Tropical Agricultural Research & Extension 20 (3 & 4): 2017

ATRAZINE RESIDUES IN IRISH POTATOE (*Solanum tuberosum* L.) VARIETIES FROM THREE SELECTED AREAS IN PLATEAU STATE, NIGERIA

OO Fayinminnu[1], MO Odewale[1], A Adebayo[1*], KA Thomas[2] and DO Omobusuyi[1]

[1]Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria

[2]Department of Agricultural Extension and Rural Development, University of Ibadan, Nigeria

ABSTRACT

Atrazine is a pre-emergent herbicide used for the control of broad-leaf weeds that has residual activity in the environment. Extensive use of atrazine (strength of 800 g/kg Atrazine 50% WP) in Irish potato production in Plateau State, Nigeria has prompted this study to evaluate the atrazine residue levels in Irish potato varieties in three selected (Mangu, Jos South and Bokkos) areas of Plateau State. A questionnaire-based survey was conducted to determine the types and extent of herbicides used by farmers cultivating Irish potatoes. Samples of four Irish potato varieties: Diamant, Marabel, Christian Lady and Yellow and soils at 0-15cm depth were collected from each of the three Local Government Areas (LGAs). All the samples were subjected to chemical extractions using standard procedures and the extracts were analyzed for atrazine residues using spectrophotometer. Data were analysed using descriptive statistics and ANOVA at p=0.05. Results showed 63.6% of farmers using synthetic herbicides on their farms, while 76.27% used atrazine as their preferred herbicide over paraquat 23.73%. Soil samples from Mangu had significantly highest value of 9.98 mg/kg of atrazine residues and from the Diamant variety with no detection of atrazine in soil samples from other selected LGAs and their respective varieties. The Yellow variety from both Jos South and Bokkos had the highest values of 3.32 mg/kg and 3.13 mg/kg atrazine herbicide residues, while the least value of 1.51 mg/kg was from Diamant variety in Bokkos. However, Atrazine residue was not detected in Yellow, Marabel and Christian lady varieties from Mangu, Jos South and Bokkos, respectively. This study showed high atrazine residues with concentrations above 0.05 mg/kg and 0.1 mg/kg (US EPA acceptable maximum residue level) in the soil and Irish potato samples, respectively. This atrazine pesticide over time could lead to bioaccumulation in living organisms, food chain and ecosystem.

***Key words*:** Atrazine, Farmers` perception, Irish potato, Maximum residue level, Residue

INTRODUCTION

Irish potato is a starchy tuber crop from the perennial S*olanum tuberosum* of the Solanaceae family. Globally, potato is the most widely grown tuber crop and the fourth largest crop after cassava, yam and cocoyam (Okonkwo *et al*., 2009). They are with annual production approaching 300 mt cultivated on over 18 million ha (Horton and Fano, 1984; Dixit, 2003). Africa has average potato yields of 14-28 t/ha, with Egypt, South Africa and Morocco as the larger producers (Dixit, 2003). Irish Potato production rose from mere 180 t in 1940 to 1,732 t in 1944 (Rhoades *et al.,* 2002). They are mainly grown in the cool highland areas as a food crop as well as vegetable. The main Irish potatoes growing area in Nigeria is the Jos Plateau, where it accounts over 90% of potato annual output (Okwonkwo *et al.,* 1995; FAO*,* 2012, NRCRI annual Reports, 2010).

The soil and climatic conditions of the Jos Plateau favour the production of exotic crops like Irish potatoes, apples, grapes, wheat, barley and vegetables. Due to suitable climate conditions, the Federal Government of Nigeria established the National Root Crop Research Institute (NRCRI) on potato programme at Kuru, Plateau State. Irish potato production in Nigeria 1991 was about 400,000 mt, while the recent annual production from

*Corresponding author: kehindeadesina@yahoo.com

the local farmers estimate is about 1,500,000 mt (Okwonkwo *et al.,* 1995; FAO*,* 2012, NRCRI annual Reports, 2010).

