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Unmarketable Tuber Yield and Other Agronomic Parameters of Four Varieties of Irish Potato (*Solanum tuberosum* L.) as Influenced by NPK Fertilizer Rate and Type of Seed Tuber at Samaru, Nigeria

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Abstract: This research was initiated with the aim at finding varieties of Potato that can respond to graded levels of NPK fertilizer and form of seed tuber. The treatments tested consist of four rates of NPK fertilizer (0, 300, 600 and 900 kg ha^{-1}), two forms of seed tuber (whole and cut-tubers) and four varieties of Irish potato (Greta, Nicola, RC 767-2 and WC 732-1). A split-plot design was used in which the factorial combinations of fertilizer rate and form of seed tuber were assigned to the main plots while the varieties occupied the sub-plots. The treatments were replicated three times. Varieties Nicola and RC 767-2 had the heaviest and least leaf and stem dry weights, respectively. Nicola, RC 767-2 and WC 732-1 produced more tubers and unmarketable tuber yield than Greta. Greta and RC 767-2 produced larger tubers than Nicola and WC 732-1. The highest NPK rate of 900 kg ha^{-1} resulted in the heaviest leaf and stem. Optimum tuber number and size was attained at the higher fertilizer rate of 600 kg ha^{-1}. Further increase above 600 kg NPK ha^{-1} depressed tuber number and tuber weight in 1997/98 and tuber size in 1998/99. The same 600 kg NPK ha^{-1} recorded the least unmarketable tuber yield. None of the factor measured was affected by type of seed tuber. In conclusion RC 767-2 had the highest plant dry weights as well as more tubers and unmarketable tuber yield that were comparable to that of Nicola and WC 732-1. Greta and RC 767-2 had larger tubers than the other two varieties. The plant dry weights were optimized at 900 kg NPK ha^{-1} while more tubers of larger size were maximized at 600 kg NPK ha^{-1}. The medium NPK rate of 600 kg ha^{-1} had least unmarketable tuber yield. Planting of either whole or cut tuber sett did not affect any of the parameter.

Key words: Fertilizer rate, form of seed tuber, unmarketable tuber yield component, Irish potato

INTRODUCTION

Potato (*Solanum tuberosum* L.) production in Nigeria is constraints by temperature and low soil fertility among other factors. In order to achieve high yield potato require cool weather, reasonable amount of nitrogen (N), phosphorus (P) and potassium (K) in the soil. Each of the nutrients has specific functions for plant growth and development. Lack of any or combinations of these nutrients can result in retarded growth (Waddell *et al*., 1999; Khiari *et al*., 2001; Crozier *et al*., 2004; Babaji *et al*., 2005, 2007; Anonymous, 2007, 2008). Among these three nutrients the demand is much higher for N due to its mobility in the soil and its significant role in the production and maintenance of an optimum plant canopy for continue tuber growth throughout the growing season (Waddell *et al*., 1999; Crozier *et al*., 2004).

Phosphorus is present either in available or fixed and unavailable forms. Phosphorus is important for early potato root development and tuber formation. It is absorbed through the root in the form of

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phosphate ion (PO^{-}_{4}) and make up about 0.2% of plant dry weight (Harris, 1992; Okonkwo *et al*., 1995; Crozier *et al*., 2004). Potassium stimulates early haulm growth and vigour as well as increases tuber size and yield (Crozier *et al*., 2004) though Locascio *et al*. (1992) found no yield response to K application. Therefore in order to obtain high yield of potato crop, there is the need for applying these nutrients particularly on poor soils as suggested by Okonkwo *et al*. (1995). The response of the crop to applied N, P and K varied with soil, weather, cultural practices employed and many other factors (Waddell *et al*., 1999; Khiari *et al*., 2001; Anonymous, 2007, 2008).

Kushwah and Grewal (1990) reported higher crop performance with whole tubers than with cut sett. While Jaiswal and Saini (1991) reported no significant differences between the yields of whole or cut seed tuber of potato. The cost of potato seeds (tubers) constitutes about 45-90% of the total production cost and most farmers in Nigeria can ouly produce 30-40% of their seed requirement. The high cost and unavailability of such input as fertilizer and plating materials (tubers) calls for efficient use of these inputs in order to have profitable production in these areas. Therefore this research was initiated with the aim at finding varieties of potato that can respond to graded levels of NPK fertilizer and form of seed tuber.

