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INTER-RELATIONSHIPS BETWEEN YIELD AND YIELD ATTRIBUTES OF POTATO GROWN UNDER SUPRA-OPTIMAL AMBIENT TEMPERATURES

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ABSTRACT

Forty eight potato genotypes were evaluated in Saminaka (Lat. 10^0 27'N and Long 4^0E, Mean Min. Temp 25°C, Mean Max Temp 31.5°C) during the rainy season of 1999 and 2000 to determine the inter-relationship between yield and some important agronomic traits in the potato grown under high ambient temperatures. The genotypes were laid out in a randomized complete block design with three replications. The genotypes exhibited highly significant variability ($P<0.01$) for all traits assessed. Tuber yield was positively associated with number of stems/plant ($r = 0.246$, $P<0.05$); plant height ($r = 0.206$, $P<0.05$); and number of leaves/plant ($r = 0.237$, $P<0.05$). Both the correlation and regression of yield on days to tuber initiation and days to maturity were negative and significant. This suggests that earliness in tuber initiation and maturity led to increased yield under supra optimal temperature probably due to reduced period of exposure to heat stress. Number of tubers per plant ($R^2 = 0.383$) and average tuber weight per plant ($R^2 = 0.125$) had the highest coefficients of determination of yield and by far the highest direct effects on yield (87.5% and 66.9%respectively) when compared to other attributes suggesting that they were the major contributors to yield under supra-optimal temperature conditions and may be relied upon in selecting for improved yield under such conditions.

KEYWORDS: Potato, genotypes, supra-optimal temperature, tuber yield, selection

INTRODUCTION

The Potato *Solanum tuberosum L* is generally best adapted to cool temperate zones (Hawkes, 1978). The optimum temperature for tuber formation and growth for most potato cultivars is about 15-20°C (Borah and Milthorpe, 1962). In tropical lowland parts of Africa, potatoes are exposed to day and night temperatures far above the optimum. Almost all potato cultivars bred in northern latitudes respond to such conditions with delayed emergence (Allen, *et al*. 1992), excessive haulm growth at the expense of the tubers (Ewing, 1981), increased rate of respiration (Sale, 1974), reduced dry matter accumulation (Bushnell, 1925), delayed tuber initiation (Menzel, 1980, Nowak and Coleborne, 1989) and maturity (Amadi, 2005) and a significant loss of tuber yield and quality (Levy, 1983, 1984). The adverse effect of high temperature on tuber yield and quality of potato is a major constraint for potato production in hot regions, and local breeding for heat tolerant cultivar is necessary to improve potato crops in hot environment (Levy, 1984). Analysis of the inter-relationship among important agronomic characters in the available germplasm is vital to the attainment of the objective of breeding for heat tolerance. The objective of this work is to furnish information on the inter-relationship between yield and yield components with a view to identifying characters of utmost importance which can be used as selection indices for tuber yield improvement in the potato germplasm exposed to heat stress prevalent in locations with supra optimal temperatures.

MATERIALS AND METHODS

Field experiments were carried out in Saminaka during the rainy season of 1999 and 2000. Saminaka is situated at Lat. 10^0 27'N and Long 4^0E in Kaduna State of Nigeria. Ambient temperature and rainfall data of Saminaka for the relevant months covering the duration of the experiment in 1999 and 2000 are shown in Fig 1. Forty-eight potato genotypes were evaluated. These genotypes were laid out in a randomized complete block design with 3 replications. Net plot size was $6m^2$ and gross plot size was $12m^2$. The seed tubers were planted at the rate of 1 tuber per stand, inter-row spacing of 1m and an intra-row spacing of 30cm giving a plant density of 33,333 plants per hectare. Weeding was carried out manually at 4 and 8 weeks after planting (WAP). Fertilizer was applied by band placement at the rate of 100kg N, 100kg P_20_5 and 40kg K_20 per hectare two weeks after planting. No fungicides were applied. The plants were harvested when the leaves began to senesce. *Desiree*, a cultivar well known for some degree of heat tolerance (Midmore, 1984) was used as a check.