Okonkwo *et al.* (1995) showed the response of farmers to cropping systems adopted in potato production in four Local Government Areas in Jos Plateau. This revealed 88.4% farmers planted potato as mixed crop in the rainy season and 80% as sole crop during the dry season. Jos South Local Government Area (LGA) accounts for 25% of the total Irish potato produced in Nigeria (Okonkwo *et al*., 1986; Wuyep, 2012). Potato crop is produced almost throughout the year under rain-fed during the rainy season and irrigated during the dry season. It is also a short maturity crop, thereby making it the highest yielding tuber crop in Nigeria (Okonkwo *et al.,* 1995). Efforts to control pests in food crops relied primarily on the application of various synthetic pesticides, which often caused toxic effects on the humans, animals and environment. Their hazardous effects on non-target and other beneficial organisms and development of resistant strains of pests, damaging the surrounding ecosystem and other living for maintaining ecological balance had been reported (Youdeowei, 1995; Siriwong*et al*., 2008). In addition, other problems include leaving toxic residues on food, soil and water that may persist many weeks or months after application (McConnell *et al.*, 1998; Sparling *et al.*, 2001). Earlier researchers had reported on continuously accumulated chronic pesticide exposure and health condition impairment, which had resulted into carcinogenesis, neurotoxicity, reproductive and growth disturbance, and immunological effects (Hernández *et al.*, 2006).

Over the past years, the amount and number of different herbicides have increased significantly. Although a good number of farmers are disposed to the use of herbicides, many are unaware of herbicide types, level of poisoning, safety precautions and potential hazards on health and environment (Yassin *et al*., 2002). Atrazine (2-chloro-4ethylamino-6-isopropy lamino-s-triazine) is a member of chloro – s - triazine family herbicide, which also includes simazine, cyanazine, amatryne, prometryne. It is still one of the most widely used as an agricultural herbicide by volume globally (Extoxnet, 1996; Duhigg, 2009). Atrazine is used to stop pre- and post-emergence broadleaf and grassy weeds in major crops.

The half-life of atrazine in loamy soils ranges from 60 to 150 days (USEPA, 2003). However, when conditions in soils are changed from aerobic to anaerobic, the rate of degradation slows considerably (half-life of about 660days in anaerobically incubated sandy clay sediments) (Goolsby *et al*., 1997). In addition, atrazine degrades very slowly once it enters the water column. Half-life in reservoirs may be 1 to 2 years (Goolsby *et al*., 1997). This slows down in rate of degradation as important consequences. When water containing residues of atrazine moves down through the soil profile and away from the root zone to where oxygen becomes less available, the persistence of atrazine is expected to increase. Its chemical properties make it susceptible to leaching and runoff, especially during heavy rains. The screening procedure developed by Goss and Wauchope (1990) gives atrazine a “large” potential to leach or to move in surface solution, and a medium potential to adsorb to sediment particles.

Agency for Toxic Substances and Disease Registry (ATSDR, 2003) had the concerns that atrazine may cause cancer in humans, while the herbicide was still under review for re-registration. Beane Freeman *et al*. (2011) reported that there was no association between use of atrazine and cancer nor evidence with most cancer cells, however, atrazine can affect human`s health by altering the works of the reproductive systems. Reports from studies carried out on people living on farms that are sprayed with atrazine for weed control revealed risk of preterm delivery which was on high side. Information on low foetal weight and heart, urinary and limb defects in humans has been provided on maternal exposure to atrazine

in drinking water. Gastroschisis (birth defects) incidence has been reported to occur in areas where surface water atrazine levels are elevated and where it is commonly applied as reported by Waller *et al*. (2010).

Considering more than 50 years of successful use of atrazine and the current situation with increased herbicide resistance in some crops, there had been reports about continuous use of atrazine herbicide over a long period of potato production in Plateau State (Nwakocha, 1987). Therefore the objectives of this study were to evaluate the preferred herbicides for Irish potato production from farmers through questionnaires in Plateau State, Nigeria and to determine atrazine residues in soil and Irish potato varieties collected from Plateau State, Nigeria.