MATERIALS AND METHODS

Three field trials were carried out during the dry seasons of 1997/98, 1998/99 and 1999/2000 at the irrigation farm of the Institute for Agricultural Research, Samaru (11°11'N, 07° 38'E, 686 m above the sea level), Nigeria. Random samples of soils to a depth of 30 cm were taken prior to land preparation in each season and analysed for physico-chemical properties. The soils are loamy, moderately acidic (pH = 4.7-5.2) and are generally low in N (0.02-0.03%), P (5.29-6.34 ppm) and to some extent K (0.17-0.21 cmol kg^{-1}). Split plot design was used with factorial combinations of four rates of NPK (20:10:10) fertilizers (0:0:0, 60:30:30; 120:60:60 and 180:90:90 kg ha^{-1}, equivalent to 0, 300, 600 and 900 kg NPK ha^{-1}) and two types of seed tuber (whole and cut tubers) occupied main plots while the four cultivars of Irish potato (Greta, Nicola, RC 767-2, WC 732-1) were assigned sub-plots. The treatments were replicated three times.

The varieties were sourced from Irish Potato Research Programme of the National Root Crop Research Institute, Vom, Plateau State, Nigeria. Two months to the date of the planting season, the tubers were spread in a well-ventilated room and covered with a single layer of jute sacks to cut-off intense light. This treatment was to initiate fast sprouting under diffused light. These partially covered tubers were regularly sprinkled with liberal amounts of water to speed up the rate of sprouting. The tubers were regularly inspected and rotten ones removed and discarded. Smaller tubers of 35-50 g weights were separated from larger ones above 50 g in weight. The first small size category formed the whole tuber planting material. The other larger tubers were cut into two or more pieces depending on size, to create pieces of equivalent weight to the whole tubers (35-50 g). The tubers were protected against fungal attack by dusting them with mixture of ash powder containing 45% Dithane M-45.

The land was cleared, harrowed and made into 75 cm wide ridges. Plots of 4.0×3.0 m dimensions were made, with each plot separated from the other by a ridge. One whole or cut seed tuber was planted per hill spaced 25 cm apart within the row and 75 cm between rows. Planting was carried out on 26th November, 4th December and 26th November, for the 1997/98, 1998/99, 1999/2000 season trials, respectively. The fertilizer was applied in two equal split doses. The first half at planting and at 3 WAP was employed using band placement. Plots were irrigated by controlled surface flooding at 7 days interval or less depending on when the soil appears dry.

Dithane M-45 at the rate of 2.5 kg ha^{-1} was applied at 3, 6 and 9 WAP to control fungal attack. Manual weeding using hand-hoe was done at 3, 6 and 9 WAP controlled weeds. The crops were harvested when the leaves turned yellow and senescent indicated full maturity. Harvesting dates for the three trials were 4th March 1998, 8th March 1999 and 3rd March 2000. At harvest data were

collected on the leaf and stem dry weight at 10 WAP, number and size of tubers and unmarketable tuber yield (%) at harvest. The crop 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).

RESULTS AND DISCUSSION

The varieties had significantly similar leaf dry weight in 1999/2000 only. During the other two seasons and the combined, the heaviest leaf dry weight was consistently produced by RC 767-2, though significantly at par with that of WC 732-1 ouly in 1997/98 dry season. The least leaf dry weight was produced by Nicola. Maximum leaf dry weight was attained at the highest fertilizer rate of 900 kg NPK ha^{-1} in 1997/98 and 1999/2000 dry seasons and the combined. In 1999/2000 leaf dry weight increased up to 600 kg NPK ha^{-1} beyond which no significant increase in leaf dry weight was recorded. Planting either whole or cut-tubers had no significant effect on leaf dry weight. None of the interactions of factors on leaf dry weight was significant (Table 1). Greta in 1997/98 and 1999/2000 and RC 767-2 in 199/99 and the combined had the heaviest stems while Nicola consistently produced the least stem weight. Heaviest stems were produced at the highest fertilizer rate of 900 kg ha^{-1} that was significantly not different from that produced by the next lower rate of 600 kg ha^{-1} ouly in 1997/98 and 1999/2000 dry seasons. Varying the tuber form or factor interaction had no significant effect on stem dry weight (Table 2).

