VOL. 2, NO. 4-5, July/September 2007 ISSN 1990-6145
Journal of Agricultural and Biological Science

www.arpnjournals.com

CONTRIBUTIONS OF SHOOT N, P AND K TO TUBER YIELD OF IRISH POTATO (*Solanum tuberosum* L.) AT SAMARU, NIGERIA

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ABSTRACT

Trials were conducted during the dry seasons of 1998/99 and 1999/2000 at the Irrigation Farm, Institute for Agricultural Research, Samaru to test the response of four varieties of Irish potato (Greta, Nicola, RC 767-2 and WC 732-1) to four rates of NPK fertilizer (0, 300, 600 and 900 kg/ha), two forms of seed tuber (whole and cut-tubers). Positive and highly significant correlation (P = 0.01) was observed between tuber yield and shoot N (r = 0.47, 0.74 and 0.57), P (r = 0.51, 0.41 and 0.57) and K (r = 0.33, 0.48 and 0.47) during the dry seasons of 1998/99 and 1999/2000 and the combined of the two seasons, respectively. A strong and positive relationship (P = 0.01) was also found when shoot N, P and K contents were correlated among each other during the two seasons and the two year combined except in 1998/99 dry season when a positive though non significant correlation was observed between shoot N and shoot K (r = 0.15). The direct contributions of shoot N and P to tuber yield were generally much higher than the indirect contributions except for shoot K whose indirect contribution to tuber yield out weighed that of the direct contributions in most cases. The indirect contributions to tuber yield were generally higher through either shoot N or shoot K. Shoot N (25.21%) generally made the highest percent contribution followed by Shoot K (3.37%) and finally shoots P (2.36%). Combined percent contribution from shoot N + P (9.11%) was more than that from shoot N + K (7.75%), and the least was from shoot P + K (2.77%). Shoot N and P contributed more to tuber yield individually and in the combined form, directly and indirectly.

Keywords: potato, shoot, nitrogen, phosphorus, potassium, yield, Irish.

INTRODUCTION

Irish potato (*Solanum tuberosum* L.) is believed to be the most efficient tuber in terms of time the crop takes to mature. Two or more crops are possible per crop of either yam or cassava (Okonkwo *et al.,* 1995). This is because a crop of potato can be harvested in 60 to 120 days as compare to yam and cassava that can take more than 200 and 360 days, respectively. Production of the crop is however constraints by factors as high temperature above 30^{o}C, low soil fertility and moisture, pests and diseases as well as those that are physiological (disease, composition etc) and morphological. Nigeria began in the early 1920s by the European miners, around Jos and Zaria provinces.

Potato is a high nitrogen (N), phosphorus (P) and potassium (K)-demanding crop. Deficiency of any or combinations of these nutrients can result in retarded growth or complete crop failure under severe cases (Beukema and van der Zaag, 1990, Harris, 1992, Waddell *et al.,* 1999; Khiari *et al.,* 2001). Application of any or combination of these nutrients on soils particularly of savanna characterized as low in N and P contents and to some extent K will certainly enhance the performance of the crop. This is because an improvement of these nutrients in the soil will surely enhance their composition in the tissue, thereby improving the overall performance of the crop. Tissue analysis could be instrumental for targeting high yield using N, P and K contents, except where the tissue nutrient contents were very high (Harris, 1992). This is because tuber yield in potato had been reported to be strongly influenced by tissue N, P and K (Beukema and van der Zaag, 1990, Harris, 1992, Waddell *et al.,* 1999; Khiari *et al.,* 2001). Most of the research conducted in Nigeria on potato mostly conducted around Jos-Plateau (1400m above sea level) whose weather and soil (largely of volcanic origin) condition varied with that of Zaria (686m above sea level). In light of the above this work seek to establish the relationship between tuber yield of Irish potato and shoot N, P and K with the aim of identifying the contribution of each of these nutrients independently and in combine situation toward enhancing tuber yield under the local condition of Samaru, Zaria.

MATERIALS AND METHODS

Two field trials were carried out during the dry seasons of 1998/99 and 1999/2000 at Samaru (11^{0}11'N, 07^{0} 38'E, 686m above the sea level). Random samples of soils to a depth of 30cm were taken prior to land preparation in each season and analysed for physico-chemical properties. The treatments consisted of combinations of No-NPK, 300, 600 and 900kg/ha of NPK (20-10-10) fertilizers and two form of seed tuber (whole and cut tubers) and four varieties of Irish potato (Greta, Nicola, RC 767-2, WC 732-1). A split plot design was used in which the combination of NPK rates and form of seed tuber were main plots while the crop varieties were assigned to sub-plots; with the treatments replicated three times. The gross sub-plot size was 4.0x3.0m.