MATERIALS AND METHODS

Study Area

The study was conducted in the central zone of Plateau State, which covers Bokkos, Mangu and Jos South Local Government Areas (longitudes 8^o 40' and 9^o 50' E and latitudes 9^o and 10^o 45' N and altitude 1,200 to 1,829 m above sea level). The mean annual temperature in Plateau State ranges between 20°C - 25°Cand summer temperatures rarely exceeds 35°C, well suited for potato production. The mean annual rainfall ranges from 131.75cm and 146 cm in the southern part and on the Jos Plateau, respectively. These areas were selected as the prominent potato producing areas accounting for over 80 -90% of the total Irish potatoes produced in Nigeria. (Nigerian Population Commission (NPC), 2006).

The experiment was carried out in the Toxicology Research Laboratory, Department of Crop Protection and Environmental Biology (CPEB), Faculty of Agriculture and Forestry, University of Ibadan, Ibadan, Nigeria.

The experimental design that was used for this study was completely randomized design. A survey was conducted at the three Local Government Areas (Mangu, Jos South and Bokkos LGAs) through National Root Crop Research Institute, Vom. Three villages were purposively selected randomly from each of the three LGAs; making nine villages. Finally a random sampling was conducted to select 10 farmers from each village. Therefore, 90 Irish potato farmers constituted the sampling size for this study according to the method of Ojo (2000). Four varieties of Irish potato: Diamant, Marabel, Christian Lady and Yellow and soil samples at 0-15cm depth were collected from each of the three Local Government Areas at the time of harvest in dry season.

Atrazine herbicide residue analysis

A 0.125 g of Atrazine herbicide powder was weighed in 1 mg/ml methanol to make the stock solution. A working standard of 10 mg/ml was prepared by appropriate dilution of the stock solution with water. Three (3) milliliters of concentrated hydrochloric acid (HCl) was mixed with 18 ml of freshly distilled pyridine and 12 ml of deionised water was poured into it to make the pyridine reagent. A 1% *p*-Amino-acetophenone solution was prepared in 1:4 hydrochloric acid and 2 M sodium hydroxide aqueous solution was used (Kesari and Gupta, 1998).

The standard calibration curve of atrazine herbicide residue determination was carried out using the method of Kesari and Gupta (1998). A standard solution containing 4 – 40 mg of Atrazine was poured in a test tube and 0.2 ml pyridine reagent was added. The solution was placed in a boiling water bath for 15 minutes at 27±2 ºC temperature and allowed to cool, afterwards 1 ml of 2 M sodium hydroxide and 2 ml of *p*-amino-acetophenone solutions were added. The solution was then kept for 5 minutes for a complete colour change and was made up to the 25 mL with water. The absorbance was measured using spectrophotometer at 470 nm against deionised water as reference.

Determination of Atrazine in Potato Soil Samples

The soil samples collected from the three selected areas were air- dried in the laboratory for a period of five days at an average temperature of 26 ºC and 84.5 % Relative Humidity. 0.5g of the finely sieved soil samples of the various varieties was weighed and these samples were washed with two 10 ml portions of methanol and filtered. The washing was collected and made up to 25 ml with methanol. The absorbance was measured using spectrophotometer at 470 nm against deionized water as reference (Kesari and Gupta, 1998). All samples in triplicates.

Determination of Atrazine herbicide in Irish potato samples

The Irish potato varieties (Diamant, Marabel, Christian Lady and Yellow) collected were sampled by randomly picking three tubers from each of the four varieties. They were crushed and the samples were washed with 100 ml of deionized water in a storage bottle and kept for one day. From this water, atrazine was extracted with two 10-ml portions of chloroform. The chloroform extract was evaporated to dryness and the residue dissolved in 25 ml of methanol. All samples were replicated three times. The absorbance was measured using spectrophotometer at 470 nm against deionized water as reference using the method described by Kesari and Gupta (1998).

Data analysis

Data were analysed using descriptive statistics and analysis of variance (ANOVA). Fischer's Least Significant Difference (LSD) compared means for significance differences at 95% confidence level ($P < 0.05$).

RESULTS

Farmers' choice of herbicides in selected Local Government Areas in Plateau State

The survey revealed that 80% of Irish potato farmers in the study area chose Atrazine as preferred herbicide over paraquat (Figure 1).

