 & 97.464 & 125.520 \\ 84.032 & 86.812 & 98.992 & 155.940 & 74.508 & 68.760 \\ 66.172 & 139.328 & 134.156 & 148.384 & 128.220 & 112.756 \\ 75.252 & 130.636 & 125.096 & 106.732 & 124.648 & 124.908 \end{bmatrix}$$

$$\bar{X}\ stemgirth, Ilora = \begin{bmatrix} .582 & .660 & .642 & .737 & .816 & .641 \\ .518 & .627 & .708 & .744 & .987 & .762 \\ .534 & .611 & .791 & .809 & .627 & .638 \\ .695 & .639 & .665 & .851 & .581 & .623 \\ .676 & .725 & .777 & .797 & .688 & .784 \\ .690 & .798 & .844 & .774 & .762 & .753 \end{bmatrix}$$

The populations' means on the other hand are 0.710cm (Ilora) and 1.01cm (Ikenne) while the samples' mean for both stem girth and plant height for Ikenne are;

$$x_{Ikenne\ ,stemgirth} = \begin{bmatrix} .825 & .824 & .998 & 1.178 & 1.166 & .941 \\ .758 & .754 & 1.256 & 1.232 & 1.118 & 1.026 \\ .844 & .829 & 1.225 & 1.033 & .968 & .963 \\ .856 & .860 & .986 & 1.266 & .896 & .958 \\ .766 & 1.096 & 1.256 & 1.194 & 1.032 & .988 \\ .776 & 1.187 & 1.206 & 1.058 & .912 & .975 \end{bmatrix}$$

$$\overline{x}_{(height, Ikenne)} \begin{pmatrix} 78.604 & 92.388 & 67.452 & 108.376 & 116.092 & 59.192 \\ 43.640 & 54.184 & 96.872 & 99.304 & 133.704 & 98.316 \\ 74.060 & 82.460 & 113.108 & 72.168 & 44.920 & 54.336 \\ 95.556 & 58.044 & 64.672 & 123.160 & 44.920 & 54.300 \\ 52.260 & 109.504 & 118.012 & 108.952 & 102.164 & 108.184 \\ 94.804 & 117.920 & 120.408 & 79.740 & 105.672 & 103.504 \end{pmatrix}$$

The population means for these two variables were 87.53 cm (Ilora) and 106.350 cm (Ikenne). From these statistics, the sample means returned for the diameter were biased estimator because substantial percentage (more than 90% - for both Ilora and Ikenne) were distinct from (greater or less than) the population means. Similarly, the same trends were obtained for plant height where almost none of the estimates was unbiased.

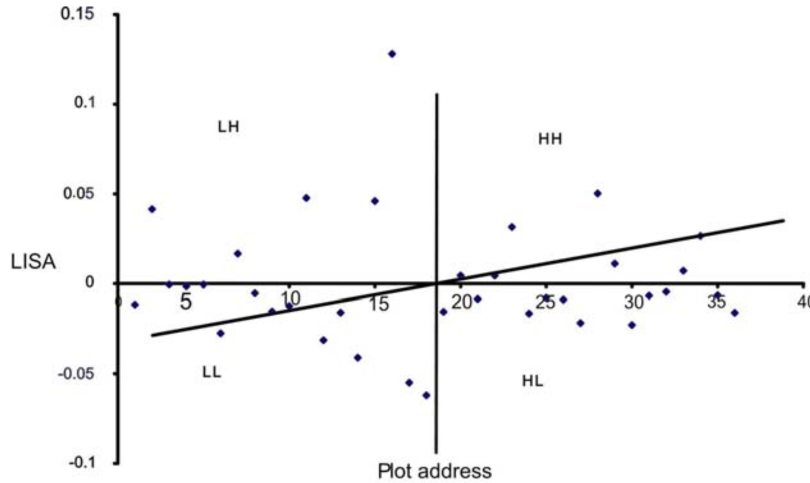
Global and local indicator of spatial autocorrelations (LISA)

