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Growth and Yield Response of Irish Potato *(Solanum Tuberosum)* to Climate in Jos-South, Plateau State, Nigeria

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Keywords : *climate, irish potato, sprouting, tuber bulking.*

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Growth and Yield Response of Irish Potato (*Solanum Tuberosum)* to Climate in Jos-South, Plateau State, Nigeria

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Abstract - The study investigates the response of Irish potato to some climate variables in Jos-South Local Government Area of Plateau State, Nigeria. The data collected include yield of Irish potato, in tons per hectare, and climatic data for twenty years (1989-2009). These data were analyzed using descriptive statistics in Statistical Package for Social Sciences (SPSS) and later on subjected to correlation and regression statistical techniques so as to determine the relationship between yield of Irish Potato and climatic elements for different phenological stages of crop growth. The results show that there is no significant variation in most of the agro-climatic data between the different years. High variations in the values of agro-climatic are only found within total rainfall, rainfall in July, May, and to some extent, rainfall in April and June. Findings on the correlation analysis show that, at sprouting to emergence/vegetative stage, maximum and minimum temperatures significantly correlate with Irish potato at 1% significance level respectively. Also, total rainfall correlates significantly with yield at tuber set/initiation stage at 5% significance level. In the same vein, minimum temperature significantly correlates with yield at tuber bulking/ripening stage at 1% significant level. Step-wise regression analysis selected two critical elements negatively influencing the yield of Irish Potato in Jos-South. These are minimum temperature at tuber bulking/ripening stage and rainfall in July. The coefficient of determination (R^2) shows that the two variables accounted for 58.1 % of the variation in the yield of Irish Potato. Further studies involving derived climatic indices, for example, precipitation effectiveness need to be undertaken to ascertain the combine effects of climate on Irish potato on the Plateau.

Keywords : climate, irish potato, sprouting, tuber bulking.

I. Introduction

Irish potato (*Solanum tuberosum)* is said to have originated from the highland of Boloivia in South America (Martin and Leonard, 1949; Ifenkwe and Nwokocha, 1987). The spread of the crop outside its centre of origin was mainly by deliberate introduction. The crop moved out of South America to Spain in 1570; to England in 1585; then to Ireland by Spanish explorers from 1963. The crop was grown on a large scale in Ireland and became so popular such that it is not surprising that it acquired the misnomer of "Irish Potato".

In development countries, Irish potato is ranked first in energy production per hectare per day, significantly above cassava and cereals. It is a lover of cool climate and therefore requires a cool growing season with a moderate and well distributed rainfall of about 800mm during growing seasons with no prolonged dry weather. It could be grown under rain-fed condition or irrigated, but waterlogged areas are unsuitable. Temperatures higher than 27^0 C are unfavourable for the production of economic size tubers. Observations have shown that temperature ranges of 21^0C – 26^0C is required for sprouting of the tubers (Ahmed 1980).

Irish potato was introduced into Nigeria early in the 20th Century by European miners in Jos Plateau. Jos Plateau has high altitude and thus, cool climate, which is favourable for the development of the crop. Jos South Local Government Area (LGA) accounts for 25% of the total Irish potato produced in Nigeria (Okonkwo et al 1986; Wuyep 2012). The crop is efficient in converting land, labour, water and capital into a highly nutritious food. This is not surprising if for no other reason than it has a shorter growing cycle of about 95 days than most other tuber crops in the tropics.

Irish potato is an important staple food as well as raw materials for industries. In order to meet the demand for industrial and human consumption, the yield per hectare needs to be improved. Such imminent improvement could be achieved through efficient management and monitoring of agro-climatic parameters, among others. Several studies have been conducted towards improving the yield of Irish potato. For instance, Damkor (1983) based his studies on effect of stem thinning on yield and other vegetative characteristics; Ajala (1981) studied growth development and yield in four varieties of Irish potato; Szlachetha (1982) studied flowering behaviour of some varieties of Irish potato; Sale (1973), Susnochi and Shimshi (1985), Zaag and Burton (1973), and Wolfe et al (1983) carried out a study on water stress and related analysis on different varieties of Irish potato.

In Nigeria, Ifenkwe and Okonkwo (1983) conducted a study on determination of the most suitable

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time to plant Irish potato, while Ifenkwe (1989) did a comparison of flat lands and ridges for dry season planting on potato. Such studies have however, not been usually geared towards determining the relationship between climate and agricultural production, particularly considering Irish potato. There is no doubt that analyzing the effect of climatic elements from the point of view on how they influence our agricultural activities is important in any meaningful plan for increase crop yield. Thus, microclimate studies have become imperative in our studies of the crop-weather relationship in the study area.