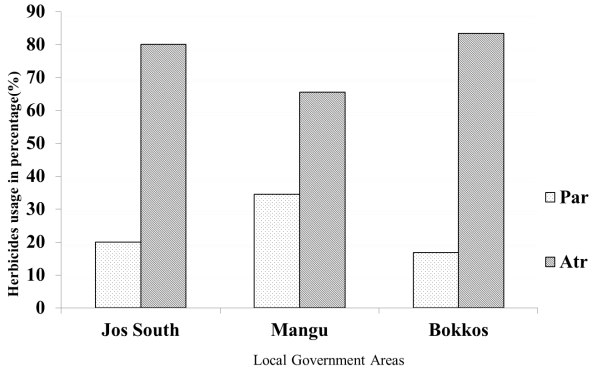

Figure 1: Farmer's choice of herbicide in percentages in three Local Government Areas in Plateau State, 2016.

The Atrazine residue levels in soil samples (0-15cm depth) among the varieties in selected Areas in Plateau State

In Mangu area, the soil sample from the Diamant variety had the highest value of Atrazine herbicide residue level over other varieties as well as in all the selected areas (Table 1). It was followed by the soil samples from Diamant variety in both Jos South and Bokkos with the same value, respectively. The Atrazine residue in Diamant soil sample was significantly higher than Yellow sample in Bokkos.

Table 1: Atrazine residue levels (mg/kg) in soil samples (0- 15cm) in three selected Local Government Area in Plateau State (N=88)

Variety	Mangu	Jos South	Bokkos
Diamant	9.98±0.02	2.06±0.03	2.06±0.03a
Yellow	ND	ND	1.07±0.04b
Marabel	ND	ND	ND
Christian Lady	ND	ND	ND

Means ± standard error within a column followed by the same letter (s) are not significantly different at $p< 0.05$

However, the value of Atrazine residues in soil were not detected in Yellow, Marabel and Christian lady in Mangu and Jos South likewise Marabel and Christian lady varieties in Bokkos selected area.

The Atrazine residue levels in Irish potato samples in selected Areas in Plateau State

In Mangu Area, the Christian lady variety had the highest value of atrazine residue, followed by Diamant variety with higher value, while Marabel had the least value of atrazine residue (Table 2). In Jos South, Yellow variety had the highest value of Atrazine residue, which was significantly different from Diamant. The Yellow variety had the higher Atrazine residue level in Irish potato in Bokkos Area, while the least value was from Diamant variety. However, Atrazine residue in Irish potato samples was not detected in yellow variety in Mangu Area, also Marabel and Christian lady varieties were not detected in both Jos South and Bokkos Areas.

Table 2: Atrazine residue levels (mg/kg) in Irish potato samples in three selected Government Areas in Plateau State (N= 88)

Variety	Mangu	Jos South	Bokkos
Diamant	1.76±0.02a	2.72±0.02a	1.51±0.04a
Yellow	ND	3.23±0.13b	3.13±0.16b
Marabel	1.42±0.02b	ND	ND
Christian Lady	2.52±0.03c	ND	ND

Means ± standard error within a column followed by the same letter(s) are not significantly different at $P < 0.05$

US EPA (MRL) = 0.1 mg/kg ND: Not detected

Distribution of respondents based on socio-economic characteristics

Result on Table 3 reveals that the mean age of respondents was 35 years, with a larger percentage (65.9%) been 40 years and below. Majority (89.8%) were males, 97.7% were Christians, over half (55.7) were single. Majority (79.5%) had a formal education, 87.9% practiced farming as primary occupation. Respondents had mean farming experience of 12 years; over half (52.3% and 56.8%) cultivated local varieties of Irish potatoes and 1 acres of land or less.

Result on Table 4 reveals that a larger percentage of respondents (63.6%) used chemical control, for weeds, atrazine was the most used (86.4%) chemical for weed control. The use of nose mask (75.0%) was the most used preventive measures. Majority (97.7%) of respondents used irrigation in applying chemicals and sourced water (96.6%) for chemical application from the rivers. Over 90% bought their chemicals from local markets, while 54.5% and 37.5% received information on chemical application from local dealers and agricultural extension agents respectively.