The global Moran I for Ilora stem girth is 0.011 and -0.063 for Ikenne stem girth, while for plant height at Ilora, it is -0.016 and for plant height at Ikenne it is –0.030. It should be noted that *n* is 666 (the number of plots under comparison). It should be noted also that Moran I value is independent of sites or sizes of the values of parameters or on the relationships between parameters. The *n* number of plots is 2 because it is a comparison of individual plots with its neighbours. y_i, the attribute value in area I, and $\bar{x} =$ Mean value in the study regions are uniform for all variables as well as sites and $\sum_{i=1}^{n}(x_i - \bar{x}_{(s)}) = 105$ and $\sum_{j=1}^{n} W_{ij}(x_j - \bar{x})$ for stem girth at Ilora = -0.2395 and Ikenne = 0.528 while for plant height at Ilora = 14.874 and Ikenne = 20.201.

Using the foregoing, LISA for all the parameters and for both sites are presented in Table. One important features of this result is the presence of both negative and positive LISA. Some of the values were also approximately zero indicating randomness.

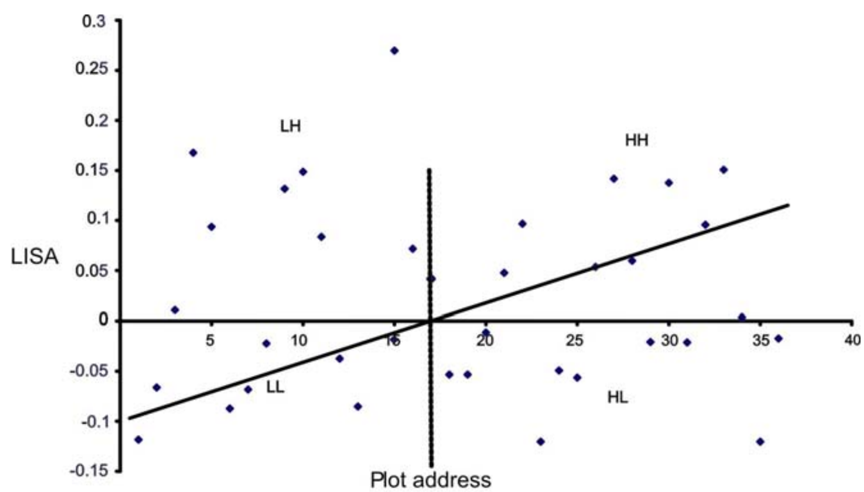
The Moran I scatter plots showed that majority of the plots (24 plots) fell in the lower right quadrant (Fig. 1 and Fig. 2) which indicates variations among the plots in comparison with their neighbours. For the treatments V_1S_1, V_2S_1 and V_1S_2, spatial similarities existed between stem girth (at Ikenne) for plots 1, 2, 3 and 4 despite the differences in treatments. This is apparent from the fact that their LISA followed similar trends. The effects of treatments on the stem girth could also be noticed from the differences in LISA values returned for each treatment (Table). Also for treatments V_2 S_2 and V_3 S_2, spatial similarities existed between plots 1, 2 and 3 despite the differences in treatments. From the scatter plots of LISA equal number of plots was found at both the upper and lower right of the quadrant. It is thus apparent that spatial similarities existed at equal elm in the plots.

For the plant height at Ilora spatial similarities were detected with plots 1 and 2 of the treatment V_1S_1 and V_2S_1. More of the plots (23) showed that they are dissimilar with their neighbours while some showed spatial similarities (Table). Sixty four percent of the LISA fell within the lower right quadrant while remaining 36 percent fell within the upper right quadrant. This showed that more of the plots showed spatial heterogeneity than spatial similarities (Fig. 3). For the plant height at Ikenne, spatial similarities were apparent for plot 4, 5 and 6 of both treatments V_1S_1 and V_3S_2. The remaining plots were spatially heterogeneous. More of the plots (53%) were spatially similar while remaining (47%) are spatially heterogeneous (Fig. 4).