Interestingly, the National Root Crop Research Institute (NRCRI), Vom and other agricultural research institutions in Nigeria and abroad have made notable achievements in increasing the yield of Irish potato. The crop breeders have developed varieties of Irish potato, which are capable of responding to improved cultural practices. They have gone a long way towards solving the pests and diseases problems both in the field and storage (Okonkwo 1992). In other to sustain these improvements, an appraisal of climatic parameters affecting Irish potato has become necessary.

In addition, there has been appreciable increase in the land area and output of Irish Potato in the area. This increase could be attributed to advances in agricultural technology such as the introduction and provision of extension services as well as way of diversifying sources of livelihood (Wuyep, 2012). However, despite the advanced techniques used in crop husbandry, the yield of Irish Potato is still variable over time and space in the area. Climate appears to be the major factor influencing the spatio-temporal variations in the yield of Irish potato in this area hence, the need for a research like this so as to unveil the prevailing situation.

II. Study Area and Methods

This study investigates a crop-climate relationship using experimental approach. An experimental farm located at the Headquarters of the National Root Crop Research Institute (NRCRI) Vom, in Jos-South Local Government Area of Plateau state served as source of data for the study. The site lies on latitude of 8^0 43'N and Longitude 8^0 46'E with an altitude of 1293.2m above sea level. Jos-South Local government area is one of the seventeen Local government areas in Plateau state of Nigeria. It is made of four districts; these include Vwang, Du, Gyel and Kuru.

The Local government area has its Headquarters in Bukuru which is located south of Jos-North Local government. It is bounded by Barkin –Ladi Local government to the South, Riyom Local government to the South West, Jos-East Local government to the East and Bassa Local government to the West. The Local government has a population of 650,835 (National Population Commission, NPC 2006) with an average land area of 1, 037km^2.

Two sets of secondary data were collected from the National Root Crop Research Institute (NRCRI) Vom. The first set is agricultural data for Irish Potato yield in tonnes per hectare of the Nicola specie over a period of 20 years (1989 to 2009). The second set of data is the basic agro-climatic variables influencing Irish Potato yield over the same period for the months of April, May, June, July and August. These months constitute the growing season on the Plateau. The final yields of crop are in many cases dependent on satisfactory growth during earlier stages of crop development. In all nine climatic parameters collected during the growing season were analyzed with a view to estimating their contribution to yield of Irish potato. These comprise three critical climatic data including rainfall; air temperature and soil temperature. Rainfall data were classified into total rainfall and rainfall amounts in April, May, June, July and August. Rainfall from April to August constitutes the rainy season in the study area. Temperature data were categorized into minimum and maximum temperatures. These data were analyzed and subjected to different statistical techniques, including correlation coefficient and multiple regressions.

In order to select the agro-climatic indices that are critical to the yield of Irish Potato, a step- wise multiple regression analysis was adopted. The yields were expressed as dependent variables (Y) and climatic indices as independent variables (X). The general form of the multiple regression equation is presented as follow:

$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + \ldots + b_nx_n$, where,

Y = Irish potato yield in ton/ha

a = constants

b = is the rise or falls as X increases

X_1 = total rainfall (mm)

X_2 = maximum temperature ^OC

X_3 = minimum temperature ^OC

X_4 = soil temperature ^oC

X_5 = Rainfall in April

X_6 = Rainfall in May

X_7 = Rainfall in June

X_8 = Rainfall in July

X_9 = Rainfall in August

III. Results and Discussions

Results and discussions in this study are considered under three sections. The first section treats the characteristics of the agro-climatic variables. This section was analyzed using descriptive statistics. The second section presents the relationship between agro-climatic variables and yield of Irish potato while the third section discusses the critical agro-climatic factors influencing the yield of Irish potato on the Plateau.

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a) Characteristics of Agro-Climatic Parameters

The descriptive statistics of the agro-climatic variables (Table 1) were derived using SPSS statistical package. The mean total rainfall (692.62mm) meets up with the requirement for Irish potato production. However, there is high variation between the annual data as seen in the results for range (196.80) and variance (3182.42). The average minimum and maximum temperatures of 24.82 ^{0}C and 18.85 ^{0}C respectively are within the range required by Irish potato crop. The standard deviation of 0.6 and variance of 0.4 in both cases means that there is less dispersion within the values. Soil temperature has similar pattern of variation like air temperature. With a standard deviation and variance of 0.6 and 0.4 respectively, it means that the element portrays a near uniform characteristics throughout the growing season on the Plateau.

