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Comparison of the response of NmF2 and NmE to variations in Sunspot number at different latitudes

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ABSTRACT

The comparison of the response of NmF2 and NmE to Sunspot Variation at Ibadan (7.4°N, 3.9°E, 6°S dip), Singapore (1.30°N, 103.80°E dip 18°s) and slough (51.5°N 359.4°E, dip 66.5°N) is studied. The results obtained from statistical analysis of data collected and from the graphs plotted show the following: NmF2 was found to respond better then NmE at the three stations. In the three stations the response of NrnE is greatest around noon. NmF2 was found to respond better than NmE at the three stations. This does not that FOE responds better to sunspot number than f0f2. NmF2 responds better to solar activity at Singapore and Slough than at Ibadan. This is probably due to the more variable F - region electron dynamics at equatorial station of Ibadan. NmE responds better at Ibadan and Singapore than at Slough. This may be due to slight decrease of NmE at temperate Latitude and a slight enhancement of NmE at equatorial Latitude by Sq current.

Keywords: NmF2, NmE, temperature and variation

INTRODUCTION

The ionosphere - a region of highly ionized particles above the stratosphere [1]. The Ionosphere is a shell of electrons and electrically charged atoms and molecules that surrounds the Earth, stretching from a height of about 50km to more than 1000km. It owes its existence primarily to x-rays and ultraviolet radiation from the sun.

The shorter wave ultraviolet solar radiation extending into the X-ray region, acts on the molecules and atoms of the upper atmosphere by detaching one of their electrons, leaving behind a molecular or atomic (positive) ion. Some of the electrons will attach themselves to an atom or molecule of oxygen to form a negative ion. These actions lead to several others particularly charge transfer and three body or radiative recombination. The region in which there are free electrons in significant number is called the ionosphere. It extends below the mesopause (80km), but the electron density is greatest above 100km, it rises to a maximum of the order of 10^5 cm-3, at the peak of the E-layer at about 120km and to a greater maximum of the order of $10^6 cm^3$ at the peak (about 300km) of the F_2 layer.

Electron density is of the order of $10^{11} m^{-3}$ at the peak of E- layer to $10^{12} m^{-3}$ at the peak of F_2 layer [2].

The existence of the ionosphere as an electrically conducting region was first suggested by, Balfour Stewart in 1883. He inferred it from a study of the small daily geomagnetic variation observed at the earth's' surface.

Chapman in his theory considered the earth's atmosphere as one that consists of a single gas of molecular weight M which is at a uniform temperature under the action of gravity over a flat earth (chapman layer formation) [3].

In the opening years of 20^{th} century after Marconi had transmitted radio waves across the Atlantic, the presence of an ionized region of the upper atmosphere was given as the explanation, by Kenelly and Heaviside. This-region can prevent the passage of radio waves of wavelength below a certain limit into outer space; instead, it reflects or bends them round the curved surface of the earth. Since 1920 the ionosphere has been widely explored by radio scientist among whom are: Appleton, Breit and Tuve.

PURPOSE OF STUDY

Sunspots are caused by very high magnetic activities taking place in the core of the sun, which hinders convection and as a result forms areas of decreased surface temperature. Whenever sunspots appear on the solar surface, the number of sunspots is a measure of the solar activity. If small number of sunspot is observed, the sun is said to be in its quite state and to have a low solar activity. When large numbers of sunspots are observed, the sun is said to be in a highly disturbed state, and to have a high solar activity. Scientists have observed that the ionization that takes place in all the regions of the ionosphere are closely associated with variations in sunspot number. The ionizations are said to increase or decrease as the sunspot number increase or decreases in course of a solar cycle. All the variations of f0f2 i.e. diurnal, the annual, and the solar cycle variations are tied to the solar activity [4]. The response of NmF_2 (the peak electron density of the F_2 layer) and NmE (the peak electron density of the E-layer) to variation in sunspot number is a function of location, latitude, time of the day and year. In this study, we intend to investigate, the extent to which the response of Nm£2 to variation in sunspot number compares with the response of NmE to variation in sunspot number at different latitudes. Our study is the 'comparison of the response of Nmf2 and NmE to sunspot variation at Ibadan (7.43°N, 3.90°E, dip 6°S), Singapore (1.30°N 103. 80°E, dip 18°S and Slough (51.5°N, 359.4°E dip 66.5°N).

METHOD

SOURCES AND COLLECTION OF DATA

Available values of foF2 and foE, were obtained from the records of the ionosonde the union Radio Mark II, recorder, type developed at the Radio Research Station in Slough. A common method of obtaining photographic sounder called the ionosonde, which was developed by [5]. The transmitter and receiver of the ionosonde are separate sub units kept in tune by a frequency sensitive servo gerro system. Pulses are transmitted over a range of 0.7MHZ to 25 MHZ in a sweep time of 5 minutes duration. The interval between the transmitted pulse and the corresponding echoes are recorded photographically. The variation of apparent height h with frequency f of radio waves is shown on the records, referred to as ionograms.

In these records, hourly mean values of the parameters of f0f2 and foE which are t tabulated, obtained from the monthly publication of university of Ibadan bulletins of Ionospheric data have been used in this research work. It is assumed that the values of the peak election density of the F2 layer. $Nmf2 = 1.24 \times 10^{10} foF2^2$ (where foF2 is the critical frequency of F2 layer). Also, it is assumed that the values of the peak electron density of the E - layer $NmE = 1.24 \times 10^{10} foE^2$ (where foE is the critical frequency of E - layer). For the periods under study, NrnF2 and NmE variability of January to December of 1958 and 1973 data for Ibadan Station were used. This represents the variability for high and low solar activities respectively. Again, the Nmf2 and the NmE variability of July 1900 to 1974 available data for Ibadan, Singapore and Slough were also used for the purpose of Latitudinal comparison.

ANALYSIS OF DATA

With the use of an electronic Calculator the hourly mean values of the critical frequencies of f2 and E regions were obtained. The results obtained for

(a) Ibadan 1958
(b) Ibadan 1973
(c) Ibadan July 1960 to 1970
(d) Slough July 1963 to 1971
(e) Singapore July 1900 to 1971

Are displayed on the tables 1 to 9.

From the relationship

$NmF2 - foF^2 \times 1.24 \times 10^{10}$, and

$NmE - FoE^2 \times 1.24 \times 10^{10}$

The values of foF_2 and FoE were converted to NmF2 mid NmE, as shown in tables 10 - table 18.

In the analysis of the data, the following statistical theories were used:

(a) A mathematical relationship between Hz (sunspot number) and

Nmf2 (peak election density of F2 layer), and between Rz and NmE (peak electron density of the E-layer), employing Regression Analysis.

(b) The correlation coefficients of Rz and Nmf2, and RZ and NmE were calculated for a period between 06 hours and 18 hours

(c) The Trend line for NmF2, NmE and Rz were calculated and drawn at 12 hours for Ibadan, Slough and Singapore.

(d) The graphs of NmF2, NmE and Rz were plotted against different months of the year for Ibadan 1958 an 1973. While graphs of Nmf2, NmE and Rz were plotted against different years for Slough and Singapore.

THE COMPARISON OF NMF2 AND NME WITH VARIATIONS IN RZ VALUES

(a) To compare NmF2 and NrnE with variation in Rz values at Ibadan, Slough and Singapore, we calculate the correlation coefficient of NmF2 with Rz and NmE with Rz

(b) A mathematical relationship is established between Rz and Nmf, and between Rz and NmE using regression analysis.

(c) A graph of Nmf2, NmE' and Rz is plotted against the months of the year for Ibadan 1958 and 1973. A graph of NmF2, NmE and Rz is plotted against different years for Slough and Singapore

(d) The equation of Trend lines for Rz. NmF2 and NmE are calculated and drawn-out in a graph.

Data from table 15 to 18 were used to plot the graphs figure 1 to figure 26 representing of the plot of NmF2, NrnE and R2 against the months of the year for Ibadan 1958 (Figures 1 to figure 13 and figures 14 to figure 26 represents that of Ibadan 1973).

With the data on tables 11 and 12 the graphs - figures 27 to figure 39 were plotted for Slough covering the period 06 hours to 18 hours. Also with the data on table 13 and table 14 the graphs - figure 40 to 52 were plotted for Singapore covering the period 06 hours to 18 hours.

In plotting the graphs, for the purpose of comparison, the values of Nmf2 and NmE are plotted on a side of the Y- axis against different years (1963 to 1971) for Slough) on the same graph, the sunspot number Rz are plotted on the second Y -axis against different years. For Singapore, the years considered are 1960-1971.

STATISTICAL ANALYSIS OF DATA

The data collected were analyzed using statistical theories as a basis for:

(a) Calculating and determining the level and extent of the response of NmF, to variation in sunspot number Rz.

(b) Calculating and determining the level and extent of response of NmE to variation in Rz.

(c) Accurate comparison of the response of Nmf, and NmE to variation in Rz:

The statistical theories employed for this purpose are;

i. Correlation analysis
ii. Regression analysis
iii. The equation of a Trend line.

RESULTS AND DISCUSION

Seasonal variation in the response of NmF2 and NmE to solar activity at Ibadan.

The seasonal variation in the response of NmF2 and NmE at Ibadan to solar activity in 1958 are illustrated in figures 1- 13.