Data were collected on the following attributes: seedling emergence at 4 WAP, number of stems per plant, plant height (cm), number of leaves per plant,

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days to tuber initiation, days to maturity, severity of early blight, number of wilted stands, number of tubers per plant, average tuber weight/plant, and tuber yield per plant. These attributes were measured as follows

Seedling emergence:- Emergence per plot was recorded at 4 weeks after planting by counting the number of stands whose shoots have broken though the soil surface.

Number of stems per plant:- Only the main stems i.e. those originating from the mother tubers were counted. The record was taken at full flowering.

Plant height (cm):- Plant height was obtained by measuring from the base of the plant to the apical bud. The measurement was taken at the 8th week after planting.

Number of leaves per plant:- The compound leaves from the base to the tip of the plants counted at 8 weeks after planting.

Days to tuber initiation:- This was counted from planting to the time when the first tuber is initiated by any plant in the plot. A plant was considered to have formed tubers when the swelling at the end of the stolon was twice by visual estimates the diameter of its stolon. To observe this the soil around the base of the plants were carefully removed to expose the stolon and replaced after observation.

Days to maturity:- This was obtained by counting the number of days from planting to the time when less than 50% of the canopy remain green.

Early blight severity:- Early blight severity was recorded at 10 weeks after planting based on a scale developed by Martin and Thurston, (1987). The scale ranges from 1 to 9 with a mid point of 4.

1	=	No blight spots seen on the foliage
4	=	25 –50% of the foliage infected by blight
9	=	foliage completely covered/killed by blight.

Incidence of bacterial wilt:- The number of stands with bacterial wilt symptoms per plot.
Number of tubers per plant:- This was obtained by counting the whole tubers produced by a plant
Average tuber weight per plant:- This was obtained by dividing the total weight of the tubers produced by each sampled plant by the number of tubers
Tuber yield:- The total weight of tubers/plant
Statistical analysis was performed on plot means for all attributes. Analysis of variance, regression analysis, multiple correlation and regression were carried out using the STATVIEW for windows software. Simple correlation analysis was carried out according to the method outlined by Gomez and Gomez, (1984) where
$r = \sum xy / \sqrt{(\sum x2)(\sum y2)}$

Path-coefficient analysis was carried out according to the method outlined by Dewey and Lu (1959).

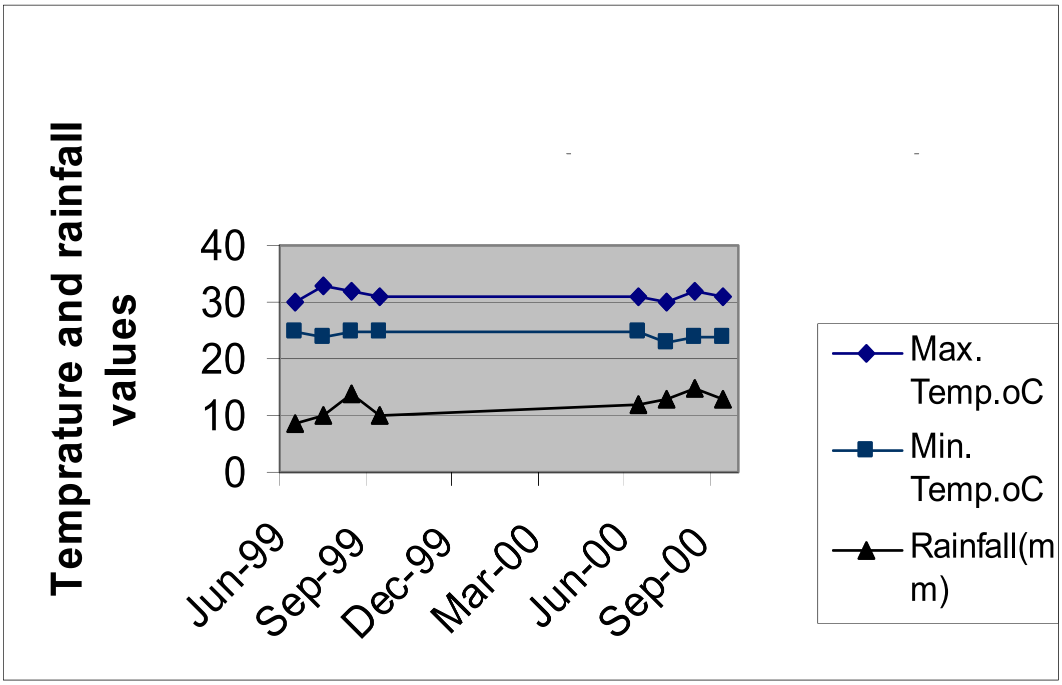

Fig. 1: Temperature and rainfall data of Saminaka (1999 and 2000)

