

SEMIARID JOURNAL OF ACADEMIC RESEARCH AND DEVELOPMENT (SJARD)

A Review on Weed Control Methods of Lowland Rice Production in Nigeria

***¹Dahiru, R., ¹Ilallah, B. M., ¹Abubakar, M. A., ¹Adamu, L. M., ¹Muhammad, L. H.,
¹Maigatari, A. A., and ²Adamu H. H**

¹School of Agriculture, Binyaminu Usman Polytechnic, Hadejia P.M.B 013 Jigawa State, Nigeria
²Jigawa State Ministry of Education

Received 7 October, 2017; Accepted December, 2017

ABSTRACT

Rice has become an important strategic and daily staple food crop in Nigeria. The potential land area for rice production in Nigeria is between 4.6 and 4.9 million ha. However, only about 1.7 million ha is presently cropped to rice. The main production ecologies for rice in Nigeria are rain fed lowland, rain fed upland, irrigated lowland, deep water/boating and mangrove swamp. Of these, rain fed lowland rice has the largest share of the rice area (50%) and rice production. Small-scale farmers with farm holdings of less than 1 ha cultivate most of the rice produced in Nigeria. However, rice productivity and production at the farm level are constrained by several factors, one of which is problem of weeds. The weed control methods practiced by farmers engaged in lowland irrigated rice production is based on two methods; traditional and modern system. This paper discussed the various practices in employed in these two methods.

Keywords: Weed Control, Lowland Rice, Production

Introduction

Background of the Study

Rice is the most important food crop in developing countries, and accounts for 29% of the total calorie intake of these populations. In the tropics, rice is largely grown on small family farms, which are usually less than 4 ha, and in Asia, rice is the most important source of employment in rural areas. Throughout these smallholder systems, weeds are one of the major biological constraints to production (Johnson, 2017).

Weeds are plants found grown on lands where they are not particularly wanted; they represent

important pest to crops, reducing world food and fibre production. Weeds are adaptable to all agronomic systems and have impacts on all aspects of crop production, competing favorably for water, space, air and nutrients with crops. Weeds also adversely affect humans in both agricultural and non-agricultural environments. Weed problem is a global phenomenon; it has been discovered that production systems have direct implications on weed management practices, difficulties, and future problems (Awotodunbo and Bello, 2011).

Weed control is one of the most laborious and expensive steps in rice production. In underdeveloped countries, weeds are removed

by hand weeding. In developed countries, weeds are removed primarily by chemicals and other cultural weed control methods.

Economic Importance of Rice

Rice is an annual grass of the genus *Oryza* with a natural family Poaceae (Abeysekera, 2001). Rice (*Oryzasativa* L.) is the staple food of more than a half of the world population (Sinha and Talati, 2007; Ginigaddara and Ranamukhaarachchi, 2009). It has contributed immensely to global food security. Rice is the world's most popular food. It shapes religious observances, festivals, customs, cuisine and celebrations. According to Abeysekera, (2001) In terms of comparative advantage, rice can be grown in flooded and non-flooded soils because it has both lowland and upland varieties that can adapt to different agro-climatic and soil conditions.

United States Department of Agriculture (USDA) put the global rice production is 486.73 million metric tons annually, which has a yield of 4.52 ton ha⁻¹. In Nigeria, the average yield is recorded at about 1.81ton ha⁻¹ and the production is 3.65 million metric tons annually.

Justification

Okonji *et al.* (2012) stated that Nigeria is the largest rice producer in the West African sub-region but ironically, Nigeria is one of the major importers of rice in the Sub-Saharan Africa because a large proportion of its foreign exchange is spent on the importation of rice. For instance, Sabair (2008) reported that Nigeria spends about hundred billion naira (N100 billion = \$ 454 million) on rice importation annually. Rice demand in Nigeria is about 5 million metric tons while according to Nwalieji and Onwubuya (2013), only 2.2 million metric tons are produced locally. The implication of this is that more than half of the rice demanded in Nigeria is imported. The importation is largely due to the increase in population because an average Nigerian according to WARDA (2001), consumes 24.8 kg of rice per year and Nigeria has over 140 million people (NPC, 2006). Apart from importation, the market price of rice and other cereal crops like maize and millet are on the

increase too (NAERLS and NPFS, 2011). In addition to the high import bill, a lot of money has been spent to improve rice production in Nigeria (Nwalieji and Onwubaya, 2013). This is discouraging because Nwajiuba and Ejiogu (2008) observed that staple foods like rice, maize and wheat account for a greater share of the food demand in the developing countries compared to developed countries.

According to report by Food and Agriculture Organization of the United States (FAO), Nigeria is the continent's leading consumer of rice, one of the largest producers of rice in Africa and simultaneously one of the largest rice importers in the world. As well as an important food security crop, it is an essential cash crop for it is mainly small-scale producers who commonly sell 80 per cent of total production and consume only 20 per cent. Rice generates more income for Nigerian farmers than any other cash crop in the country. In 2008, Nigeria produced approximately 2 million MT of milled rice and imported roughly 3 million metric tons, including the estimated 800,000 metric tons that is suspected to enter the country illegally on an annual basis (FAO, 2017).