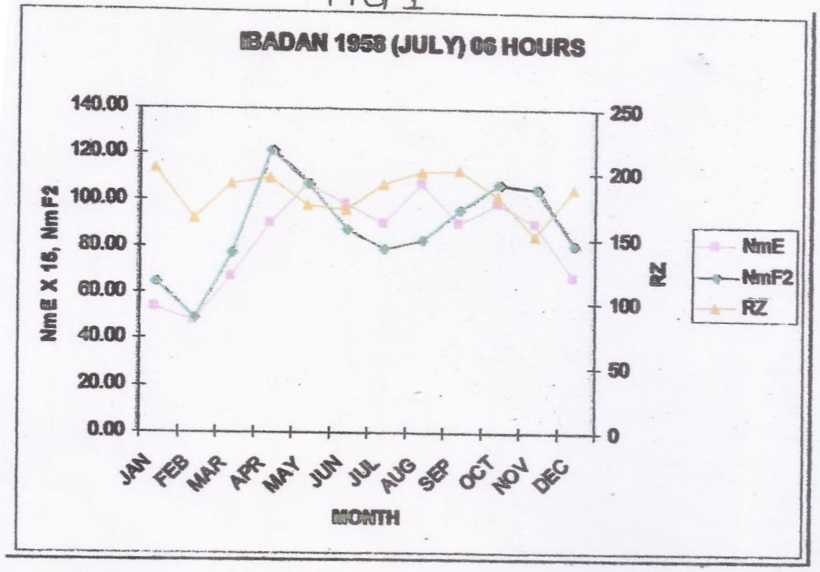
The peak values for NmE occur in June solstice (in August in the first half of the day [figures 1 -7] and in July in the second half of the day (figures 8 - 13).

On the other hand, the peak values for NmF2 occur in the March equinox and in Autumn Equinox. The peak value in March Equinox occurs between 08h and 16h and that of Autumn Equinox occur between 06h and 07h.

During 1973, seasonal variation found in the response of NmF2 and NmE to solar activity at Ibadan show that, the peak value of NmF2 occur in March Equinox

between 08h and 16h, and in June solstice at 17h and 18h. (See figures 14 - 26).
The peak values of NmE occur in September Equinox and in June solstice generally.

FIG 1



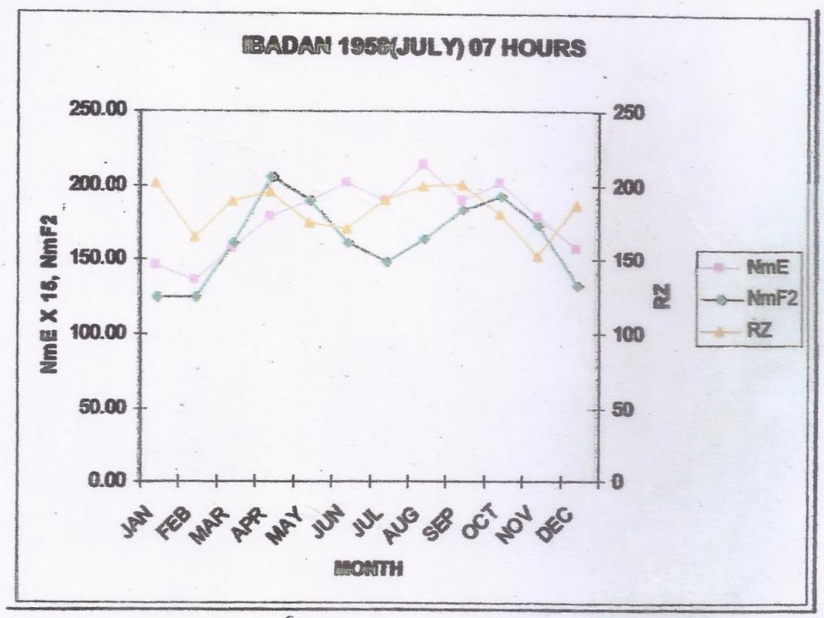
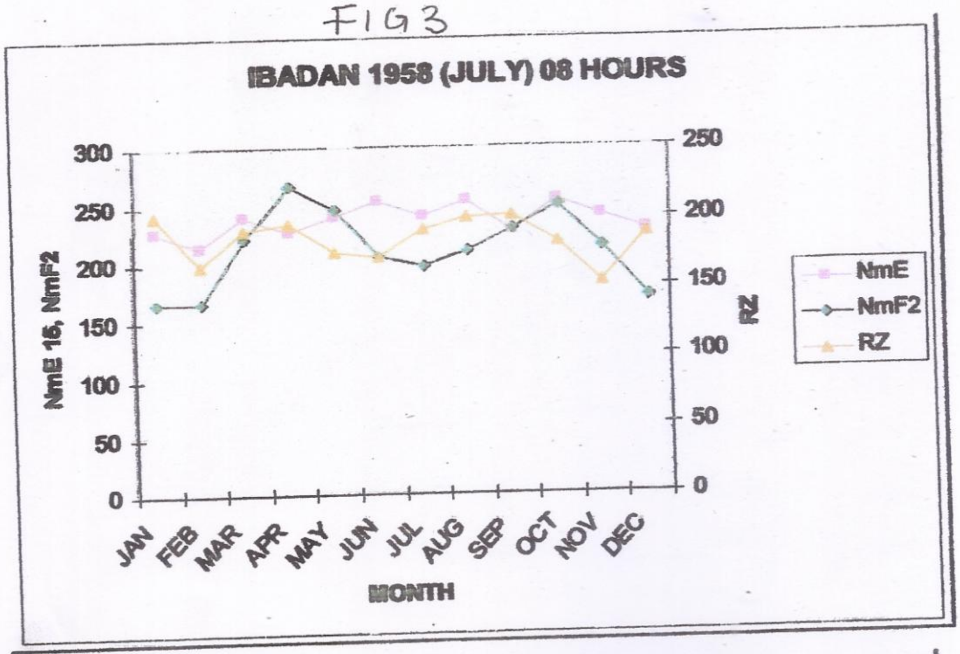


FIG 2

FIG3


IBADAN 1958 (JULY) 08 HOURS
NmE 16, NmF2
RZ
MONTH
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
NmE
NmF2
RZ

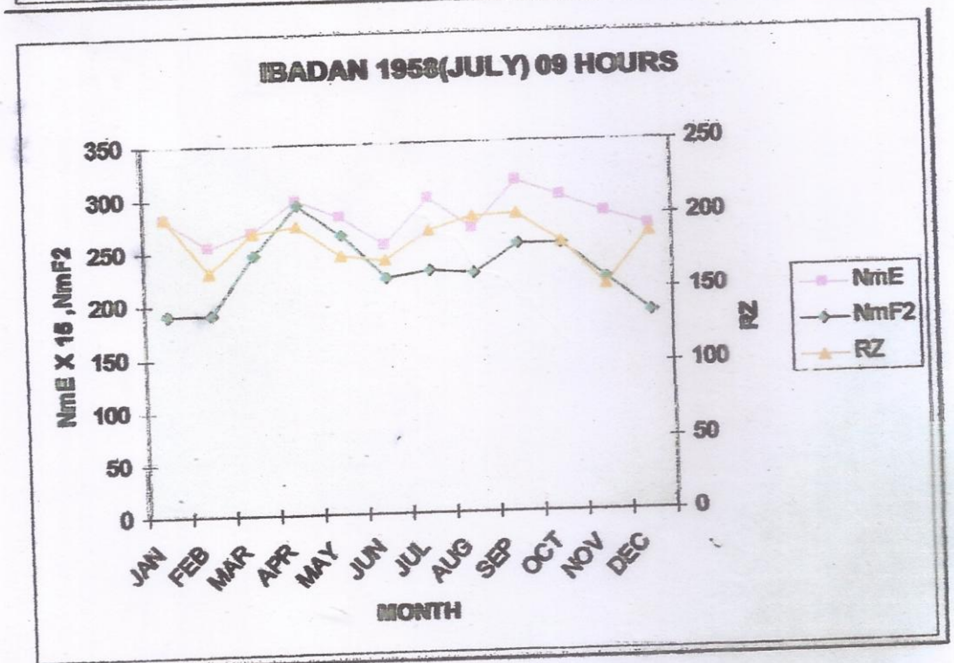
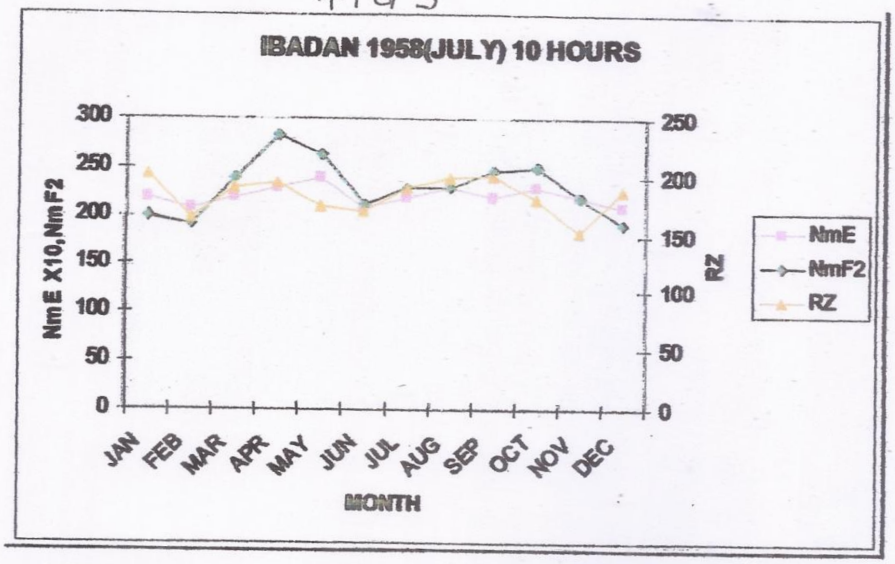

IBADAN 1958(JULY) 09 HOURS
NmE X 16 ,NmF2
RZ
MONTH
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
NmE
NmF2
RZ