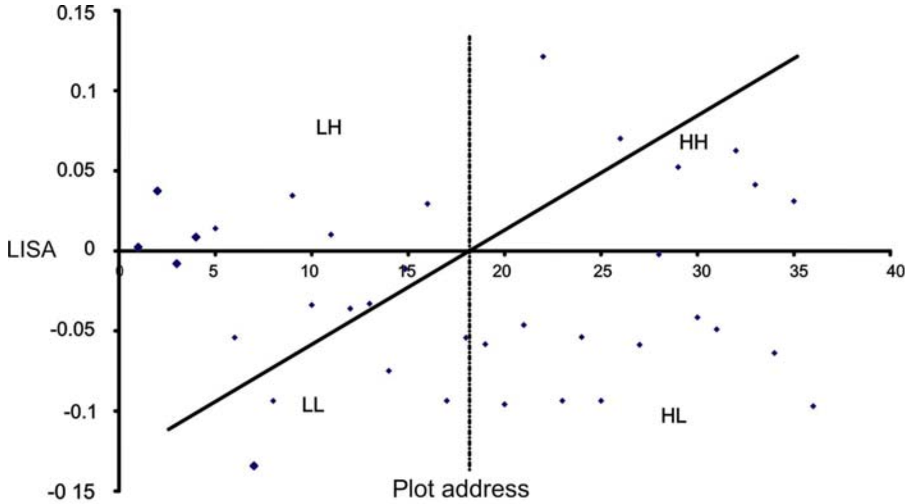
The line trend falls within the LL and HH region which implied similarities with one's neighbour.

Fig 1. Moran I scatter plot of the stem girth at Ilora.



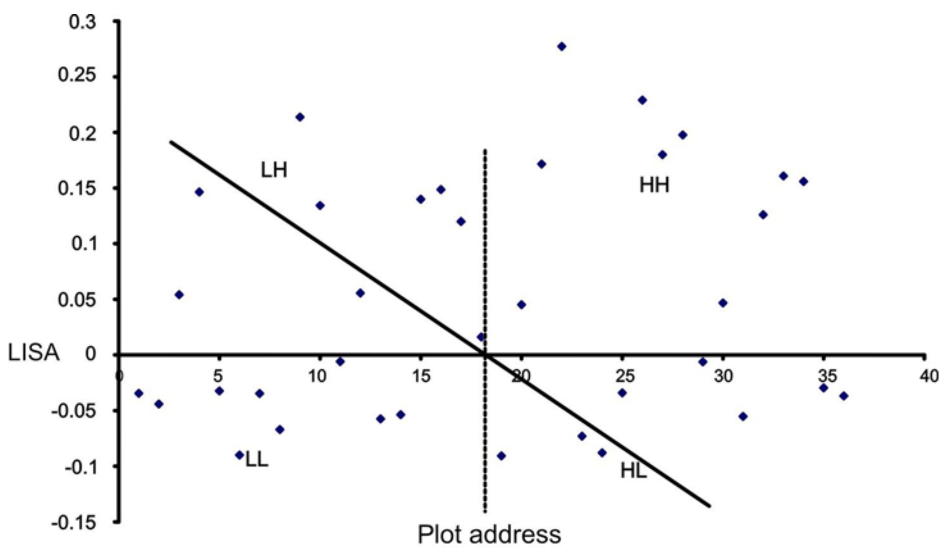
The trend line falls within the LL and HH region which implied similarities with one's neighbour.

Fig 2. Moran I scatter plot of the stem girth at Ikenne.



The trend line falls within the LL and HH region which implied similarities with one's neighbour.

Fig.3 Moran I scatter plot of the plant height at Ilora.



The trend line falls within the LH and HL which implied non similarity with one,s neighbour.

Fig. 4 Moran I scatter plot of the plant height at Ikenne.

Table Local indicator of spatial autocorrelation (LISA) at two stations.