The varieties used in these experiments (Greta, Nicola, RC767-2 and WC732-1) were sourced from Irish Potato Research Programme of the National Root Crop Research Institute, Vom, Plateau State, Nigeria. Tubers of 35-50g weights were separated from larger ones that weigh above 50g. The smaller weight category (35-50g) formed the whole tuber planting material. The other larger tubers were cut into two or more piece depending on size, to create pieces of equivalent weight to the whole tubers (35-50g). Each cut piece contained one or more eyes (or sprouts) depending on the size of the tuber. Tubers less than 35g were considered too small and were culled-out. Cut sets were dusted with mixture of ash and fungicide powder (45% Dithane M-45), to prevent fungal attack as recommended by Beukema and Vander Zaag, (1990). Thereafter, the cut sets were spread in an airy room to allow for healing of the wound for 3 to 4 days. The whole tubers used were also dressed with Dithane M-45 a day to planting.

The land was cleared, harrowed and made into 75cm row ridges. Sub-plots of 3.0 x 4.0m dimensions were marked out. Each sub-plot was separated from the other by 1 unplanted ridge while 2 unplanted ridges separated the main-plots. A whole or cut seed tuber was planted per hill spaced 25cm apart within the row and 75cm between rows. Planting was carried out on 4th December, and 26th November, for the 1998/99 and 1999/2000 season trials, respectively.

The fertilizer treatments were applied in two-split doses, by band placement at planting and at 3 weeks after planting (WAP). The plots were irrigated by surface flooding at regular intervals of 5-7days. To pre-empt fungal attack, the crop was sprayed with 2.5kg/ha of Dithane M-45 at 3, 6 and 9 WAP as recommended by Okonkwo *et al.* (1995). Manual hoe weeding carried out at 3, 6 and 9 WAP kept the plots relatively weed free.

Shoot samples collected at 9WAP (corresponding to the time 50% of the plant population attained flowering stage) were oven-dried. The oven dried shoots were grounded into powder respectively as per treatment using a grinder. The powder was sieved (using 2mm sieve) and later used to analyze for N, P and K content in the laboratory using one gram each of the sample. One gram of the sieved sample was digested using sulphuric acid and perchloric acid with copper and sodium sulphates acting as catalyst. The digest was later used to determine the following. For the purpose of determining either shoot parts of the digest was used and distilled into boric acid as per treatment. Thereafter, the distillate was titrated against a standard hydrochloric acid (HCL) and the percent N content determined from the titre using macro-Kjedhal (Bremmer 1965; IITA 1975).

Phosphorus content of either shoot or tuber was determined by the triple acid (H_2SO_4-$HCLO_3$-HNO_3) wet digestion method. The phosphorus within the digest was estimated by the molybdo-phosphoric yellow colour method as described by Dirk and Myrna (1984).

Potassium was determined flame photometrically on an aliquot of the digest solution, which had been alkaline by the addition of a slight excess of dilute ammonia solution. The potassium content was thereafter determined photometrically using atomic absorption spectrophotemetry, Perkin Elmers Model 403.

The crops were harvested on 8th March 1999 and 3rd March 2000 for 1998/99 and 1999/2000 dry season trials, respectively. Tubers harvested from each net plot ($3m^2$) were weighed and expressed in tonnes per hectare.

All the data collected were statistically analysed and where the F-values were found to be significant, the treatment means were separated using Duncan's Multiple Range Test, DMRT (Duncan, 1955). The strength of relationship between shoot N, P and K (x) and tuber yield/ha (y) was studied using correlation coefficient analysis (Little and Hills, 1978).

$r = SP_{xy}/\sqrt{SS_x.SS_y}$
Where,
r = Coefficient of correlation
SP_{xy} = Sum of product x and y $\sum$ (x-x) (y-y)
SS_x = Sum of squires of x $\sum (x-\bar{x})^2$
SS_y = Sum of squires of y $\sum (y- \tilde{y})^2$

The results of the above correlation were used to develop the following simultaneous equations to work out the path coefficients (P1-P5) (Dewey and Lu, 1959).

$r_{14} = P_1 + r_{12}P_2 + r_{13}P_3$ ----------------------------(1)
$r_{24} = r_{12}P_1 + P_2 + r_{23}P_3$ -----------------------------(2)
$r_{34} = r_{13}P_1 + r_{23}P_2 + P_3$ -----------------------------(3)

where P_1 - P_3 are path coefficients, while r_{12} - r_{34} are the coefficients of correlation.