FIG4

FIG 5


IBADAN 1958(JULY) 10 HOURS
NmE X10,NmF2
RZ
MONTH
NmE
NmF2
RZ

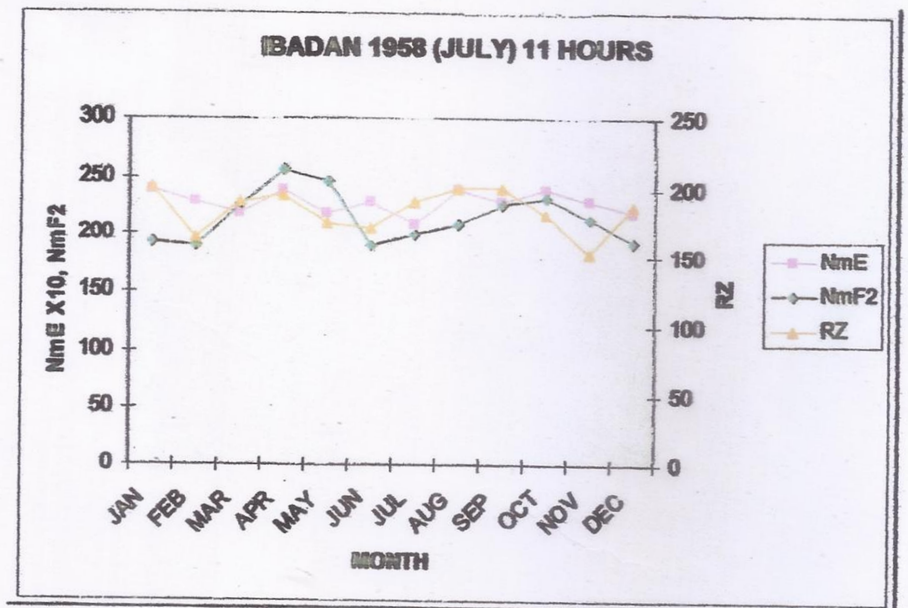
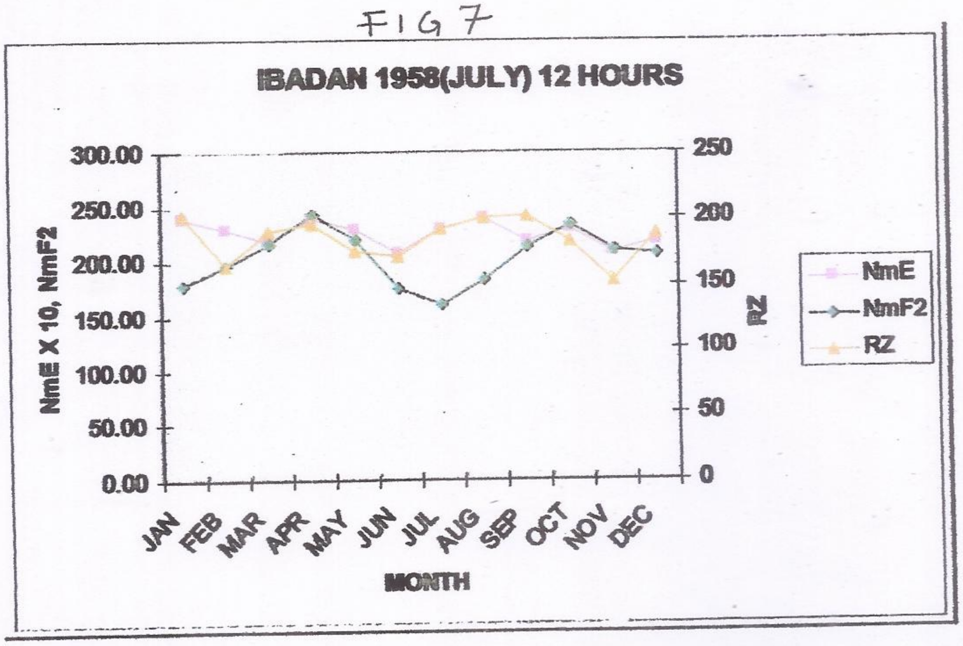

IBADAN 1958 (JULY) 11 HOURS
NmE X10, NmF2
RZ
MONTH
NmE
NmF2
RZ

FIG 6

FIG 7


IBADAN 1958(JULY) 12 HOURS
NmE X 10, NmF2
300.00
250.00
200.00
150.00
100.00
50.00
0.00
250
200
150
100
50
0
RZ
NmE
NmF2
RZ
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

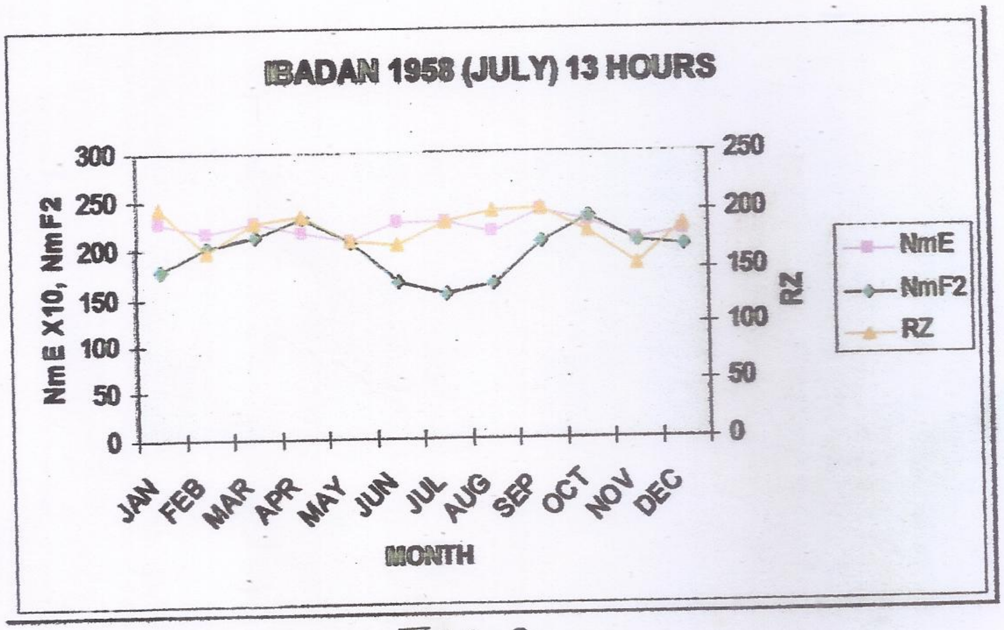
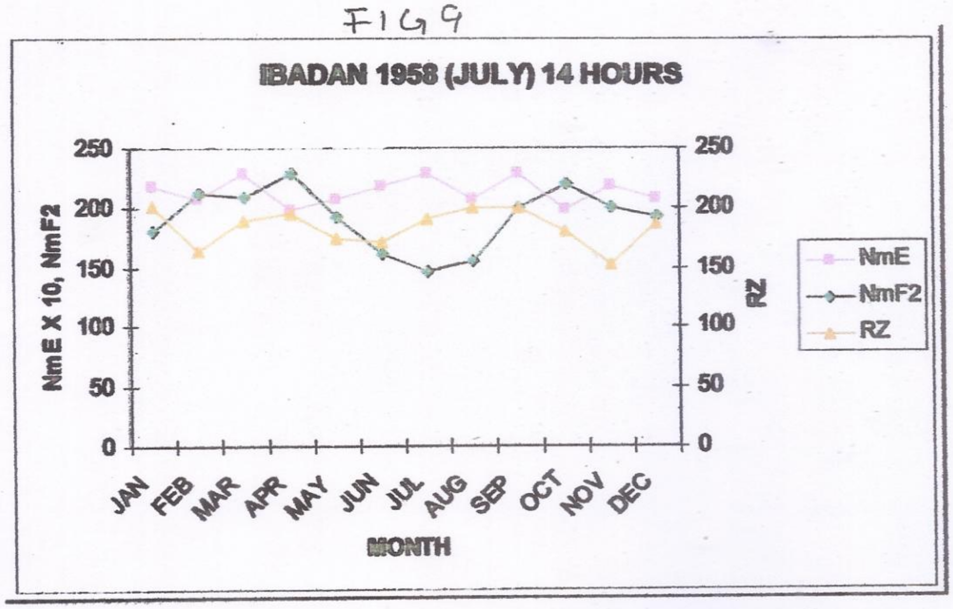

IBADAN 1958 (JULY) 13 HOURS
NmE X10, NmF2
300
250
200
150
100
50
0
250
200
150
100
50
0
RZ
NmE
NmF2
RZ
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

FIG 8

FIG 9


IBADAN 1958 (JULY) 14 HOURS
NmE X 10, NmF2
RZ
MONTH
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
NmE
NmF2
RZ