RESULTS AND DISCUSSION

Analysis of variance

The analysis of variance (ANOVA) is summarized in Table 1. The mean values of the various attributes are shown in Table 2. There were significant differences between the potato genotypes in all the attributes assessed. Variations among the potato genotypes for different traits have been reported by various authors (Sidhu and Pandita, 1979; and Birhman and Kang, 1993). Highly significant variability in plant attributes within a population suggests the existence of sufficient variability upon which selection for improvement in these attributes can be based.

Table1: Values of sum of squares (SS), mean squares (MS) and variance ratios (VR) from ANOVA for plant attributes in Saminaka (1999)

Attributes	Source of variation	SS	MS	VR
Plant Emergence	*genotype*	127.97	2.72	2.92***
	error	87.57	0.93	
Number of stems/plant	*genotype*	26.28	0.56	5.18***
	error	10.14	0.11	
Plant height	*genotype*	6729.07	143.17	18.49***
	error	727.97	7.74	
Number of leaves/plant	*genotype*	55193.47	1174.33	55.60***
	error	1985.54	21.12	
Days to tuber initiation	*genotype*	2762.89	58.79	2841.83***
	error	1.94	0.02	
Days to maturity	*genotype*	2706.64	57.59	233.81***
	error	23.15	0.25	
Early blight severity	*genotype*	51.97	1.11	21.20***
	error	4.90	0.05	
Number of wilted stands	*genotype*	80.33	1.71	3.64***
	error	44.15	0.47	
Number of tubers/plant	*genotype*	154.73	3.29	3.49***
	error	88.81	0.95	
Average tuber weight	*genotype*	9129.50	194.25	3.37***
	error	5414.38	57.60	
Tuber Yield/plant (g)	*genotype*	191922.57	4083.46	3.14***
	error	122457.76	1302.74	

Table 2: Mean for various potato plant attributes studied at Saminaka the year 2000