The direct and indirect effects of individual and combined (two factors) contributions of shoot N, P and K composition to tuber yield/ha were determined using path-coefficient analysis. The combined contribution is estimated using the following formula:

$C_{ij} = 2P_iP_j$

Where C = combined effect of i and j, r_{ij} = coefficient between i and j (i and j are the direct and indirect contributions) (Ajala *et al.,* 1996).

The residual factor Rx that is unaccounted for by the direct and combined contributions was estimated using the following formula:

$Rx = 1 - \sqrt{(P_1 r_{14} + P_2 r_{24} + P_3 r_{34})}$

RESULTS

Tuber yield had the strongest relationship with shoot P during 1998/99 (r = 0.51**) and shoot N in 1999/2000 (r = 0.74**) and combined (r = 0.67**). Shoot K (r = 0.33** - 0.48**) generally had the weakest relationship with tuber yield. The inter-relationship that exist within shoot N, P and K were positive and highly significant throughout the sampling periods and combined except during the second season of 1998/99 when the correlation between shoot N and shoot K (r = 0.15) was positively not significant. The correlation between shoot N and P were stronger than that between shoot N and K or shoot P and K during 1998/99 (r = 0.53**) and combined (r = 0.59**). In 1999/2000 dry season the relationship between shoot N and K was the strongest (r = 0.54**). The weakest correlation within shoot N, P and K even though significantly positive was that between shoot P and K in all the years of the trials and combined (Table-1).

VOL. 2, NO. 4-5, July/September 2007 ISSN 1990-6145
Journal of Agricultural and Biological Science

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Partitioning the total correlation values into direct and indirect contributions showed that shoot N directly contributed to tuber yield much more than it's indirectly made via either shoot P or K in each of the seasons (Table-2). Shoot P directly made more contributions to tuber than through the indirect means in 1998/99. Generally the indirect contribution of shoot P via shoot N was much greater than that via shoot K. Only in 1998/99 dry season does the direct contribution of shoot K outweighed that through the indirect means. The in direct contributions shoot K via shoot P in 1998/99 (0.1289) and via shoot N in 1999/2000 (0.3532) and combined (0.2109) represents the highest indirect contributions of shoot K via other means.

Table-3 shows the percent contribution of individual and combined parameters to tuber yield. Shoot N made the greatest % contribution to tuber yield during the two seasons and the combined (8.89 - 42.77%). In all the seasons and the combined shoot K contributed the least to tuber yield. The combined contribution of shoot N and P (5.66 - 14.29%) to tuber yield was the highest in all seasons and the combined. This is followed by that from shoot P + K in 1998/99 (4.03%) and shoot N + K in 1999/2000 (5.59%) and the combined (7.75%). The unaccounted residual effects constitutes 66.54%, 43.37% and 49.43% for 1998/99, 1999/2000 and the combined, respectively.

Table-1. Simple correlation between tuber yield of Irish Potato and shoot N, P and K Contents at Samaru during 1998/99 and 1999/2000 dry seasons.

Treatment	**1998/99**	**1999/2000**	**Mean**
Yield Vs shoot N	0.47**	0.74**	0.67**
Yield Vs shoot P	0.51**	0.40**	0.54**
Yield Vs shoot K	0.33**	0.48**	0.47**
Shoot N Vs shoot P	0.53**	0.39**	0.59**
Shoot N Vs shoot K	0.15NS	0.54**	0.42**
Shoot P Vs shoot K	0.46**	0.43**	0.49**

** = Significant (P = 0.01), NS = Not significant.

Table-2. Direct and indirect contributions of shoot N, P and K contents to tuber yield of Irish Potato at Samaru during 1998/99 and 1999/2000 dry seasons.

Shoot composition	**Shoot N**	**Shoot P**	**Shoot K**
	1998/99		
Shoot N	**0.2981a**	0.1580	0.0447
Shoot P	0.1484	**0.2801a**	0.1289
Shoot K	0.0235	0.0719	**0.1564a**
Total correlation	0.47	0.51	0.33
	1999/2000		
Shoot N	**0.6540a**	0.2551	0.3532
Shoot P	0.0433	**0.1109a**	0.0477
Shoot K	0.0428	0.0341	**0.0792a**
Total correlation	0.74	0.40	0.48
	Mean		
Shoot N	**0.5021a**	0.2962	0.2109
Shoot P	0.0907	**0.1537a**	0.0753
Shoot K	0.0772	0.0901	**0.1838a**
Total correlation	0.67	0.54	0.47

a = Direct contribution.