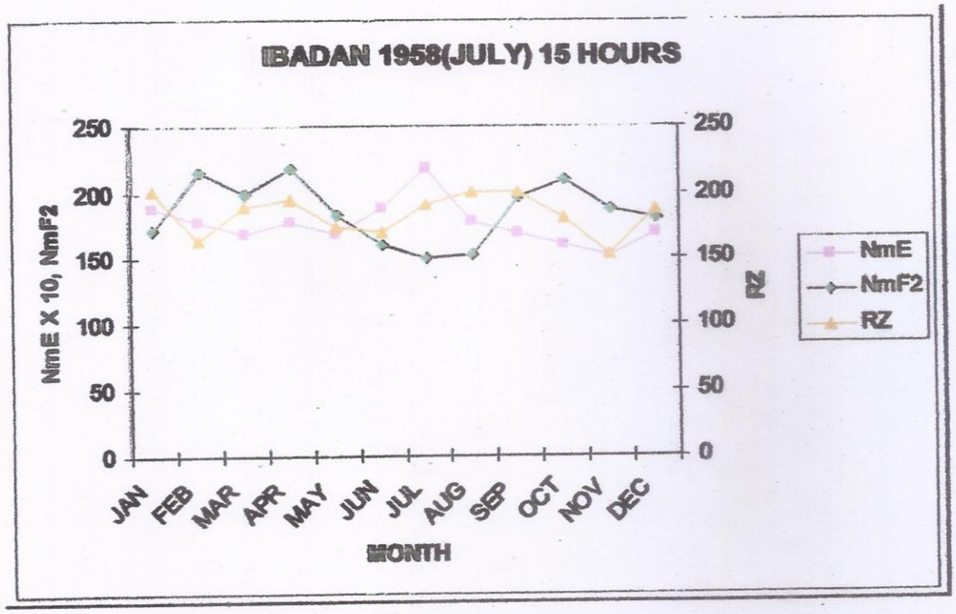
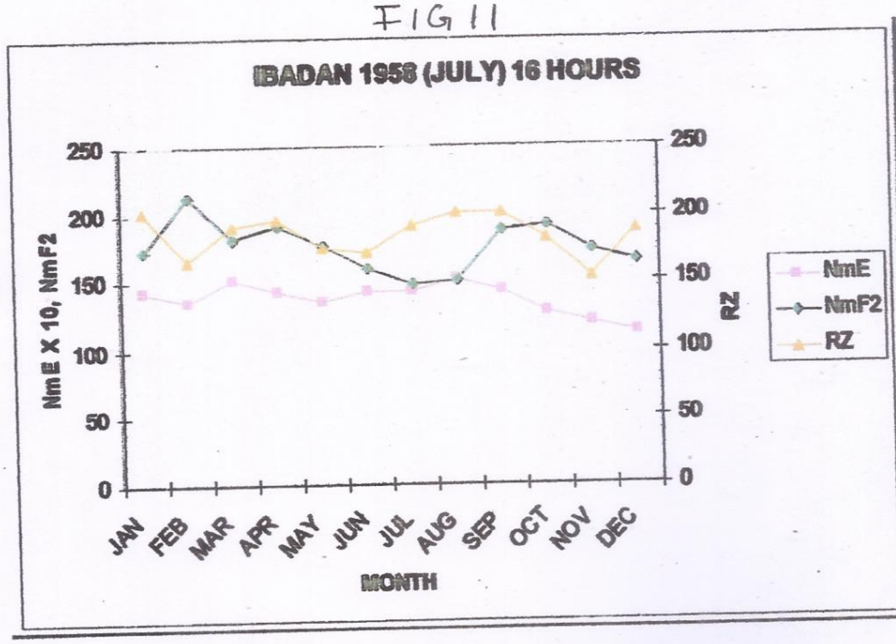

IBADAN 1958(JULY) 15 HOURS
NmE X 10, NmF2
RZ
MONTH
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
NmE
NmF2
RZ

FIG 10

FIG 11


IBADAN 1958 (JULY) 16 HOURS
NmE X 10, NmF2
RZ
MONTH
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
NmE
NmF2
RZ
0
50
100
150
200
250

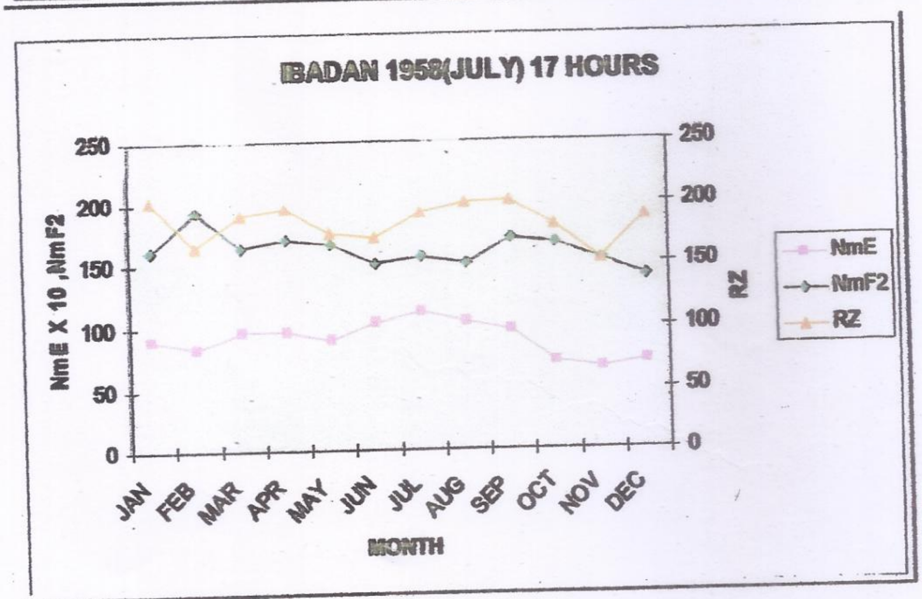

IBADAN 1958(JULY) 17 HOURS
NmE X 10 ,NmF2
RZ
MONTH
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
NmE
NmF2
RZ
0
50
100
150
200
250

FIG 12

FIG13

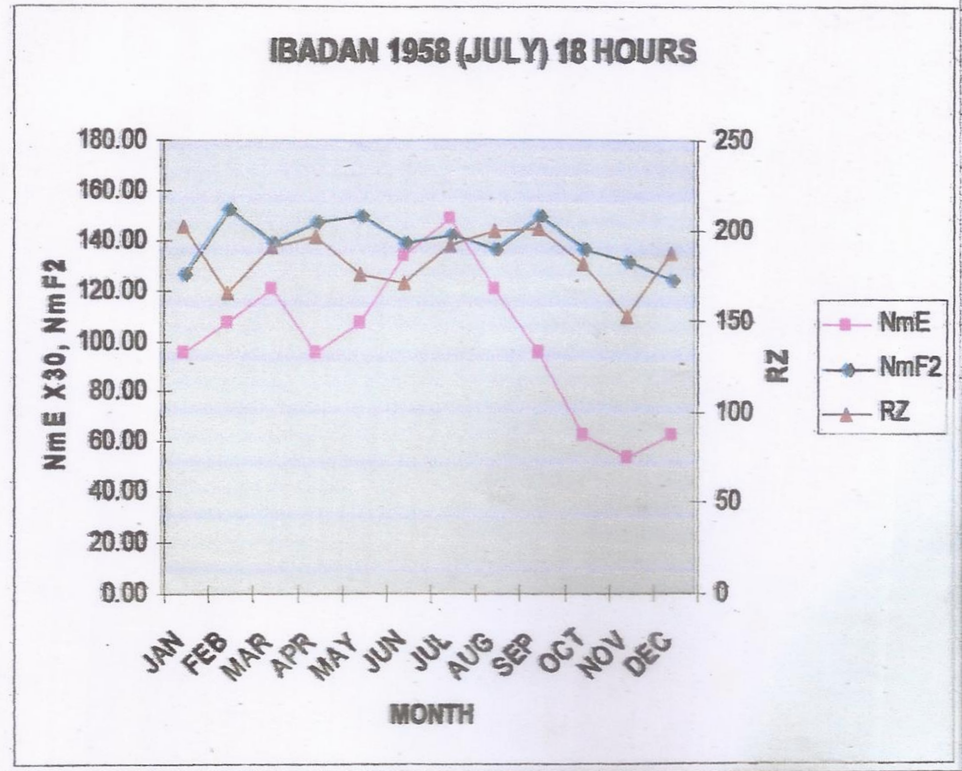
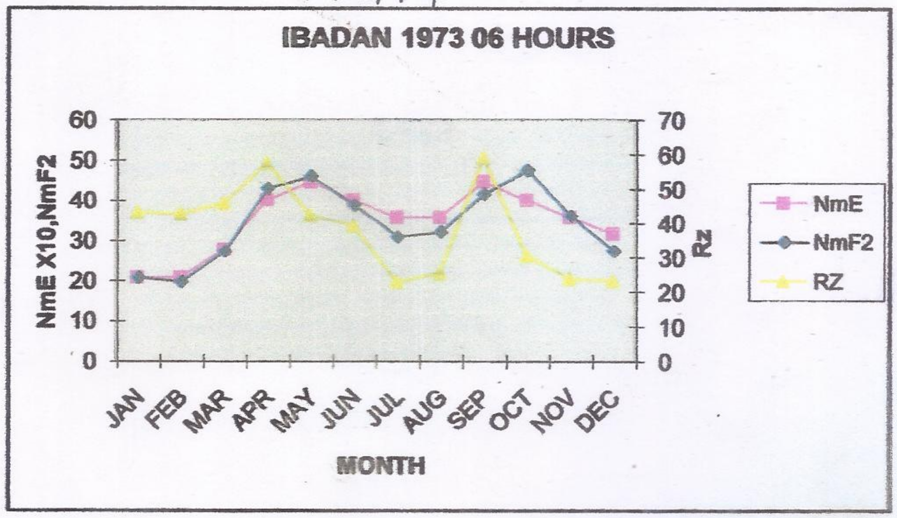

IBADAN 1958 (JULY) 18 HOURS
NmE X30, NmF2
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
250
200
150
100
50
0
RZ
NmE
NmF2
RZ
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

FIG 14


IBADAN 1973 06 HOURS
NmE X10,NmF2
Rz
MONTH
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
NmE
NmF2
RZ