The varieties tested significantly differed in terms of number of tubers per hill and diameter per tuber in each of the year and the combined (Table 3 and 4, respectively). The response was not consistent among the years but when averaged over the three years Nicola, RC 767-2 and WC732-1 had more tubers than Greta while Nicola and WC 732-1 on the other hand had smaller tubers than Greta and RC 767-2. Increasing NPK rate from 0-300 and from 300-600 kg ha^{-1} significantly increased leaf and stem weights. Further increase to 900 kg NPK ha^{-1} only increased the leaf weight in 1997/98 and 1998/99 and the combined as well as stem dry weight in 1998/99 and the combined. Application of 600 kg ha^{-1} of NPK fertilizer produced more tubers of large size and weight. Further increase in fertilizer level to 900 kg ha^{-1} depressed number of tubers and tuber weight in 1997/98 and tuber size in 1998/99. In 1999/2000 dry season the number of tuber was maximized at the highest NPK rate. The form of seed tuber had no significant influenced on number of tubers/hill, size and weight per tuber in all the seasons.

Table 1: Effects of fertilizer rate and form of seed tuber on leaf dry weight (g) of four varieties of Irish Potato at Samaru during 1997/98, 1998/99 and 1999/2000 dry seasons

Treatments	1997/98	1998/99	1999/2000	Combined
Varieties				
Greta	10.00b	10.50c	5.90	8.80c
Nicola	7.40c	9.40c	4.70	7.20d
RC-767-2	12.70a	14.90a	5.20	11.00a
WC-732-1	12.90a	12.40b	4.80	10.00b
SE±	0.33	0.48	0.37	0.23
Fertilizer rate (20:10:10 kg NPK ha^{-1})				
0	4.50d	5.10d	2.10c	3.90d
300	9.50c	10.00c	4.70b	8.10c
600	12.50b	13.10b	6.60a	10.70b
900	16.60a	19.10a	7.20a	14.30a
SE±	0.35	0.49	0.39	0.24
Form of seed tuber				
Whole-tuber	10.80	11.60	5.20	9.20
Cut-tuber	10.70	12.00	5.20	9.30
SE±	0.25	0.35	0.28	0.17
Interaction	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group and column are not statistically significant using DMRT ($p = 0.05$). NS = Not Significant ($p = 0.05$)

Table 2: Effects of fertilizer rate and form of seed tuber on stem dry weight (g) of four varieties of Irish Potato at Samaru during 1997/98, 1998/99 and 1999/2000 dry seasons (10 WAP)

Treatments	1997/98	1998/99	1999/2000	Combined
Varieties				
Greta	4.11a	4.63c	2.04a	3.59b
Nicola	2.33c	3.81c	1.49b	2.54c
RC-767-2	2.74bc	7.95a	1.58b	4.09a
WC-732-1	3.04b	6.21b	1.57b	3.61b
SE±	0.17	0.30	0.14	0.12
Fertilizer rate (20:10:10 kg NPK ha^{-1})				
0	1.25c	2.01d	0.52c	1.26d
300	2.85b	4.20c	1.36b	2.80c
600	3.80a	7.13b	2.29a	4.41b
900	4.32a	9.26a	2.50a	5.36a
SE±	0.19	0.33	0.13	0.14
Form of seed tuber				
Whole-tuber	3.15	5.59	1.69	3.47
Cut-tuber	2.96	5.71	1.65	3.44
SE±	0.14	0.23	0.09	0.10
Interaction	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group and column are not statistically significant using DMRT ($p = 0.05$). NS = Not significant ($p = 0.05$)

Table 3: Effects of fertilizer rate and form of seed tuber on number of tubers/plant of four varieties of Irish Potato at Samaru during 1997/98, 1998/99 and 1999/2000 dry seasons

Treatments	1997/98	1998/99	1999/2000	Combined
Varieties				
Greta	6.95c	8.86d	9.19b	8.33b
Nicola	7.72b	10.36c	12.52a	10.19a
RC-767-2	7.73b	11.62b	10.91ab	10.16a
WC-732-1	8.70a	12.55a	9.57b	10.27a
SE±	0.20	0.25	0.70	0.28
Fertilizer rate (kg NPK ha^{-1})				
0	4.74c	0.55c	7.80c	6.70c
300	8.48b	9.92b	8.60c	9.00b
600	9.88a	12.73a	11.80b	11.47a
900	8.21b	13.19a	14.00a	11.80a
SE±	0.23	0.27	0.72	0.29
Form of seed tuber				
Whole-tuber	7.86	10.87	10.72	9.82
Cut-tuber	7.79	10.82	10.38	9.67
SE±	0.16	0.19	0.51	0.21
Interaction				
V×F	NS	*	NS	NS
V×S	NS	NS	NS	NS
F×S	NS	NS	NS	NS
V×F×S	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group and column are not statistically significant using DMRT ($p = 0.05$). NS = Not significant ($p = 0.05$), *Significant ($p = 0.05$)