Table 1 : Descriptive Statistics of Climatic Variables and Yield of Irish Potato (1989 – 2008)

Variables	N	Range	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
Total Rainfall (mm)	20	196.80	575.30	772.10	13852.30	692.62	56.41	3182.42
Mean Max. Temperature (^{0}C)	20	2.60	23.30	25.90	496.40	24.82	0.601	0.36
Mean Min. Temperature (^{0}C)	20	2.00	17.80	19.80	376.90	18.85	0.59	0.35
Mean Soil Temperature (^{0}C)	20	2.40	23.40	25.80	491.70	24.59	0.63	0.40
Mean Rainfall in April	20	55.60	40.30	95.90	1383.40	69.17	18.23	332.40
Mean Rainfall in May	20	70.30	126.10	196.40	3155.90	157.80	22.89	524.14
Mean Rainfall in June	20	50.80	129.30	180.10	3129.20	156.46	12.48	155.83
Mean Rainfall in July	20	99.20	213.10	312.30	5279.40	263.97	25.97	674.46
Mean Rainfall in Aug.	20	21.40	30.00	51.40	821.60	41.08	6.58	43.23
Yield (tonnes/hectare)	20	8.70	11.10	19.80	286.50	14.33	1.99	3.94
Valid N (listwise)	20							

Source: Calculated from the agro-climatic data used for the study

There seems to be high variability only in April to August rainfall amounts between the years. This variation tends to be more in the months of July and May, while the month of August exhibits a lower variation (3.94) in rainfall amounts within the 20 years considered. It can therefore be concluded that the variations in the agro-climatic data presented above is partly responsible for the nature of variations in the yield of Irish potato in the area. The standard deviation and variance of 1.99 and 3.94 respectively, for the yield of Irish potato is relatively high. This calls for further probe into these factors so as to determine the degree of contributions of each of these factors. It is on the basis of this that the use of correlation and regression analysis was employed to determine the contribution of these factors to growth and yield of Irish potato.

b) Agro-Climatological Factors and Irish Potato

At the various stages of Irish potato development, striking findings were observed (Table 1). For examples, the result of the correlation analysis between yield and the climatic parameters at sprouting to emergence stage revealed that maximum temperature and minimum temperature have significant correlations ($r = 0.594$ and $r = 0.548$ respectively) with Irish potato yield, at 1% probability level. This indicates that, temperature range of 21-26^{0}C is good for sprouting of Irish potato. This consequently, plays a vital role in determining higher yield obtained on the plateau. The high correlation obtained in this study confirms the assertion made by Ahmed (1980) that temperature ranges of 21-26^{0}C is required for sprouting of tubers. He reported that a shift in temperature range of 21^{0}C - 26^{0}C at sprouting to emergence/vegetative stage may often induce knobbiness and secondary growth in tubers and consequently affects the yield negatively.

At the tuber set initiation, total rainfall was found to correlate significantly ($r = 0.470$) with Irish potato at 5% probability level .This signifies the importance of moisture during the tuber set/initiation stage. It confirms the findings of Levi (1999) and Eliot (2007) that precipitation is significant and positively correlated at tuber set/initiation stage with Irish potato in Ireland. The plants require more frequent supply of rainfall than many other tuber crops. It is the moisture and nutrient within this stage that is useful to the plant. Water is required for transpiration and regulation of leaves temperature (Burton 1989).

However, at the tuber bulking or ripening stage, minimum temperature was discovered to correlate negatively ($r = -0.616$) at 1% probability with Irish potato. This shows that the lower the temperature during this stage, the higher the yield will be. This result confirms the assertions made by Levi (1999) and Eliot (2007) that minimum temperature of 15^{0}C at tuber bulking stage positively correlates with Irish potato yield in Ireland. Lopez et al (1987) also stated that at bulking stage minimum temperature should not exceed 15^{o}c for

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maximum yield, and that tuber decreases with increasing temperature at tuber bulking stage.

Furthermore, Kochalar (1991) reported that the minimum temperature of 15^{0}C is required for tuber bulking, while Ochigbo (1993) observed that low temperature is more conducive to tuber growth at bulking stage and economic tuber production occurs when the average temperature falls below 15^{0}C. More importantly, Ifenkwe and Okonkwo (1983) stated that, under irrigation, Irish potato production should coincide with the coldest month (November – January) so that the time of tuber bulking will coincide with the period of low temperature. Shimshe's (1986) finding corroborated this when he reported that once there is fluctuation in minimum temperature, it enhances rottenness and malformation in tuberization.

Results for the total growing season indicate that Irish potato yield is significantly correlated with two of the variables (rainfall in April and July) at 1% probability level. Rainfall in April has high correlation(r=0.599**) with Irish potato yield. This indicates that the higher the amount of rainfall in April, the higher will be the yield of Irish potato. It signifies the importance of rainfall during the sprouting to emergence/vegetative stage, which is a measure, to some extent, of the soil moisture available at emergence. During the raining season time of planting depends on the onset of rains (Ifenkwe and Okonkwo, 1983). In Jos-South, Irish potato is planted when rain becomes stable usually between the last week of April and first week of May. This result has collaborated Kowal and Andrew (1973) that the antecedent moisture status of the soil at planting is important for good germination or sustained growth of seedlings which may have effect on the final yield.