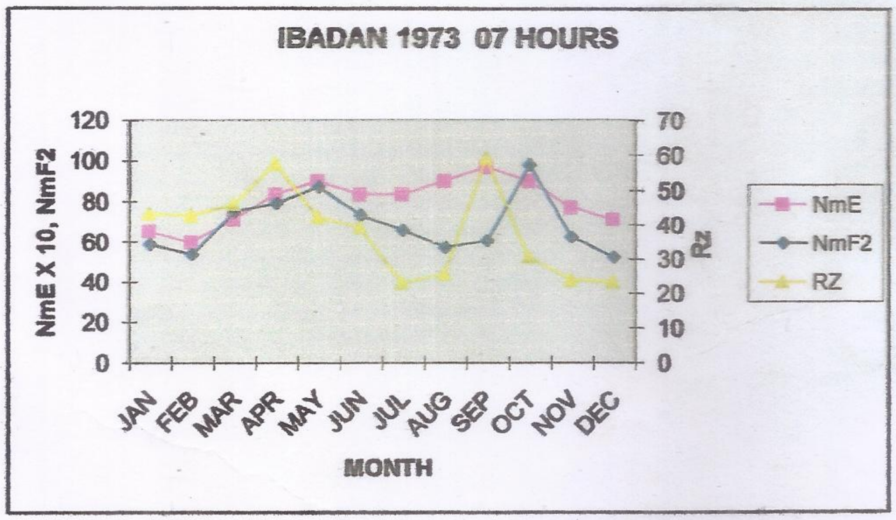
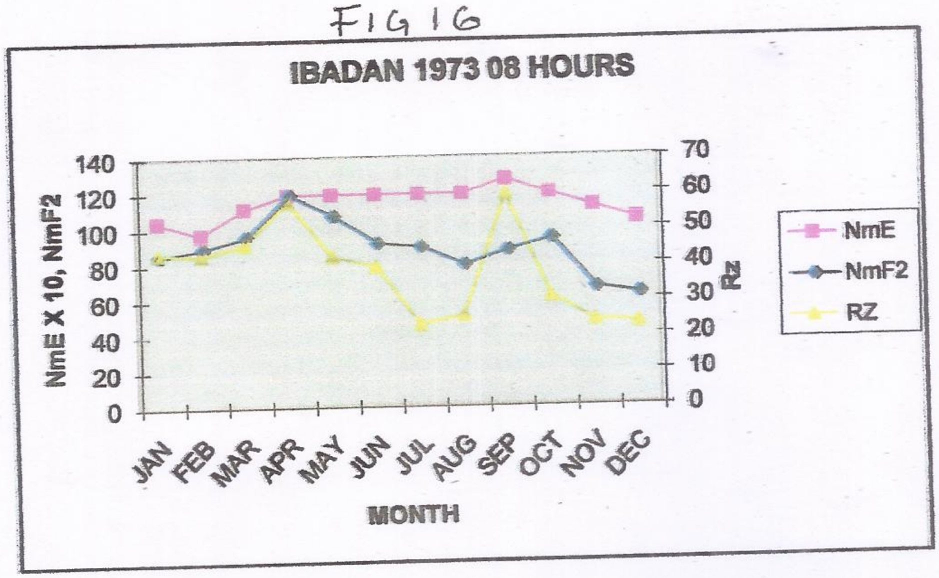

IBADAN 1973 07 HOURS
NmE X 10, NmF2
Rz
MONTH
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
NmE
NmF2
RZ

FIG 15

FIG 16


IBADAN 1973 08 HOURS
NmE X 10, NmF2
Rz
0
20
40
60
80
100
120
140
0
10
20
30
40
50
60
70
JAN
FEB
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SEP
OCT
NOV
DEC
MONTH
NmE
NmF2
RZ

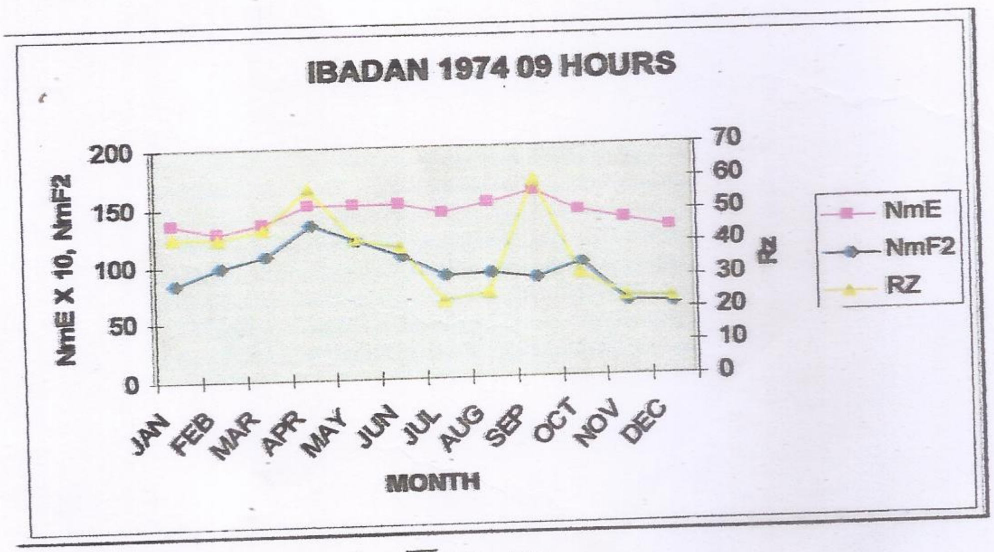
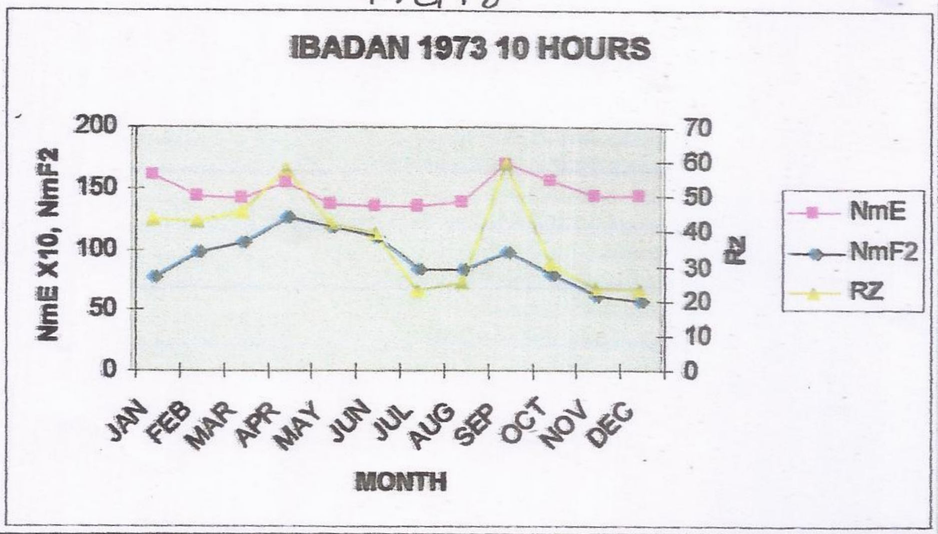

IBADAN 1974 09 HOURS
NmE X 10, NmF2
Rz
0
50
100
150
200
0
10
20
30
40
50
60
70
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH
NmE
NmF2
RZ

FIG 17

FIG 18


IBADAN 1973 10 HOURS
NmE X10, NmF2
Rz
NmE
NmF2
RZ
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH

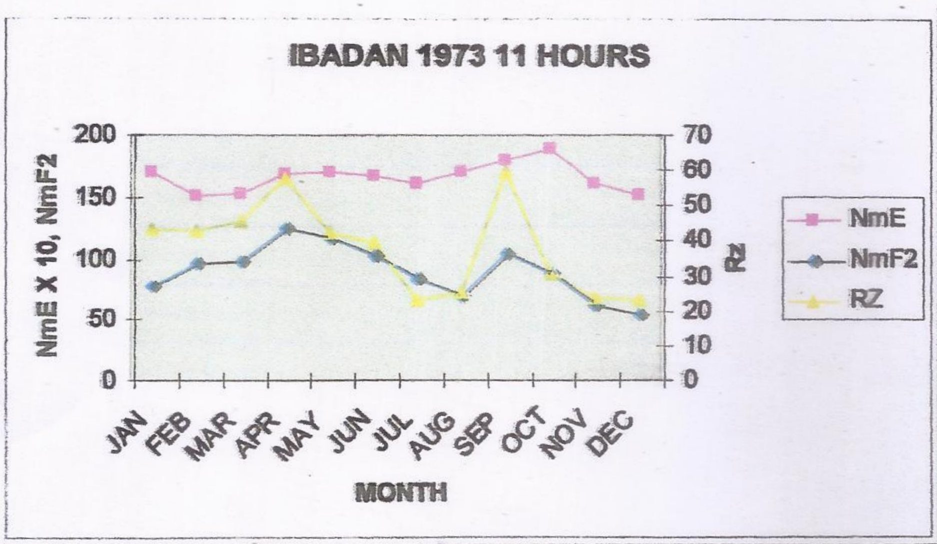
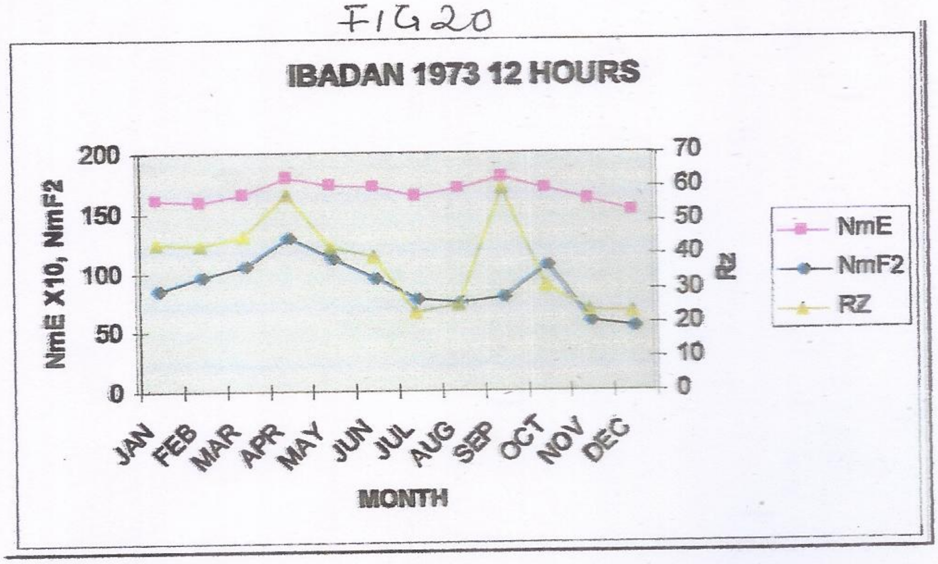