DISCUSSION

This study revealed that, higher percentage of Irish potato farmers in all the Local Government Areas use atrazine as pre and post emergence herbicide, this may be due to its relatively low cost and ability to increase yield (Christian, 2011). Atrazine residues were detected in the soil samples at 0-15cm soil depth in all the Local Government Areas (LGAs), this may be due to the persistence nature of atrazine which conforms with the findings of Fasola and Oyedunmade (2007). The atrazine residues level detected in the soil samples were higher than the USEPA (1997) Maximum Residue Level of 0.05 mg/kg.

Detection of atrazine residues in most of Irish potato and soil samples revealed the sensitive method of Konig's reaction, which involved a systematic procedure of yellow- orange coloration to confirm the presence of atrazine in the samples as described by Kesari and Gupta (1998). The atrazine residue levels detected in the Irish potato samples in all the LGAs were

Table 3: Distribution of respondents based on socio-economic characteristics (n=88)

Variable		Frequency	Percentage	Mean
Age (years)	Less than 21	12	13.6	35 years
	21-30	35	39.8	
	31-40	11	12.5	
	41-50	15	17.0	
	51-60	9	10.0	
	Above 60	6	6.8	
Sex	Male	79	89.8	
	Female	9	10.2	
Religion	Christianity	86	97.7	
	Islam	2	2.3	
Household size	Single	49	55.7	2 Persons
	2-3 persons	32	36.4	
	4-5 persons	7	8.0	
Educational attainment	No formal education	18	20.5	
	Primary education	21	23.9	
	Secondary education	35	39.8	
	Tertiary education	14	15.9	
Primary occupation	Farmer	77	87.5	
	Trader	3	3.4	
	Civil servant	8	9.1	
Experience in farming	1-5 years	27	30.7	12 years
	6-10	26	29.5	
	11-15	10	11.4	
	16-20	7	8.0	
	above 20	18	20.4	
Variety	Improved	42	47.7	
	Local	46	52.3	
Acres cultivated	Less than 1acre	12	13.6	
	1 acre	38	43.2	
	Above 1-2 acre	19	21.6	1.72 acres
	Above 2-acre	19	21.6	

Field survey, 2016

Table 4: Distribution of respondents based on chemical weed control practices (n=88)

Variable	Categories	Frequency	Percentage
Weed control method	Cultural	25	28.4
	Physical	7	8.0
	Chemical	56	63.6
Type of herbicide	Atrazine	76	86.4
	Paraquat	12	13.6
Protective measures	Protective jacket	1	1.1
	Safety boots	20	22.7
	Nose mask	66	75.0
	None	1	1.1
Do you adopt Irrigation method	No	2	2.3
	Yes	86	97.7
Source of water	River	85	96.6
	Stream	3	3.4
Source of pesticide	Farm cooperative	8	9.1
	Local market	80	90.9
Source of information on chemical application	Local dealers	48	54.5
	Agricultural Extension Agent	33	37.5
	Farm cooperative	5	5.7
	Manufacturer's instruction	2	2.3

Field survey, 2016

also higher than the USEPA (1997) approved maximum Residue Level of 0.05 mg/kg.

This study shows that, plants can contribute to the removal of pesticide from the soil (environment) through uptake into the plant tissues as reported by Cunningham *et al*. (1997). In addition, the reason for the varying concentrations of atrazine in some Irish potato varieties and non-detection in other soil samples may be connected with the fact that atrazine herbicide degradation might have occurred at different rates in different Irish potato varieties and varying soil properties. Also the microbial activities might vary in the rhizosphere of the plant. More so, the detection and non-detection of atrazine residue in some samples may be due to some factors such as application, application method, spray volume and formulation characteristics as reported by Bates (1990) and Linder *et al*. (2000).

The relatively young age of respondents implies that they have the energy required to copy will agricultural production. The predominance of males suggests that Irish potato is perceived as commercial crop; hence males are likely to be more involved in production than females. This is in consonance with findings of Kaaria *et al.* (2007) and World Bank (2009) that studies in Africa have shown that when a crop is perceived as commercial, men are more likely to take over from women. Farming is the predominant occupation with a relatively high level of farming experience,

which is would translate into enhance the production of Irish potato and use of chemical for weed control production. The relative small farm area could lead to continuous cropping on same land, while the high use of atrazine for weed control is likely to increase the residual effect of the use of chemical on the crop.