Genotype	%Emergence (4WAP)	Number of Stems/ plant	Plant height (cm)	Number of leaves /plant	Days to Tuber Initiation	Days to maturity	Early blight severity	Number of wilted stands/m^2	Number Tuber /plant	Average tuber weight/ plant	Tuber Yield (t/ha)
392286.14	80	1.43	46.1	62.1	49.0	97.0	4.0	1.00	4.8	34.0	5.44
RC7716-17	90	2.03	46.0	41.3	48.0	81.0	5.0	0.89	3.5	38.4	6.28
Nicola	80	1.27	39.3	40.1	50.0	92.0	5.0	0.33	2.3	34.5	2.65
Kondor	73	1.60	46.3	38.1	54.0	94.0	3.0	1.22	4.8	43.0	6.31
391538.3	80	1.30	42.2	52.4	50.0	89.0	3.0	1.22	4.7	32.0	4.76
RC777-8	80	2.40	44.1	53.6	59.0	88.0	3.7	1.11	3.3	39.2	4.28
Baraka	83	1.80	41.6	43.7	46.0	92.0	3.0	0.89	6.0	32.4	6.28
392011.041	67	1.20	45.5	35.8	57.3	91.0	4.0	1.00	2.8	40.8	3.93
RC7716-3	87	1.30	54.3	64.1	51.0	83.3	3.0	1.00	2.6	36.8	3.15
392277.41	90	2.07	50.2	51.5	45.0	85.0	4.0	0.89	7.1	33.1	7.00
392225.047	67	2.50	52.3	47.7	49.0	87.0	3.0	0.89	2.9	56.1	4.65
392287.048	83	1.53	53.3	45.3	58.7	90.0	3.0	1.11	3.2	37.0	3.89
ML98.12	87	1.53	45.2	43.7	49.0	92.0	4.0	1.11	3.1	40.5	3.89
B9449-17	83	1.70	36.5	46.0	54.0	87.7	3.3	0.89	5.2	32.8	5.26
Alpha	63	1.60	43.0	52.7	60.0	98.0	3.0	1.11	2.6	37.2	3.22
392243.048	63	1.53	44.8	41.6	49.0	87.0	3.0	1.33	3.2	35.0	3.54
BR63-18	80	2.40	45.9	33.1	45.0	86.0	4.0	1.78	3.2	47.5	5.15
WC732-1	73	2.63	42.3	87.6	50.0	90.0	4.0	1.67	4.0	39.8	5.65
Greta	63	2.20	43.8	44.3	58.0	94.9	4.0	0.89	3.1	44.0	3.85
LadyChriste	63	1.87	45.9	42.9	55.0	92.0	4.0	1.11	3.2	37.5	4.02
392282.061	73	1.60	40.1	54.1	49.0	92.0	4.3	1.00	4.4	33.2	3.70
392207.042	90	1.83	36.2	44.2	53.0	88.0	4.0	1.00	2.1	41.7	2.78
392269.027	87	1.33	49.9	56.8	54.0	98.0	3.0	1.00	2.6	40.8	3.69
ML98.14	67	1.90	47.7	60.6	44.0	86.0	4.0	0.89	3.5	42.9	4.72
Redone	90	2.27	53.9	44.5	50.0	87.0	4.0	1.00	3.9	36.8	4.57
ML98.015	90	2.43	53.6	62.4	48.0	99.0	4.0	1.00	3.2	43.3	4.59
392288.044	60	1.63	55.2	43.3	50.0	91.3	3.0	1.56	2.7	43.9	3.85
VC785-2	80	1.90	55.6	63.8	51.0	81.0	3.3	1.00	3.6	44.0	4.85
Roslin Ruaka	87	1.30	48.8	54.3	55.0	92.0	3.0	1.44	3.0	44.3	4.28
384300.8	77	2.27	30.6	35.1	58.0	96.0	3.0	1.00	3.3	34.3	3.59
392010.12	7.3	2.23	42.1	53.1	52.0	91.0	4.0	1.33	4.1	32.9	4.56

377865.35	73	1.73	47.8	71.1	52.0	89.0	3.0	1.00	5.1	42.5	6.50
392280.1	80	2.00	42.3	56.8	47.0	86.3	3.0	0.89	3.0	66.7	6.19
RC7716-3	70	2.10	60.8	68.3	51.0	84.7	3.0	1.22	3.5	72.7	7.52
392282.010	60	1.37	54.5	62.9	50.0	93.0	3.0	1.11	3.7	44.7	5.24
Rosamunda	90	2.23	35.9	30.0	44.0	85.0	4.0	1.44	2.9	32.6	2.76
392278.4	73	1.30	52.4	46.8	58.7	90.0	3.0	1.00	4.6	34.0	4.52
LL98.01	70	1.57	47.0	54.3	49.0	90.0	3.0	0.89	3.3	41.6	4.57
392228.045	57	1.93	34.1	49.6	44.0	82.7	5.0	1.44	4.6	40.5	5.48
392281.040	77	2.07	44.9	57.1	46.0	92	4.0	1.00	5.2	42.2	6.37
392260.30	77	2.07	46.5	62.4	50.0	92	3.7	1.22	3.3	43.5	4.28
387300.8	90	1.30	51.3	148.7	50.0	91.7	3.0	1.00	3.9	41.2	5.05
Desiree	90	3.00	62.4	110.5	54.0	94.0	3.0	1.56	5.3	43.3	7.30
Famosa	77	1.83	52.1	65.4	53.0	90.0	3.0	1.11	3.7	42.1	4.94
392280.029	77	1.57	46.7	45.2	50.0	90.0	3.0	1.00	4.1	34.5	4.22
392246.017	67	1.43	36.1	44.6	44.0	89.0	4.0	1.22	4.0	52.0	6.26
Accent	73	2.60	40.8	44.8	45.0	90.0	4.0	1.33	6.0	34.3	6.61
Bertita	77	1.87	56.6	39.3	46.0	80.0	4.0	1.33	4.3	46.5	5.91
CV%	12.6	17.8	5.98	8.49	0.28	0.55	6.40	20.52	25.56	18.54	24.88
SED	7.881	0.268	2.272	3.753	0.117	0.405	0.187	0.187	0.794	6.197	0.982