IBADAN 1973 11 HOURS
NmE X 10, NmF2
Rz
NmE
NmF2
RZ
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH

FIG19

FIG 20


IBADAN 1973 12 HOURS
NmE X10, NmF2
Rz
NmE
NmF2
RZ
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH

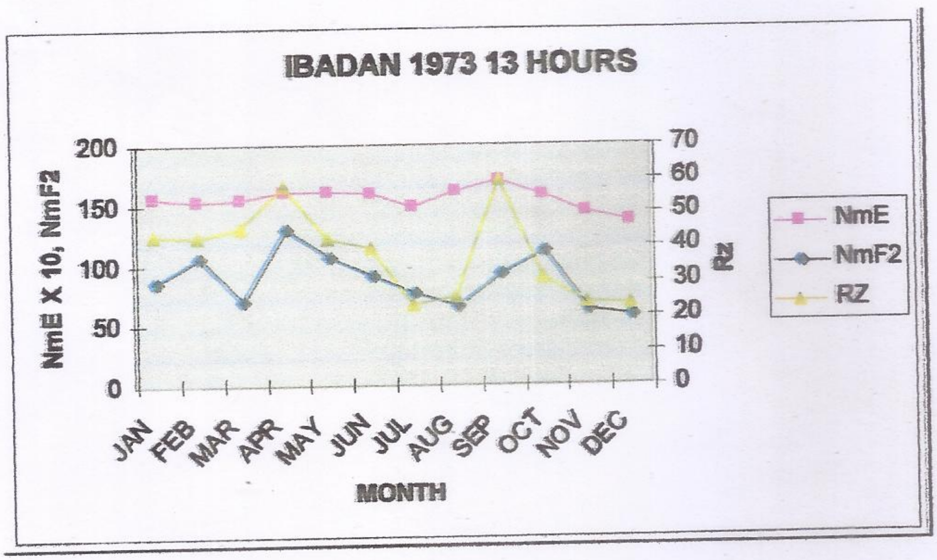
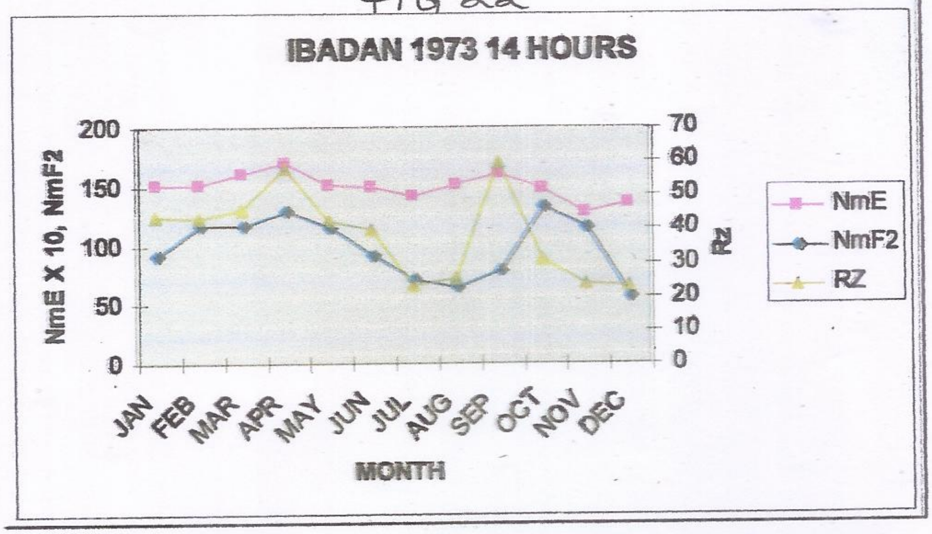

IBADAN 1973 13 HOURS
NmE X 10, NmF2
Rz
NmE
NmF2
RZ
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH

FIG 21

FIG 22


IBADAN 1973 14 HOURS
NmE X 10, NmF2
200
150
100
50
0
70
60
50
40
30
20
10
0
Rz
NmE
NmF2
RZ
JAN
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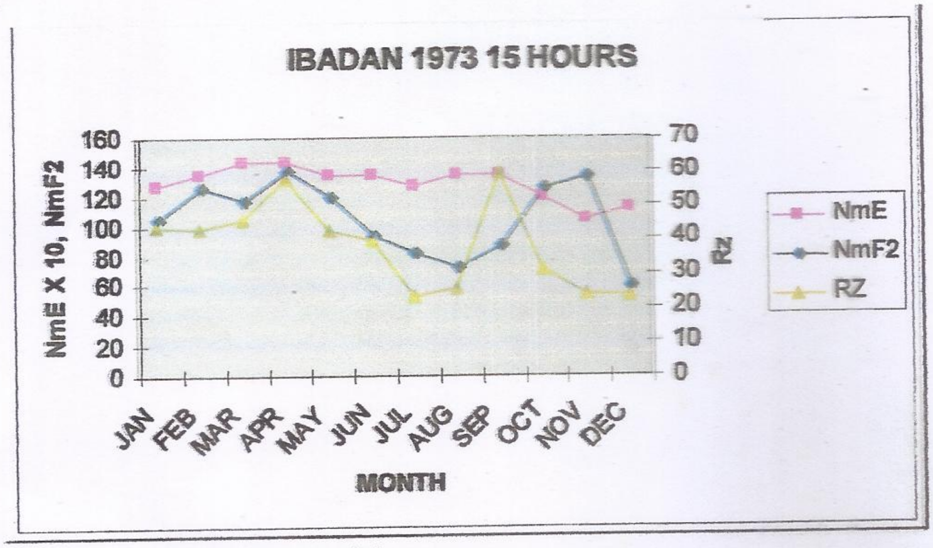
SEP
OCT
NOV
DEC
MONTH


IBADAN 1973 15 HOURS
NmE X 10, NmF2
160
140
120
100
80
60
40
20
0
70
60
50
40
30
20
10
0
Rz
NmE
NmF2
RZ
JAN
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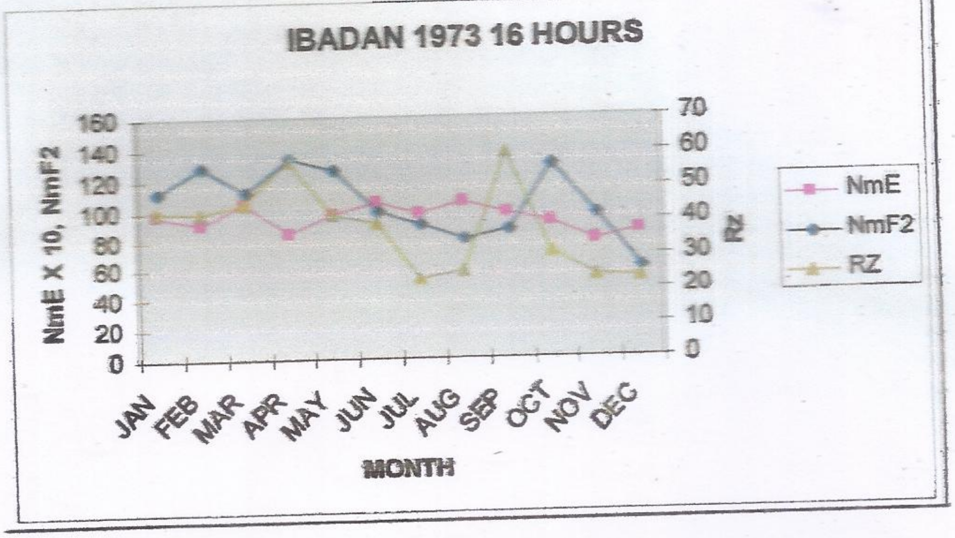
SEP
OCT
NOV
DEC
MONTH

FIG 23

FIG 24


IBADAN 1973 16 HOURS
NmE X 10, NmF2
Rz
MONTH
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
NmE
NmF2
RZ

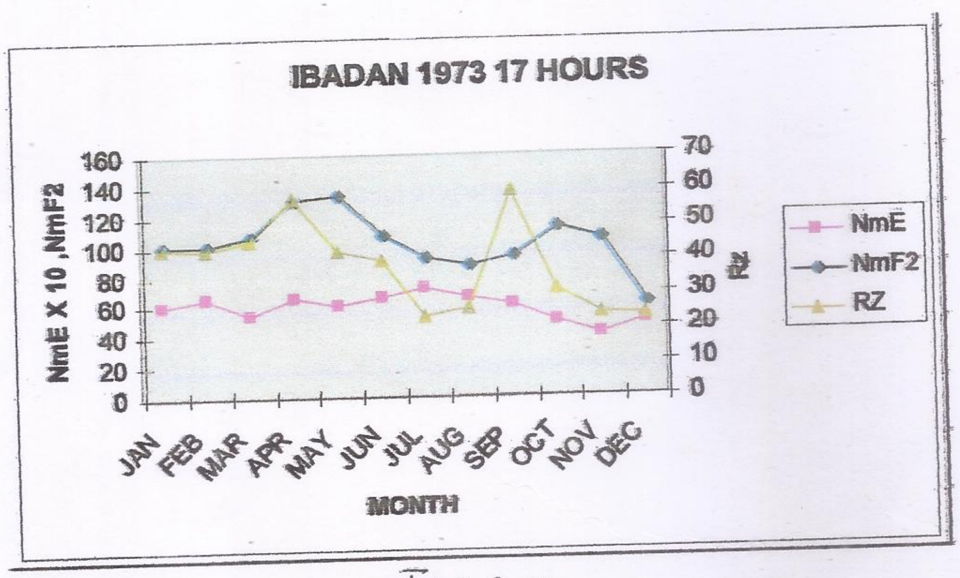

IBADAN 1973 17 HOURS
NmE X 10 ,NmF2
Rz
MONTH
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
NmE
NmF2
RZ