	Stem girth		Plant height	
	Ilora	Ikenne	Ilora	Ikenne
1	-0.012	-0.118	0.002	-0.03444
2	0.042	-0.066	0.037	-0.04403
3	-0.001	0.011	-0.008	0.054175
4	-0.002	0.168	0.009	0.146515
5	-0.001	0.094	0.014	-0.03225
6	-0.028	-0.087	-0.054	-0.08999
7	0.017	-0.068	-0.134	-0.03464
8	-0.005	-0.022	-0.094	-0.06704
9	-0.015	0.132	0.034	0.213755
10	-0.012	0.149	-0.034	0.134255
11	0.048	0.084	0.010	-0.00584
12	-0.031	-0.037	-0.036	0.055615
13	-0.016	-0.085	-0.033	-0.05736
14	-0.041	-0.018	-0.075	-0.05361
15	0.046	0.270	-0.011	0.139915
16	0.128	0.072	0.029	0.148635
17	-0.055	0.042	-0.094	0.119895
18	-0.062	-0.053	-0.054	0.016145
19	-0.016	-0.053	-0.058	-0.0906
20	0.005	-0.011	-0.09586	0.045165
21	-0.009	0.048	-0.04633	0.171575
22	0.005	0.097	0.121242	0.277265
23	0.032	-0.120	-0.09358	-0.07287
24	-0.017	-0.049	-0.05387	-0.08791
25	-0.008	-0.056	-0.09356	-0.03402
26	-0.009	0.054	0.070052	0.228995
27	-0.022	0.142	-0.05866	0.179935
28	0.050	0.060	-0.00229	0.197655
29	0.011	-0.021	0.052242	-0.00625
30	-0.022	0.138	-0.04152	0.046815
31	-0.007	-0.021	-0.04899	-0.05531
32	-0.004	0.096	0.062592	0.125959
33	0.007	0.151	0.041292	0.160765
34	0.026	0.004	-0.06382	0.155835
35	-0.006	-0.120	0.030992	-0.02953
36	-0.016	-0.017	-0.09697	-0.03686

Scatter plot map

The scatter plot map of the stem girth at Ilora (Fig. 5a) for different weeks showed the following plots cluster together;

Week 4; $X_{14, 12, 15}$ Week 6; $X_{14, 13, 12}$ & $X_{17, 18, 15}$ Week 8; $X_{16, 11}$ Week 10; $X_{17, 18, 21}$ $X_{31, 33, 36, 34, 35}$ Week 12; $X_{18, 21.}$

For the stem girth at Ikenne (Figure 5b), however, the following plots clustered at the different weeks;

Week 4; $X_{6,8,10,12,14,}$ $X_{23,24,25,}$ & $X_{19,15}$ Week 6; $X_{16,17}$ & $X_{21,22,23}$ Week 8; $X_{19,20}$. Week 10; $X_{18,22,23,}$ $X_{18, 21}$ $X_{18,19,17}$ $X_{14,15,16}$ Week 12; $X_{13,14,15,16.}$

Also, for plant height and at Ilora (Figure 6a) the following plots clustered together;

Week 4; $X_{23,24,}$ & $X_{23,22,21,}$ Week 6; $X_{19,18,17,}$ $X_{16,14}$ & $X_{24,25,23,}$ Week 8; $X_{21,20}$. Week 10; $X_{16,18,19}$ $X_{17,15}$ $X_{18,19,20,21}$. Week 12; $X_{17,15}$ $X_{20,21..}$

For plant height at Ikenne station, (Figure 6b) the clustered plots at the different weeks were;

Week 4; $X_{21,22.,}$ Week 6; $X_{22, 17,18,}$ Week 8; $X_{17,18,}$ $X_{23,24,22}$.$X_{21,11,12.}$ Week 10; $X_{4,5,6}$. Week 12; $X_{15,14}$ $X_{23,24.}$

Generally, it was observed that neighbouring or near neighbouring plots clustered together in most cases at the different times. This confirms the spatio temporal autocorrelation between some of plots (that is spatial similarities at different times of the plant growth between some of plots can be suspected). Also, it is obvious that different number of plots clustered together at different weeks and on different levels. The pattern of clustering to add differs by weeks and parameters. This could also be deduced from the different pattern of patches existing within each map (Fig. 5a & b, 6 a & b). However, spatial variabilities were also suspected between majority of the other plots. Some of plots sharing the same treatment also exhibited spatial heterogeneity. Thus it implied that treatment effects not withstanding, spatial differences could still be suspected between and within the plots.