Least tuber number was recorded by variety Nicola at 0 kg NPK ha^{-1} while the highest number of tubers was produced by RC 767-2 and WC 732-1 when each supplied with 600 kg NPK ha^{-1}. WC 732-1 produced its maximum at 900 kg NPK ha^{-1} that was comparable to that at 600 kg NPK ha^{-1} (Table 5). Tuber size was influenced by the interaction of variety and fertilizer rate when combined (Table 6). The largest tubers were produced by Greta and RC-767-2 when given 600 kg NPK ha^{-1} while smallest tubers were produced by WC-732-1 and Nicola when no fertilizer was applied.

Significant differences in unmarketable yield occurred among the varieties tested, but the trend were not consistent among the seasons (Table 7). The combined result showed that Nicola, RC 767-2 and WC 732-1 produced similar and significantly higher unmarketable tubers yield than Greta. Increasing NPK fertilizer rate from 0 to 300 kg ha^{-1} and further to 600 kg NPK ha^{-1} during 1997/98 and 1999/2000 dry seasons significantly reduced unmarketable tuber yield. In 1998/99 and the

Table 4: Effects of fertilizer rate and form of seed tuber on diameter per tuber (cm) of four varieties of Irish Potato at Samaru during 1997/98, 1998/99 and 1999/2000 dry seasons

Treatments	1997/98	1998/99	1999/2000	Mean
Varieties				
Greta	4.22a	5.11a	5.78a	5.04a
Nicola	3.69b	4.13b	4.83c	4.22b
RC-767-2	4.22a	5.13a	5.39b	4.91a
WC-732-1	3.97ab	4.25b	4.81c	4.34b
SE±	0.10	0.07	0.08	0.05
Fertilizer rate (kg NPK ha^{-1})				
0	2.84b	3.35d	3.56c	3.25c
300	4.41a	4.34c	5.21b	4.65b
600	4.45a	5.72a	5.96a	5.38a
900	4.40a	5.22b	6.09a	5.24a
SE±	0.11	0.08	0.09	0.06
Form of seed tuber				
Whole-tuber	4.09	4.70	5.15	4.64
Cut-tuber	3.96	4.61	5.26	4.61
SE±	0.07	0.06	0.07	0.04
Interaction				
V×F	NS	NS	NS	*
V×S	NS	NS	NS	NS
F×S	NS	NS	NS	NS
V×F×S	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group and column are not statistically significant using DMRT (p = 0.05). NS = Not significant (p = 0.05), *Significant (p = 0.05)

Table 5: Interaction between fertilizer rate and variety on number of tubers per plant of Irish potato at Samaru during 1998/99 dry season

	NPK rate (kg ha^{-1})			
Varieties	0	300	600	900
Greta	6.97h	8.03gh	9.87ef	10.58de
Nicola	6.17i	9.92ef	12.15cd	13.20bc
RC-767-2	8.15gh	10.30ef	14.34ab	13.69bc
WC-732-1	8.92fg	11.42de	14.57ab	15.03a
SE±	0.55			

Means followed by the same letter(s) within a set of interaction are not statistically different using DRMT (p = 0.05)

Table 6: Interaction between fertilizer level and variety on diameter per tubers (cm) of Irish potato at Samaru (three year-mean)

	NPK rate (kg ha^{-1})			
Varieties	0	300	600	900
Greta	3.39f	5.11c	6.05a	5.60b
Nicola	3.12fg	4.30e	4.73d	4.74d
RC-767-2	3.46f	4.77c	5.75ab	5.68b
WC-732-1	3.30g	4.42e	5.00cd	4.93c
SE±	0.12			

Means followed by the same letter(s) within a set of interaction are not statistically different using DRMT (p = 0.05)

combined reduction in unmarketable tuber yield was observed when 300 kg and 900 kg NPK ha^{-1} were supplied, respectively. Planting either whole or cut tubers had no significant effect on percent unmarketable tuber yield.

For each of the variety unmarketable tuber yield was observed to reduce with application of NPK up to 600 kg NPK ha^{-1}. Addition of NPK fertilizer above 600 kg ha^{-1} significantly increased unmarketable tuber yield of varieties Greta and WC 732-1 in 1999/2000. In 1997/98 and 1999/2000 each of the varieties had its maximum unmarketable tuber when no fertilizer was applied (Table 8).