Rainfall amount in July, with a correlation coefficient of -0.665, also its high relationship with Irish potato yield, though negatively, at 1% level of significance. This indicates that, the higher the amount of rainfall in July, the lower the yield will be. This is not surprising because July coincides with tuber bulking /ripening stage. The higher correlation obtained in this study confirms the assertion by Zaag et, al (1981) that excess soil moisture at tuber bulking/ripening stage causes poor soil aeration and root damage which influence crop development and yield. It further confirms the work of Nwakocha (1987) that blight causes between 40-80% reductions in yield. The peak incidence is between July and August when the haulm of most susceptible varieties are destroyed by inciting pathogen *phythopthora*. The disease is accompanied by high relative humidity, dew and frequent rainfall (Hienfling 1987).

Table 2 : Results of Correlation of Climatic Elements with Irish Potato Yield at Various Phonological Stages

Climatic element	Sprouting to emergence/Vegetative	Tuber set/initiation	Tuber bulking/ripening	Total growing season
X_1=Total rainfall(mm)	0.332	0.470*	-O.122	O.333
X_2= max. Temp. ^{0}C	0.594**	0.202	0.412	0.250
X_3= min. temp. ^{0}C	0.548**	0.219	-0.616**	0.300
X_4= soil temp. ^{0}C	-0.041	-0.335	-0.097	0.362
X_5= Rainfall in April	-	-	-	0.599**
X_6=Rainfall in may	-	-	-	0.014
X_7= Rainfall in June	-	-	-	0.306
X_8= rainfall in July	-	-	-	-0.665**
X_9= rainfall in August	-	-	-	-0.391

** Significant at 1% r = 0.530 *Significant at 5% r = 0.430

c) Combine Effects of Agro-climatic Parameters on Irish potato Yield

The result of the bivariate correlation discussed above only depicted the isolated relationship between the climatic variables and Irish potato yield. It does not indicate the level of importance of such climatic variable influencing yield. Therefore, in order to identify clearly those climatic variables that are critical to Irish potato production, those five climatic parameters that were found to have contributed significantly during the three stages of growth were further subjected to step-wise regression analysis

Table 3 therefore, shows the result of the step-wise regression analysis. Only those climatic parameters which contribute significantly (at P< or = 0.01) to variation in Irish potato yield are included in the analysis. Two out of the nine observed climatic factors considered were found to have contributed significantly to the variation in the yield of Irish potato in Jos-South. These indices are rainfall in July and minimum temperature at tuber bulking/ripening stage. The two variables together accounted for 58.1% of the total variance in Irish potato yield in the area. Rainfall in July has the highest contribution of 44.25% to yield variation and minimum temperature contributed 13.85% to yield variation.

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Table 3 : Step-wise Regression of the Agro-Climatic Parameters on Irish Potato Yield

Variables	Partial R^2	Model R^2	T	P > t	F - ratio
X_8 = Rainfall in July	44.25	44.25	2.86	0.01	11.78
X_3 = minimum temperature at tuber bulking stage	13.85	58.1	2.37	0.03	

IV. Conclusions

The conclusion drawn from the findings of this study is that total rainfall, maximum temperature, minimum temperature, rainfall in April, rainfall in July all correlate significantly with Irish potato at various stages of the crop's development. This means that the crop depends on these factors for better growth and yield. However, minimum temperature and rainfall in July are the most critical climatic element affecting the yield of Irish potato in the study area. These findings have underscored the importance of agro-climatic parameters as critical factors controlling crops growth and yield in Jos- South and in plateau State. It was also discovered that late blight disease contributes significantly in reducing the crop yield.

V. Recommendations

Based on the findings of this study, the following recommendations are presented:

i. The present planting period for Irish potato is found suitable and should be maintained. This will help to maximize the advantage of minimum, maximum temperature and rainfall in April for the sprouting to emergence or vegetative stage and minimum temperature at tuber bulking stage.
ii. More weather stations should be established in areas where none existed so as to facilitate generating climatic data all over the area to provide information for long term planning of agricultural development in the area.
iii. Late blight resistant varieties of Irish potato should be developed in order to eradicate late-blight diseases which reduce the yield of Irish potato.
iv. This study only considered basic climatic elements of rainfall, air temperature and soil temperature. Subsequent studies should encompass all climatic variables, especially the derived data such as onset dates of rains, dry spell or drought etc.

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