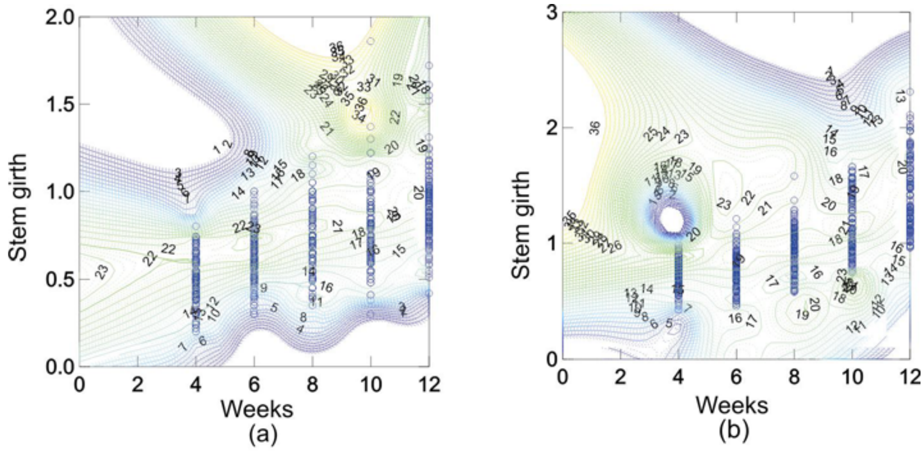


Fig 5. Scatterplot map of stem girth at Ilora (a) and Ikenne (b)
(Note. The different plots cluster together at different weeks and levels)

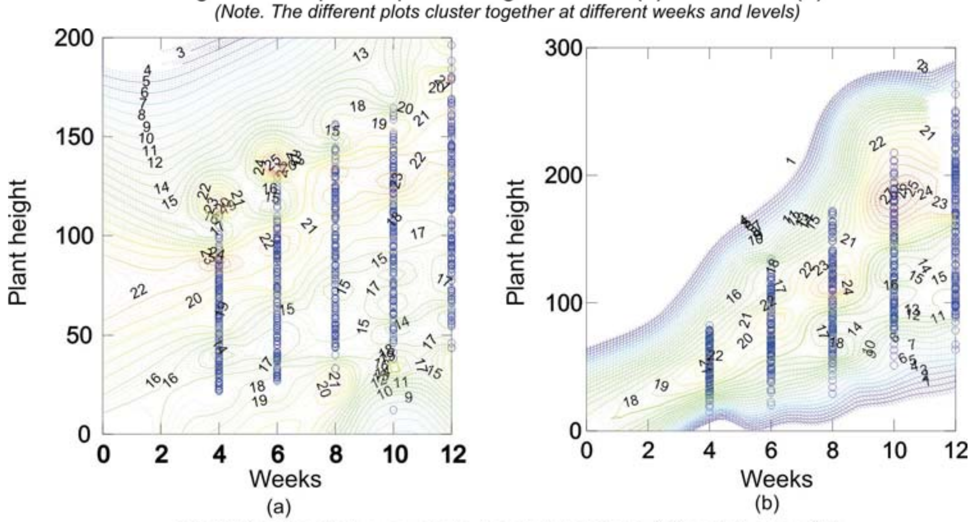


Fig.6 Scatterplot map of plant height at Ilora (a) and Ikenne (b)
(Note. The different plots cluster together at different weeks and levels)