Table-3. Percentage contributions of shoot N, P and K contents to tuber yield of Irish potato at Samaru during 1998/99 and 1999/2000 dry seasons and combined.

Shoot composition	1998/99	1999/2000	Mean
Individual contribution			
Shoot N	8.89	42.77	25.21
Shoot P	7.85	1.23	2.36
Shoot K	2.45	0.63	3.37
Contributions of two parameters			
Shoot N + shoot P	8.85	5.66	9.11
Shoot N + shoot K	1.40	5.59	7.75
Shoot P + shoot K	4.03	0.76	2.77
Residual	66.53	43.36	49.43
Total	100	100	100

DISCUSSIONS

Physico-chemical properties of the fields on which the trials were conducted showed that the soil had low N (0.03 %), available P (5.29 – 5.38 ppm) and K (0.17 – 0.18 cmol/kg^{-1}).The low N, P and K observed in the soil confirm the report by Klinkenberg and Higgins (1970) and Enwezor *et al.* (1989) who reported that soil of the savannah are generally classified as Alfisol with low pH, organic matter content (<2%), N (0.15%) and available phosphorus (<8ppm). Therefore for enhance crop performance the nutrient status of these soil need to be augmented through fertilizer application.

The strong and positive correlation observed between tuber yield shoot N, P and K contents further emphasized the importance of these nutrients for growth and development of Irish potato. N is a component of protein which in turn is an integral part of chlorophyll molecule and of nucleic acids that make up the chromosome and thus, very essential and important for growth and development (Harris, 1992). Phosphorus on the other hand is an essential element in plant chemical compound that are responsible for energy transfer necessary for metabolic processes within the plant. It is also a part of the nucleic acid and thus very important for seed formation and root growth as well as increase leaf in the early stages of growth, hastened the senescence of leaves thus depressing leaf are toward the end of the growing period (Harris, 1992). K acts in carbohydrate formation and the transformation and movement f starch from potato leaves to tubers. It play important role in controlling stomatal movement and water status of the plant and increase leaf area later in the season and delayed senescence of leaves (Beukema and van der Zaag, 1990, Harris, 1992; Waddell *et al.,* 1999;Khiari *et al.,* 2001).

The relationship was observed to be stronger between tuber yield and shoot N and P which further proved the general believed that potato like most crops respond more to N and P. Higher shoot N and P means greater vegetativeness and therefore more assimilate production by the green leaves that would translate into higher yield (Harris, 1992; Waddell *et al.,* 1999; Khiari *et al.,* 2001).

The strong and positive relationship among shoot N, P and K observed in this study stressed the importance of these nutrients in the growth and the development of the crop as well as the degree of interdependence that exist between these nutrients. N, P and K play a major important role in the increase in dry matter composition in plant and hence in leaf area. The weaker relationship between shoot P and K could be due to fact that the sampling and analysis of the shoot was done at the growth stage of the crops life.

The direct and indirect contributions of shoot N, P and K to tuber yield revealed that in most cases shoot N and P made greater direct contribution to tuber yield more than they indirectly made. This further stressed the importance of each in growth and development of plants. That is why even the highest indirect contribution was observed to be through either shoot N or P (Beukema and van der Zaag, 1990; Harris, 1992).

The generally higher % contribution of either shoot N or P further indicates the importance of these nutrients to growth and development Irish potato. They play an important role in the overall growth of plants, hence higher tuber yield. This could further be seen from the higher combined % contribution to yield from these two nutrients that is more than that from shoot N + K or shoot P + K. The seasonal variations in the result obtained could be attributed to differences in weather conditions, soil inherent fertility status among other factors (Westermann and Kleinkopf 1985; Harris, 1992; Waddell *et al.,* 1999; Khiari *et al.,* 2001).

In conclusion shoot N and P contributed more to tuber yield individually and in the combined form, directly or indirectly under the condition of weather condition of Zaria.

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Appendix-A. Meteorological data showing temperature and sunshine hours during 1998/99 and 1999/2000 dry seasons.

Month	Minimum air temperature (^{0}C)	Maximum air temperature (^{0}C)	Sunshine hours
1998/99			
November 20-30	19.50	31.50	9.17
December	16.38	32.50	5.34
January	16.07	33.23	7.43
February	18.80	35.57	8.60
March 10-20	21.40	37.90	8.41
1999/2000			
November 20-30	16.20	34.10	5.45
December	15.30	31.07	4.99
January	17.56	32.47	8.18
February	16.73	38.50	6.53
March 10-20	19.30	38.10	6.36