Inter relationships between yield and yield components

The simple correlation coefficients between attributes studied and simple regression coefficients for the regression between yield and yield components are shown in Tables 3 and 4 respectively. Tuber yield was positively associated with stem number (r = 0.246, $P<0.05$); plant height (r = 0.206, $P<0.05$); number of leaves (r = 0.237, $P<0.001$) while plant height was positively correlated with number of leaves. The regression of yield on plant height, stem number and number of leaves per plant reflected the correlation. Lopez et al (1987) detected a significant positive correlation between plant height and tuber yield. Taller genotypes had more leaves, which enabled them to produce more photosynthate for storage in the tubers. This suggests that optimal shoot development is necessary for improved yields under supra optimal ambient temperature conditions. However since high temperature favour shoot growth by decreasing the partitioning of assimilates to tubers (Ewing, 1981) care must be taken not to exceed the optimum.

Both the correlation and regression of yield on days to tuber initiation and days to maturity were negative and significant. This suggests that earliness in tuber initiation and maturity led to increased yield under supra optimal temperature probably due to reduced period of exposure to heat stress.

Number of tubers per plant correlated positively with tuber yield in this study. This result agrees with the report by Lopez et al, (1987). However Birhman and Kang, (1993) reported either negative or absence of correlation between number of tubers and tuber yield. There was a highly significant positive correlation between average tuber weight and tuber yield; and a negative correlation between average tuber weight and number of tubers suggesting that selecting for increase in average tuber weight would lead to a reduction in number of tubers.

Number of tubers per plant (R^2 = 0.383) and average tuber weight per plant (R^2 = 0.125) had the highest coefficients of determination of yield (Table 5) and by far the highest direct effects on tuber yield (87.5% and 66.9%respectively) when compared to attributes (Table 6) suggesting that they were the major contributors to tuber yield under supra-optimal temperature conditions and may be relied upon as indices for selection for improved tuber yield under such conditions. Further more path coefficient analysis (Table 6) showed that the observed correlation between tuber yield and number of stems, plant height, number of leaves, days to tuber initiation and maturity were largely indirect through their effect on tuber number and average tuber weight.

Table 3: Correlation coefficient (r) between potato attributes at Saminaka in the year 2000

Traits	Number of stems/pt.	Plant height	Number of leaves/pt	Days to tuber initiation	Days to maturity	Early blight severity	Number of wilted plants	Number of tubers/pt	Average tuber weight	Tuber yield/pt
Plant Emergence	0.053	0.098	0.167*	-0.046	-0.031	0.038	-0.146	0.000	-0.072	-0.006
Number of stems/pt.		0.043	0.002	-0.136	-0.128	0.148	0.183*	0.077	0.160	0.246**
Plant height			0.356**	0.094	-0.081	-0.362**	0.058	-0.005	0.235**	0.206*
Number of leaves/pt				0.022	0.142	-0.251**	0.044	0.105	0.139	0.237**
Days to tuber initiation					0.419**	-0.370**	-0.100	-0.208*	-0.103	-0.284**
Days to maturity						-0.208*	-0.078	-0.044	-0.147	-0.165*
Early blight severity							-0.022	0.054	-0.175	-0.036
Number of wilted plants								0.029	-0.020	0.067
Number of tubers/pt									-0.372**	0.619**
Average tuber weight										0.354**

* $P<0.05$, ** $P<0.01$

Table 4: Simple regression coefficients between *tuber yield and yield components in Saminaka in the year 2000

Attributes	Regression coefficient	level of significance
Plant Emergence	-0.21	ns
Number of stems/pt.	19.44	$p<0.001$
Plant height	1.33	$p<0.05$
Number of leaves/pt	0.56	$p<0.01$
Days to tuber initiation	-3.04	$p<0.001$
Days to maturity	-1.77	$p<0.05$
Early blight severity	-2.64	ns
Number of wilted plants	3.34	ns
Number of tubers/pt	20.94	$p<0.001$
Average tuber weight	1.60	$p<0.001$