CONCLUSION

Based on the findings, atrazine residues levels in Irish potatoes in the selected sites in the study area were higher than USEPA (1997) approved maximum Residue Level of 0.05mg/kg. It is suggested that government and concerned agencies should make periodic visit to farms most especially the commercial ones, in order to ensure compliance to proper use of herbicides.

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR, 2003). "Public Health Statement for Atrazine". Toxic Substances Portal - Atrazine. Center for Disease Control, Agency for Toxic Substances and Disease Registry, Division of Toxicology and Human Health Sciences. Retrieved May 2, 2015.

Bates FS 1990 Block Copolymer Thermody namics: Theory and Experiment. An nual Review of Physical Chemistry 41: 525-57.

Beane Freeman LE, Jennifer A, Rusiecki JA, Hoppin JH, Lubin SK, Gabriella A, Zahm SH, Hines CJ, Coble JB, Barone-Adesi F, Sloan J, Sandler DP, Blair A and Alavanja MCR 2011 Atrazine and Cancer Incidence among Pesticide Applicators in the Agricultural Health Study (1994–2007). Environmental Health Perspectives. Vol. 119 (9): 1253-1259.

Cunningham SD, Shann JR, Crowley DE and Anderson TA 1997 Phytoremediation of contaminated water and soil. *In* E. L. Kruger, T. A. Anderson, and J. R. Coats (eds.). *Phytoremediation of Soil and Water Contaminants*, American Chemical Society Symposium Series 664, Washington, D. C. pp 12-17.

Dixit P 2003 History of Potato. www. Potato Online. com., Accessed 9 September, 2017.

Duhigg C, 2009 Debating How Much Weed Killer Is Safe in Your Water Glass. www.nytimes.com accessed 23/08/2009

Extension Toxicology Network. Oregon State University 1996 Atrazine Pesticide Information Profile, 1996. http:// ace.orst.edu/info/extonet/pips/ atrazine.htm.

FAO: Food and Agriculture Organization of the United Nations (FAO) 2012 FAO-STAT database. Available: http:// faostat.fao.org/ (Accessed, 28 April 2013).

FAOSTAT 1998 The Food and Agriculture Organization production statistics. Statistics database (http://apps.fao.org) (Accessed , July 2017)

Fashola OO and Oyedunmade EE A 2007 Determination of Atrazine and Metolachlor Residues in Two Fields in Ilorin, Nigeria. Environment and Ecology 25S (4): 1057-1061.

Goolsby DA, Thurman EM, Pomes ML 1997 Herbicides and their metabolites in rainfall: Origin, transport, and deposition patterns across the Midwestern and Northeastern United States, 1990-1991. *Environ Sci Technol* 31:1325-1333.

Goss DW and Wauchope D 1990 The SCS/ ARS/CES. Pesticide Properties Database: II, using it with soils data in a screening procedure. In Weigma D.L. (Ed.). Pesticides in the Next Decade: The Challenges Ahead, Virginia Water Resources Research Center, Blacksburg, Virginia, pp.471-493.

International Potato Center (CIP) 1984 Pota toes for the Developing World: A col laborative Experience. Lima Peru.

P.1 3-20.

Hernandez AF, Gomez M, Penan AG, Fernandez Gil. Lourdes, R., Villanueva, Enrique and Antonio, Pla 2004 Effect of long-term exposure to pesticides on plasma esterases from plastic green house workers. Journal of Toxicology and Environmental Health. Part A., 67., 14; 1095-08.

Horton D and Fano H 1984 "Potato for the developing world. "In: Potato Atlas. International Potato Centre, Lima, Peru. pp. 13, 14 & 18.

Iyagba AG and Ayeni AO 2000b Efficacy of post-emergence herbicides on Guinea grass and Siam weed in Cassava 2: Influence of rate and time of application. Nigerian Journal Crop Soil and For. 6: 70-81.