FIG25

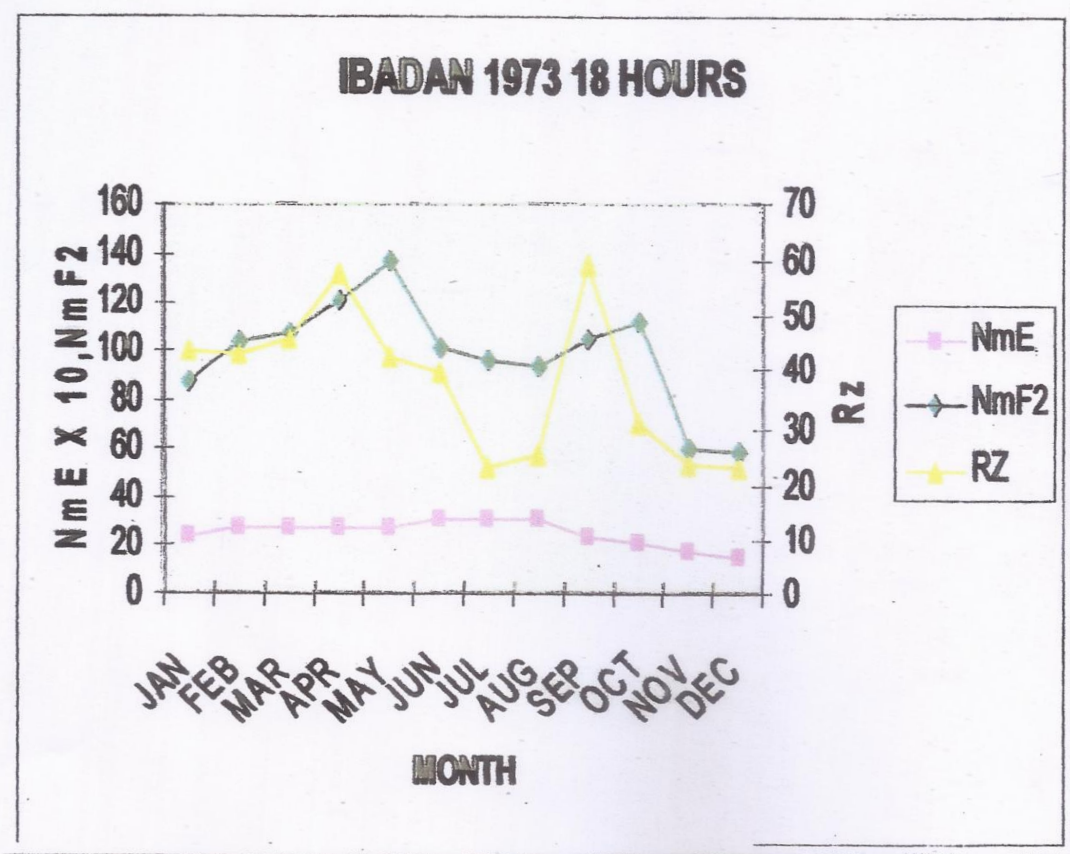

IBADAN 1973 18 HOURS
160
140
120
100
80
60
40
20
0
NmE X 10, NmF2
70
60
50
40
30
20
10
0
Rz
NmE
NmF2
RZ
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

FIG 26

Diurnal variation in the response of NmE and NmF2 to solar activity in 1958 at Ibadan

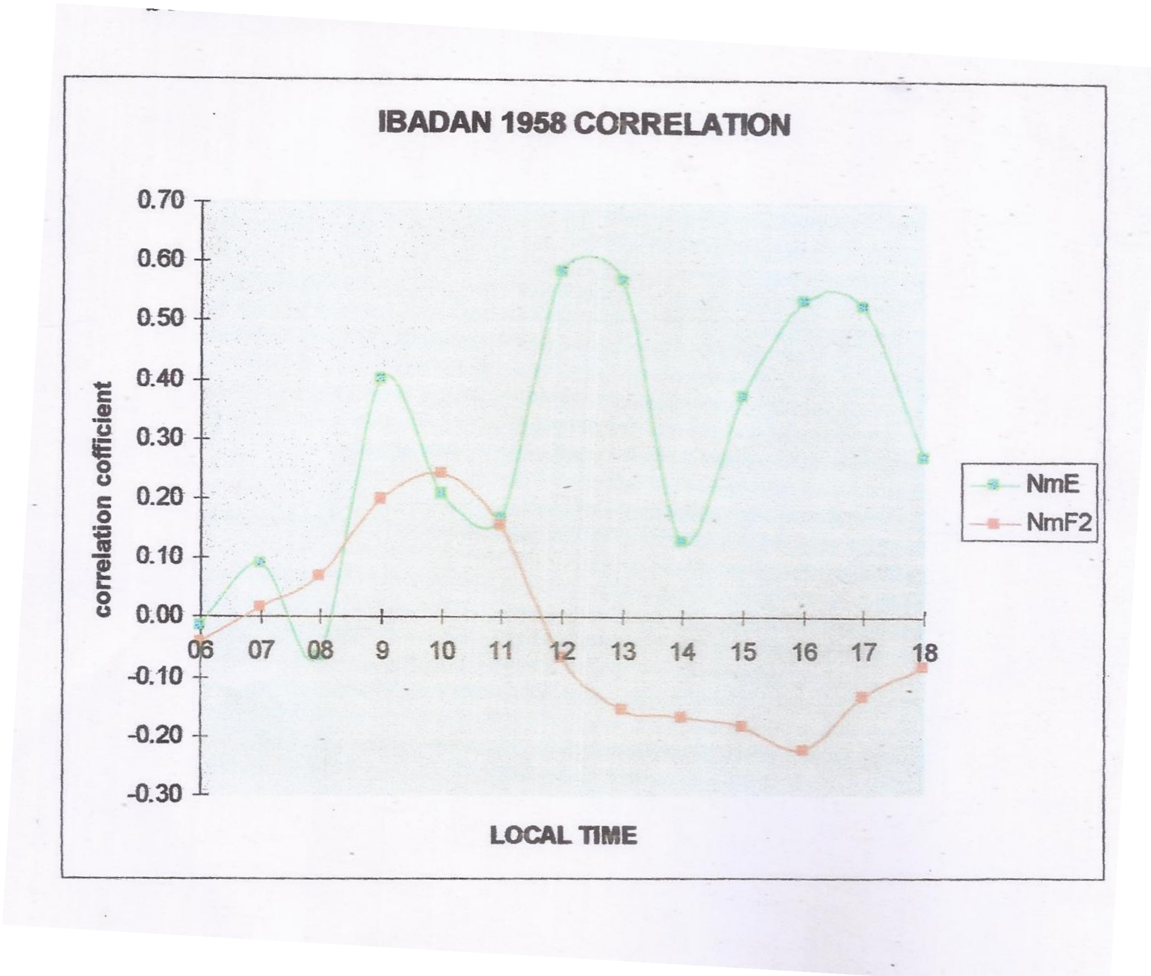


FIGURE 27

Figure 27 in which the diurnal variation of the correlation coefficient between NmE and sunspot number, Rz and between NmE and Rz for Ibadan during 1958 is illustrated.

It shows that NnF2 increases with sunspot number Rz between 06h and 10h. NmE is observed to increase or decrease alternately with Rz. The mean correlation coefficient r for NmE is 0.29 while that of NmF2 is – 0.0278. NmE therefore is found to respond better to Variation in sunpot number Rz than NmF2, since a positive relationship exists between Rz and NmE while a negative relationship exists between Rz and NmF2.

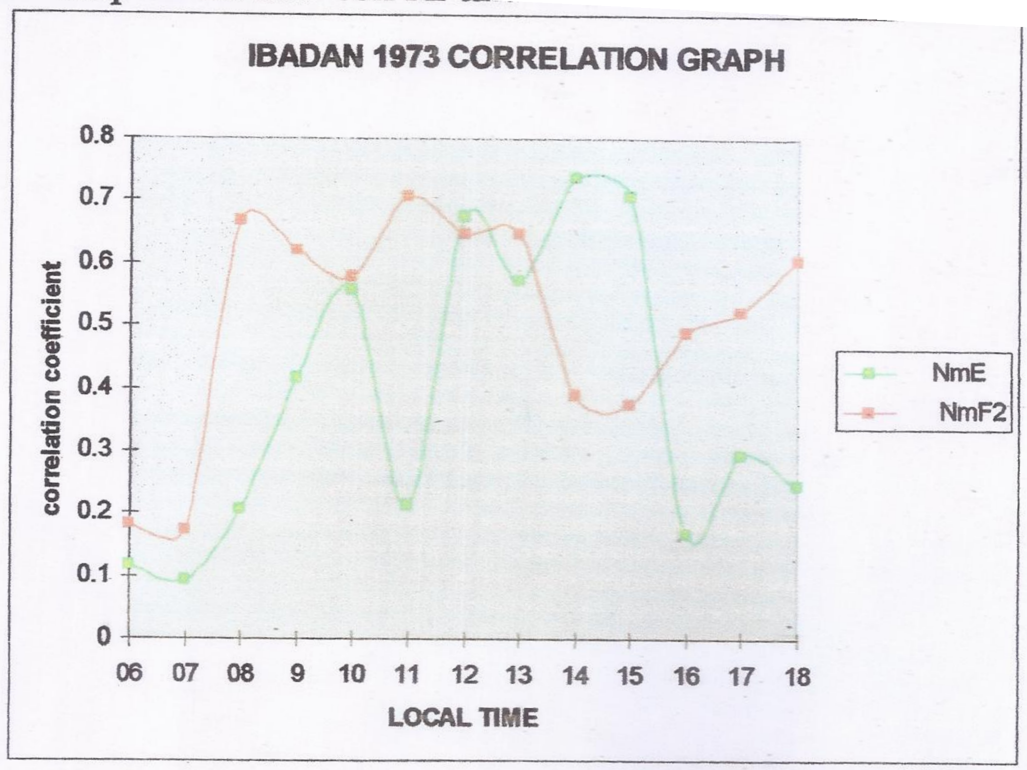


FIG.28

During 1973, the diurnal variation of the correlation coefficient of NmE and NmF2 with Rz (see figure 28) shows that NmF2 increase or decreases alternately with Rz.