* Dependent variable = tuber yield/plant

Table 5: Coefficient of determination (R^2), Adjusted R^2 and Standard error of the estimate for the regression of tuber yield on yield components of potato in Saminaka in the year 2000

Attributes	**Coefficient of determination**	**Adjusted R^2**	**Standard error of estimate**
Plant Emergence	0.000	-0.007	47.221
Number of stems/pt.	0.060	0.054	45.772
Plant height	0.042	0.036	46.209
Number of leaves/pt	0.056	0.050	45.873
Days to tuber initiation	0.081	0.074	45.280
Days to maturity	0.027	0.020	46.578
Early blight severity	0.001	-0.006	47.192
Number of wilted plants	0.005	-0.002	47.115
Number of tubers/pt	0.383***	0.379	37.096
Average tuber weight	0.125**	0.119	44.161

Potato tuber yield is influenced largely by the number of tubers and average tuber weight (Birhman and Kang, 1993). Lynch and Kozub (1991) observed that while number of tubers was more important in determining tuber yield in some progenies and environments, it was average tuber weight that was more important for tuber yield determination in other genotypes and environments. In this study, number of tubers was more important than average tuber weight for tuber yield determination going by its higher coefficient of determination (Table 5) and direct effect (Table 6).

Multiple correlation coefficient for the relationship between tuber yield and other attributes was highly significant and positive (0.891) (Table 7). This means that 89% variation in tuber yield can be attributed to the influence of the ten attributes assessed. The multiple regression was also very highly significant (Table 7).

Results presented in this study showed that number of tubers per plant and average tuber weight per plant were the major contributors to yield under supra-optimal temperature conditions and may be relied upon as indices for selection for improved yield under such conditions.

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Table 6: Path analysis showing direct and indirect influences of 10 attributes on tuber yield per plant of potato genotypes in Saminaka in1999

Character	Direct effect	Indirect effect via										Corr. Coef. (r)
		Plant emergence (4WAP)	Number of stems /Plant	Plant Height (cm)	Number of leaves/pt	Days to Tuber initiation	Days to maturity	Early Blight Severity	Number of wilted stands/m^2	Number Of tubers /plant.	Average Tuber Weight /plant	
Plant Emergence (4WAP)	0.036	1	0.003026	0.00291	0.008281	-0.001196	0.000186	0.00285	-0.007008	0.0035	-0.04683	-0.006
Number of stems /Plant	0.034	0.003204	1	0.00081	0.003087	-0.003698	0.000582	0.01425	0.012576	0.13825	0.074259	0.278
Plant Height (cm)	0.030	0.003492	0.000918	1	0.017787	0.002496	0.000498	-0.027075	0.002736	0.01925	0.154539	0.205
Number of leaves/plant	0.049	0.006084	0.002142	0.01089	1	0.000572	-0.000852	-0.01875	0.002112	0.095375	0.090315	0.236
Days to Tuber initiation	0.026	-0.001656	-0.004828	0.00288	0.001078	1	-0.002514	-0.02775	-0.0048	-0.20125	-0.070245	-0.284
Days to maturity	-0.006	-0.001116	-0.003298	-0.00249	0.006958	0.010894	1	-0.0156	-0.003744	-0.05075	-0.099012	-0.165
Early Blight Severity	0.075	0.001368	0.00646	-0.01083	-0.01225	-0.00962	0.001248	1	-0.001056	0.030625	-0.117.75	-0.036
Number of wilted stands/m^2	0.048	-0.005256	0.008908	0.0171	0.002156	-0.0026	0.000468	-0.00165	1	0.0315	-0.016056	0.068
Number Of tubers/plant.	0.875	-0.000144	0.005372	0.00066	0.005341	-0.00598	0.000348	0.002625	0.001728	1	-0.242847	0.642
Average Tuber weight/ plant	0.669	-0.00252	0.003774	0.00693	0.006615	-0.00273	0.000888	-0.013125	-0.001152	-0.317625	1	0.351
Residual							0.427					