Table 7: Effects of fertilizer rate and form of seed tuber on unmarketable tuber yield (%) of four varieties of Irish Potato at Samaru during 1997/98, 1998/99 and 1999/2000 dry seasons

Treatments	1997/98	1998/99	1999/2000	Mean
Varieties				
Greta	34.90b	33.80a	30.20c	33.00b
Nicola	35.30b	35.50a	33.50b	34.70a
RC-767-2	38.90a	30.30b	36.50a	35.60a
WC-732-1	36.10b	30.60b	36.80a	34.50a
SE±	0.77	0.904	0.89	0.49
Fertilizer rate (20:10:10 kg NPK ha^{-1})				
0	61.70a	57.30a	61.20a	60.00a
300	32.80b	24.80b	31.10b	29.60b
600	24.80c	24.40b	20.90c	23.40d
900	25.80c	23.80b	24.80c	24.80c
SE±	0.77	0.94	0.89	0.409
Form of seed tuber				
Whole-tuber	36.30	32.70	34.50	34.50
Cut-tuber	36.20	32.40	34.50	34.40
SE+	0.54	0.67	0.63	0.35
Interaction				
V×F	*	NS	*	NS
V×S	NS	NS	NS	NS
F×S	NS	NS	NS	NS
V×F×S	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not statistically significant using DMRT (p = 0.05). NS = Not significant (p = 0.05), *Significant (p = 0.05)

Table 8: Interaction between NPK (20:10:10) fertilizer levels and varieties on unmarketable tuber yield (%) of Irish potato at Samaru during 1997/98 and 1999/00

	NPK rate (20:10:10 kg ha^{-1})			
Varieties	0	300	600	900
1997/98				
Greta	56.30c	33.33de	24.33gh	25.50gh
Nicola	59.67bc	30.17ef	25.00gh	26.17fgh
RC-767-2	66.83a	34.83d	25.50	28.50fg
WC-732-1	63.83ab	33.00de	24.33gh	23.17h
SE±	1.54			
1999/2000				
Greta	61.18a	21.41de	15.05f	23.11de
Nicola	61.08a	30.67c	19.01ef	23.07de
RC-767-2	62.58a	36.20b	24.76d	26.42cd
WC-732-1	59.90a	35.96b	24.83d	26.49c
SE±	1.78			

Means followed by the same letter(s) within a set of interaction are not statistically different using DRMT (p = 0.05)

The result of this study have indicated variety Nicola to be a small stature crop due to lower leaf and stem dry weight it recorded when compared with robust variety RC 767-2 and to some extent Greta and WC 732-1. These variations could be genetic as earlier observed by Beukema and Zaag (1990), Harris (1992) and Babaji *et al.* (2006). The genetic variation could be responsible for Greta having relatively larger tubers than other varieties and significantly so (especially) when compared with variety Nicola. Therefore, production of more tubers of moderate sizes was reported as an important factor in increasing yield in potato (Krantzer and Waschl, 1992; Babaji *et al*., 2006).

Maximum plant dry weights (leaf and stem) was attained at the highest fertilizer rate of 900 kg NPK ha^{-1} indicating that the potential for these parameters is yet to be attained. The low fertility status of the soil of the experimental site might also have triggered such positive response to such enviroumentally limited resources. Beukema and Zaag (1990) and Harris (1992) have all observed that adequate NPK fertilization resulted in high haulm production in potatoes. Tuber number and size

were maximized at 600 kg NPK ha^{-1}. Studies conducted by Mancini and Marzi (1991); Sharma and Grewal (1991) and Babaji *et al.* (2005, 2006) showed that yields of different potato varieties were improved by NPK fertilizer application.

The use of cut or whole tuber produced no significant effect on growth and yield components such as dry leaf and stems weights, tuber number size and unmarketable tuber yield weight. This might have been due to the fact that both cut and whole planting materials were of similar weight and age. Large tubers were cut to sizes that were approximately same as for the whole tubers. This confirmed the research of Kushwah and Grewal (1990), Jaiswal and Saini (1991), Babaji *et al.* (2005) and Babaji *et al.* (2006) who reported no significant differences in yield components recorded by planting potato using either whole or cut tubers.

From the result of this trial Greta had larger tubers and lower proportion of unmarketable tubers than other varieties. More tubers of larger size were produced at 600 kg NPK ha^{-1} while unfertilized plots produced the higher proportion of unmarketable tubers. Planting of either whole or cut tuber sett did not affect any of the parameter measured.

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