NmE is also found to increase or decrease alternately with Rz.

The mean correlation coefficient r between NmE and Rz is 0.385 while that of NmF2 is 0.508.

NmF2 therefore responds better to variation in sunspot number Rz than NmE, though a positive relationship exists between both NmF2 and NmE, with Rz.

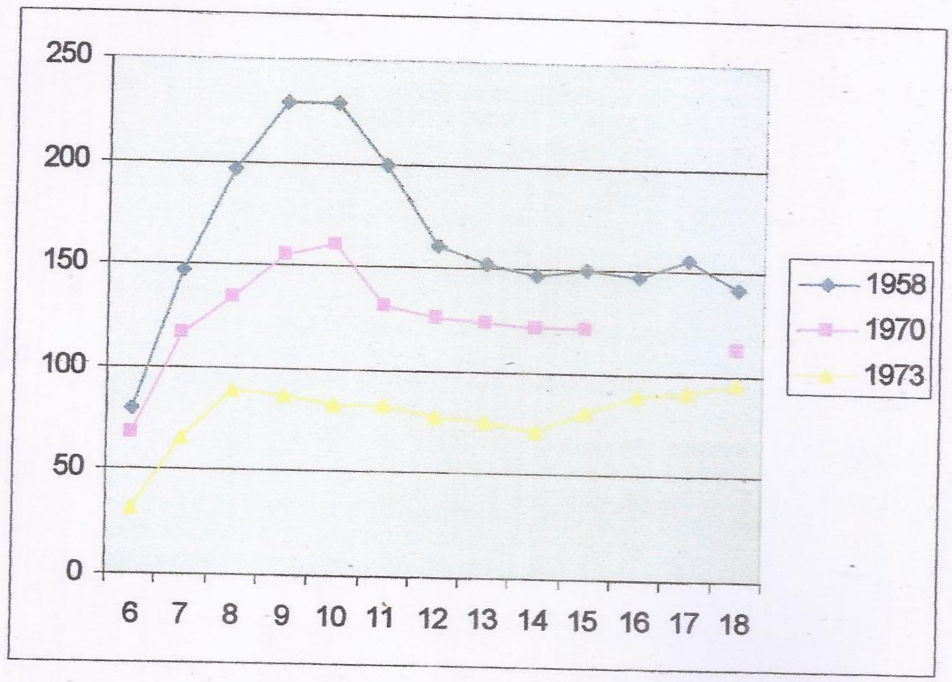


Fig.29

Diurnal variation of NmF2 and NmE of July 1958, 1970 and 1973 at Ibadan

From figure 29, the values of NmF2 are found to be high during years of high solar activity and low during years of low solar activity. The peak value of NmF2 are between 09h and 10h.

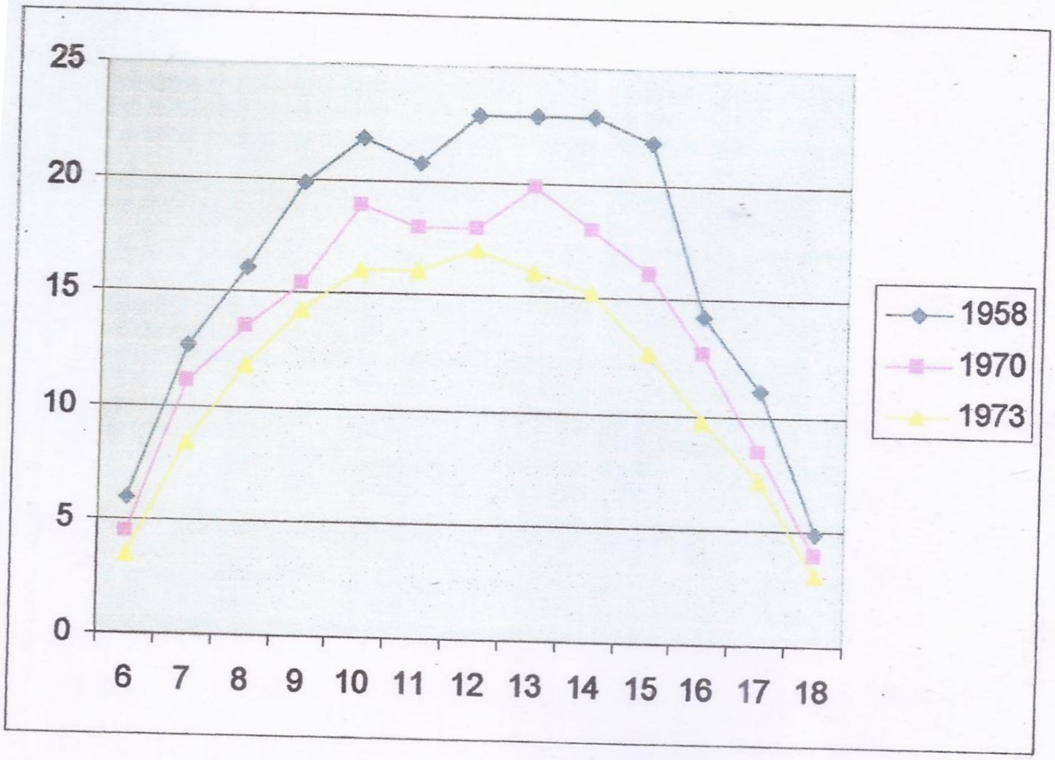


FIG 30

FIG 30 shows the diurnal NmE variation For July 1958; 1970 and 1973. From the graph the following results were obtained:

(a) The values of NmE are high during years of high solar activity and low solar activity.

(b) It therefore shows that both NmF2 and NmE varies with change in sunspot number Rz.

(c) In the years under consideration the peak values of NmE were obtained between 11h and 15h.

GENERAL DISCUSSION

1. Nmf2 was found to respond better than NmE at the three stations. This does not contradict [6] who said that FoE responds better to sunspot number than foF2.
2. NmF2 to solar activity responds better at Singapore and Slough than at Ibadan. This is probably due to the more variable F- region electron dynamics at equatorial station of Ibadan
3. NmE responds better at Ibadan and Singapore than Slough. This may be due to slight decrease of NmE at temperate Latitude and a slight enhancement of NmE at equatorial Latitude by Sq current [7].

Enhancement in equatorial NmE is due to vertical drift of electrons as a result of E-W electric field present in the E region [8]. The Sq current is known to increase with solar cycle.

CONCLUSION

1. For Slough, Ibadan and Singapore, NrnF2 response is greater at noon and sunset than in the morning than at other hours.
2. In the three stations the response of NmE is greatest around noon.
3. Nmf2 was found to respond better than NmE at the three stations. This does not contradict [8] who said that FoE responds better to sunspot number than fof2.
4. NmF2 to solar activity responds better at Singapore arid Slough than at Ibadan. This is probably due to the more variable F- region electron dynamics at equatorial station of Ibadan
5. NmE responds better at Ibadan and Singapore than Slough. This may be due to slight decrease of NmE at temperate Latitude and a slight enhancement of NmE at equatorial Latitude by Sq current [9].

Enhancement in equatorial NmE is due to vertical drift of electrons as a result of E-W electric field present in the E region [10]. The Sq current is known to increase with solar cycle

6. NmF2 and NmE values depend on the sunspot number Rz. The values of both show a positive correlation with sunspot number Rz at the three Stations. The mean values of both Nmf2 and NmE were found to be higher during years of high solar activity and lower during years of moderate and low solar activity.

REFERENCES

1. Adeniyi, J. O. (1980). A study of some features of the equatorial ionosphere on magnetically quiet and disturbed days. PhD Thesis University of Ibadan.
2. Appleton, E. V. (1960). Some Ionospheric results obtained during the I.G.Y (Edited by Beyon W. J. C) p. Elsevier Amsterdam.
3. Balfour, S. (1882). Encyclopedia Britannica, published by Williams's pen ton (copyright 1962) pp. 12, 577.
4. Bandyopadhary p. (1963). Journal of Geophysics Res.68, 2453.
5. Beynon, W. J. G. and Brown, G. M. (1959). Geomagnetic distortion of E- region. Atmospheric terr. physics, 14. pp.138 - 166.
6. Bradley, P. A. (1991). Improvement in mapping the critical frequency of the F2 layer .Adv. space Res.
7. Cable, E. J (1959). The Ionosphere in the physical Science. pub. by Prentice - Hall Inc. Englewood cliffs N. J 4th Edition. pp 114, 499-500
8. Chapman, S. and Bertel, J. (1960). Geomagnetism, Vol.1 p.272 Oxford University Press
9. Heaviside, O. (1902). Ency. Brit. Pub. by Williams Benton.
10. Lockwood, G. E. K. (1983). Sample M. factor algorithm for improved estimation of the basic max. useable freq of radio waves reflected from the atmospheric F region. H. I prod. 130 (4) 296.
11. Marconi, G. (1901). Ency crit. Pub. by William Benton (copyright (1962) pp . 12, 577.
12. Ratcliff, J. A (1960). The Ionosphere in 'physics of the upper Atmosphere (J.A Ratchcliff) pp. 390.Academic press London.
13. Ratchliff, J. A (1960). Morphology of the ionosphere in physics of the upper atmosphere (J.A Ratcliff) pp. 160 - 186 Academic Press London.
14. Risbeth, H. and Garriot, O. K. (1969). Introduction to ionospheric Physics. Academic Press N.Y London.
15. Somoye, E. O. (1984). Statistical study of the critical frequency of the ionospheric region.M.sc Thesis P.59