Table 7: Multiple correlation and regression of tuber yield on other potato plant attributes in Saminaka the year 2000

Source of variation	degree of freedom	sum of squares	mean squares	f value
Regression	10	251476.43	25147.643	51.327***
Residual	133	65163.461	489.951	
Total	143	316639.89		

Coefficient of determination	0.794***
Multiple correlation	0.891***
Standard error of estimate	22.135

$Y = -130.94 + 1.14X_1 + 4.33X_2 + 0.00X_3 + 0.11X_4 - 0.13X_5 - .08X_6 + 3.60X_7 + 2.21X_8 + 28.61X_9 + 2.94X_{10}$

Where: X1 = Plant emergence, X2 = Number of stems, X3 =Plant height, X4 =Number of leaves, X5 =Days to tuber initiation, X6 =Days to maturity, X7 =Early blight severity, X8 = Number of wilted plants X9 = Number of tubers, X10 =Average tuber weight,

REFERENCES

Allen, E.J., O'brien, P.J. and Firman, D., 1992. Seed tuber production and management. In: The Potato Crop (edited by P.M. Harris) Chapman and Hall London pp 247-287.

Amadi, C. O., 2005. Evaluation of potato genotypes for adaptation to heat stress. PhD Thesis Michael Okpara University of Agriculture Umudike. 285pp

Birhman, R. K. and Kang, G. S., 1993. Analysis of variation and inter -relationships in potato germplasm. Euphytica 68:17-26

Borah, M.N. and Milthorpe F. L., 1962. Growth of potato as influenced by temperature. Indian J. Plant Physiology, 5:53-72

Bushnell, J., 1925. The relationship of temperature to growth and respiration in the potato plant Tech. Bull. Minn. Agric. Exp. Stn. No. 34, 29pp.

Dewey, D. R. and LU, K. H., 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. Agron. J., 51:515-518.

Ewing, E.E., 1981. Heat stress and tuberization stimulus. Am. Potato J., 58:31-49.

Gomez, K.A. and Gomez, A. A., 1984. Statistical Procedure for Agricultural Research John Wiley and sons New York. 2nd edition. 680pp

Hawkes, J. G., 1978. History of potato. In: P. M. Harris ed. The Potato Crop. The Scientific Basis for Improvement. Chapman and Hall, London, pp. 1-14

Levy, D., 1983. Varietal differences in the response of potato to repeated short periods of water stress in hit climates. 2. Tuber yield and dry matter accumulation and other tuber properties. Potato Res., 26: 315-321

Levy, D., 1984. Cultivated *Solanum tuberosum L*. as a source for the selection of cultivars adapted to hot climates Trop Agric. (Trinidad), 61:167-70

Lopez, D. F., Boe, A.A., Johansen, R.H. and Jansky, S.H., 1987. Genotype x Environment interactions, correlations and combining ability of six traits in potato (abstract) Am. Potato J. 64:447

Lynch, D.R. and Kozub, G.C., 1991. The association between potato tubers yield and components of yield in irrigated and dry land environments in the prairies. Can. J. Plant Sci 71: 279-287.

Martin, C. and Thurston, H. D., 1989. Factors affecting resistance to A*lterneria solani* and progress in early blight research at CIP. In: Fungal diseases of the potato report of the planning conference on fungal diseases of potato held at CIP, Lima 1987 101-118

Menzel, C. M., 1980. Tuberization in potato at high temperatures: responses to gibberillins and growth inhibitors. Annals of Botany, 46:259-265

Midmore, D. J., 1984. The potato (*Solanum* spp) in the hot tropics 1. Soil temperature effects on emergence, plant development and yield. Field crops Res. 8: 255 - 71

Nowak, J. and Coleborne, D., 1989. In vitro tuberization and tuber proteins as indicators of heat tolerance in potato. American Potato Journal, 66: 35 - 45

Sale, P.J.M., 1974. Productivity of vegetable crops in a region f high solar input III. Carbon balance of potato crops, Austral. J. Pl. Physiol. 1:283 – 96.

Sidhu, A. S. and Pandita, M. L., 1979. Genetic variability and correlation studies in potato (*Solanum tuberosum* L). J. Indian Potato Assoc. 6:103-108.