Kaaria S, Sanginga P, Njuki J, Delve R, Chitsike C and Best R 2007 Enabling rural innovation in Africa: An approach for empowering smallholder farmers to access market opportunities for improved livelihoods, retrieved from http://www.future-agricultures.org/farmerfirst

Kesari R, and Gupta VK 1998 A simple meth od for the spectrophotometric determi nation of atrazine using *p*- amino acetophenone and its application in environmental and biological sam ples.school of studies in chemistry, Pt. Ravishankar Shukla University, Rai pur (M.P.), 492010, India.

Linder DR, Lee ML and Kuei JC 2000 Handbook of chemistry and physics.74th edition CRC press, Boca Florida.

McConnell LL, Le Noir JS, Datta S and Seiber JN 1998 Wet deposition of current-use pesticides in the Sierra Nevada mountain range, California, USA. Environmental Toxicology and Chemistry, 17: 1908-1916.

Nwokocha HN 1987 Weed interference studies in potato. Annual report. National Root Crops Research Institute, Umudike, pp. 88-93.

National Population Commission (NPC, 2006). Abuja, Nige ria.population.gov.ng. Retrieved 2017-10-10.

Ojo AM 2000 Economic Analysis of Irish potato Production in Plateau State. M.Sc thesis, Department of Agricultural Economics and Rural Sociology Faculty of Agriculture, Ahmadu Bello University Zaria, Nigeria.

Okonkwo JC, Amadi CO, Nwosu KI 2009 Potato production, storage, processing and utilization in Nigeria. National Root Crops Research Institute, Umudike, Nigeria.

Okonkwo JC, Ene LSO and Okoli OO 1995 Potato Production in Jos, Plateau National Root Crops Research institute, Umudike, Nigeria. pp. 1-33.

Okonkwo JC, Nwokocha HN, and Ifenkwe OP 1986 Survey Report on Irish Potato Production and Storage in Local Government Areas of Plateau State, Annual Report, National Root Crops Research Institute, Umudike, Umuahia, Nigeria.

Onochie BE 1978 Weed Control in root and tuber crops. Proceedings of the 1st National Seminar on root and tuber crops. Umudike. March 21-25, 1977: 12-24.

Rhoades RE, Hijmans RJ and Huaccho L 2002 Potato Production in Nigeria. International potato centre, Lima, Peru. pp. 25.

Scott G J, Best MR and Bokanga M 2000 Roots and fibers in the Global Food System: A Vision Statement to the Year 2020. International Potato Center Lima, Peru.

Siriwong W, Thirakhupt K, Sitticharoenchai D, Borjan M and Robson M 2008 Organochlorine Pesticide Residues in Plankton, Rangsit Agricultural Area, Central Thailand, [10.1007/s00128-008-9532-4].Bulletin of Environmental Contamination and Toxicology, 81 (6), 608-612.

Sparling DW, Fellers GM and McConnell LL

2001 Pesticides and amphibian popu lation declines in California, USA. Environmental Toxicology and Chem istry, 20: 1591-1595.

U.S Environmental Protection Agency (U.S EPA), 1997 Method 8080 and 8141. Eco toxicological impacts of agricultural drain water in the saline river, California, USA. pp. 2375-2384.

Waller SA, Paul K, Peterson SE and Hitti JE 2010 "Agricultural-related chemical exposures, season of conception, and risk of gastroschisis in Washington State.". American Journal of Obstetrics and Gynecology Vol. 202 (3) 241-246.

World Bank 2009 Gender in agriculture sourcebook, the World Bank, Washington DC. Retrieved from http://www.worldbank.org.html.

Wuyep SZ 2012 Effects of Climate on the Growth and Yield of Irish Potato in Jos South, Plateau State, Unpublished M.Sc. Research Project, Geography Department, Federal University of Technology, Yola, Nigeria.

Yassin MM, Abu T, Mourad AM and Safi JM 2002 Knowledge, attitude, practice, and toxicity symptoms associated with pesticide use among farmworkers in the Gaza Strip, Journal of Occupational Environment Medicine, 59: 387-394.

Youdeowei A 1995 Pest and vector management in the tropics, Longman Nigeria PLC. Oba Akran Avenue, Ikeja Lagos, Nigeria. pp 52.