The biasness of sample mean could be linked to the influence of spatial variability on the experimental sites and it is not parameter dependent. This implies that further statistical analysis without reference to these spatial variations means wrong, misleading and unreliable results. Generally, the very low global Moran I returned for stem girth for the plots at Ilora implies a region where clusters of similar values could be found (that is weak spatial homogeneity). Also, for the stem girth at Ikenne (-0.063) as well as plant height at both sites (-0.0158 for Ilora and -0.0304 for Ikenne), the low and inverse spatial autocorrelation returned for global Moran I is an indication of cluster of dissimilar plots. It could be deduced from the results that the lower the mean of parameters the higher the spatial autocorrelation. The presence of both spatial homogeneity and heterogeneity in an experimental plots agree to earlier findings (6) where it was recommended that spatial locations at which variations will be related to spatial variability must be dependent on the size of the plots else such experimental plots should be subjected to blocking. Also plots variabilities could not be associated with the treatment. That is Moran I is not a function of treatment alone i.e $Moran - I \neq f(Z_i)$ where (Z_i) is the treatment difference. However, plots variabilities and similarities in some other plots could be traced to the treatment effects. This could perhaps be hinged on the similarities of some other aggregate soil nutrient. The similarities or otherwise of the plots can be said to be a function of both plots residual nutrients $f(x_i)$ and treatment $f(z_i)$. Contrary to spatial autocorrelation in ecology and other related fields, three types of spatial autocorrelations were obtained in the experimental plots. This may be hinged on the fact that while the former operates in a naturally endowed environment with little or no disturbances, the latter operates within an artificially (in form of treatments' application) manipulated environment. Similarly, consistence of the results of scatter plots and scatter map with two selected spatial autocorrelation confirms the sufficiency of two statistics. Global and local Moran I were though computed from the same data, but these were found to be independent of each other.

From the results, it could be established that pattern of spatial variation differs from site to site as well as parameter to parameter. Also, both spatial heterogeneity and homogenous are obtainable for either of the sites and of either parameters but spatial heterogeneity is more prominent than spatial similarities. Also, none of the data sets do satisfy the theory of regionalized variables. Theory of regionalized variable according to Pasztor and Toth (7), states that the spatial index *t* varies continuously throughout a fixed subset *T* of a *d* – dimensional euclidean space. So, ignoring these spatial patterns could lead to erroneous conclusion about environmental and or edaphic relationship of the experimental site and thus increase the likelihood of a poorly specified model. This is consistent with the findings of Betts *et al.* (3) who established that accounting for spatial autocorrelation in models tends to increase predictive accuracy and versatility. Soil nutrients based on the foregoing could be said to be having a magnificent impact on the spatial pattern of plots. This is because regionalization of soil nutrients is expected to be down the soil profile and not across the field. Based on these, the indicator for spatial autocorrelation can be decomposed into a model of the form, where x_i is soil nutrients autocorrelation y_j is the treatment variation and $x_i y_j$ is interaction between the soil nutrient autocorrelation and treatment variation.

CONCLUSION

It is noteworthy that two spatial autocorrelation indicators (global and local indicator of spatial autocorrelation) have sufficiently established spatial pattern existing in an experimental site and using independent approaches. Thus, these are found useful in agricultural field too. Also, understanding spatial pattern is one of the fundamental issues in spatial statistical analysis. This is ensured through the two assessed (local and global) indicators of spatial autocorrelation and it is not unconnected with the fact that;

1. The autocorrelation's conditions are satiable in any environment (whether natural or artificial).
2. The variance covariance matrices which was the denominator of the Moran I indices is not environmentally dependent.

The establishment of these pattern types (which is non -regionalized pattern but random) gives an insight into the spatial variation of the experimental sites. Thus it provides insight as well as guide for the delineation of any experimental sites for various preliminary assessments. It could, therefore, be recommended that further study in spatial statistics in agriculture should focus on method(s) of delineating the different pattern for accurate measurements. Finally, since the spatial pattern of any experimental plots may change over time, it is worth recommending that these global and local indicators of spatial autocorrelation test be carried out at the instance of any experimentation. Also, preliminary investigation should be done along the gradient of the spatial pattern.

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