This ugly scenario calls for a comprehensive research to identify factors influencing rice production in Nigeria hence, the need for the study.

Methodology

The main aim and contribution of this paper is to synthesize and systematize the existing literature on weed control methods of lowland rice production in Nigeria. Structured literature review was the main methodology employed in this research; literatures such as Journals as well as internet services and other relevant publication were consulted with regard to the weed control methods of rice production in lowland rice production.

Lowland Rice Production

Lowland rice describes crops where the fields are inundated for at least part of the time between establishment and harvest, and may depend on rainfall or irrigation. Production

systems with effective water control present the greatest technical opportunities for intensification and diversification of the cropping system. In West Africa, of the 20-50 million ha of inland valley bottoms and hydromorphic fringes, only about 15% are currently utilized for crop production. Appropriate weed control regimes are a vital component of sustainable development for such areas (Johnson, 2017).

Weed Control in Rice Production

Weeds are the cause of serious yield reduction problems in rice production worldwide. Losses caused by weeds vary from one country to another, depending on the predominant weed flora and on the control methods practised by farmers. Two examples give an idea of the dimensions of the problem. In China, 10 million tonnes (Mt) of rice are lost annually due to weed competition (ZePu Zhang, 2001); such a quantity of rice is sufficient to feed at least 56 million people for 1 year. In Sri Lanka, a country considered self-sufficient in rice, weeds are the major biotic stress in rice production and account for 30 to 40 per cent of yield losses (Abeysekera, 2001). Mahadi *et al.*, (2006) reported that the lack of weed control in rice fields causes 80-100% yield reduction in Nigeria.

Weed control in overpopulated areas of Asia has mainly been carried out through a combination of water management and hand-weeding, but the latter is becoming less common in areas with an increasing labour shortage problem; furthermore, this method affects transplanting. For these reasons, many farmers in several regions of the world, including Asia, have shifted from transplanting to direct seeding rice; less labour is required but herbicides must be used for weed control (Glover, 2011). Farmers are then faced with no option other than the application of herbicides, despite their lack of knowledge concerning the proper use of these chemicals (Abeysekera, 2001).

Herbicide-based weed management is becoming the most popular method of weed control in rice (Abeysekera, 2001). However, while herbicide application certainly controls several weeds, it does not eliminate others,

thereby provoking a weed shift of tolerant species (Abeysekera, 2001). Experience shows, however, that although herbicide use alleviates the problem of labour for weeding, incorrect use of herbicides may bring about other environmental problems (Abeysekera, 2001). The advent of herbicide-resistant species is an increasingly worrying problem for farmers, extension workers and policy-makers in many rice-producing areas in Asia and Latin America (FAO, 2002).

Weed Control Methods in Low Land Rice

These systems vary considerably according to the degrees of land levelling, drainage, bounding, to enable either rainfall to be retained or irrigation water supplied to flood the rice crop. The rice crop may either be direct sown or transplanted from a nursery bed. Production systems with effective water control present the greatest technical opportunities for intensification and diversification of the cropping system. In West Africa, of the 20-50 million ha of inland valley bottoms and hydromorphic fringes, only about 15% are currently utilized for crop production. Appropriate weed control regimes are a vital component of sustainable development for such areas. The most serious weeds of lowland rice are pan-tropical and the more widespread include sedges, such as *Cyperusdifformis*, *C. iria*, *Fimbristylis* spp. and *Scirpusmaritimus*, the grasses *Echinochloa crus-galli*, *E. crus-pavonis*, *E. glaberescens*, *E. pyramidalis*, *Ischaemumrugosum*, *Leptochloa* spp., *Oryzabarthii*, *O. longistaminata*, *O. rufipogon* and the broadleaves *Ludwigia* spp., *Ecliptaprostrata* and *Sphenochleazeylanica*. These weeds are well adapted to the aquatic environment, capable of rapid growth and multiplication and are very competitive with rice. Such integrated crop management (ICM) practices can reduce the weed problems in lowland rice fields and were shown to increase productivity by 4-25%, depending on the level of water control (Adakayi, 2000).

Weed Control Method Using Chemicals

Chemical control of weeds involves the use of herbicides. Herbicides control weeds either by speeding up, stopping, or changing the weed's normal growth patterns (Adakayi, 2000). This affects the weed by drying out the leaves or stems, or by making it drop its leaves.

Conventional chemical weed control

Herbicides are important control methods in the lowlands (Adakayi2000). The use of herbicides is economically attractive as it requires less overall weeding time and it enables the farmer to use time- and labour-saving planting methods such as direct (broadcast) seeding (Adakayi, 2000). Herbicides are likely to be particularly useful in areas where labour is in short supply. Farmers should have sufficient financial resources to invest in herbicides and the return of such investments should be high enough. In the rain-fed lowland rice production systems in the Casamance (South Senegal) herbicides were found to be a profitable investment on fertile soils (Rood, 2004). Herbicides are often used in combination with other control options and, for example, in the irrigated rice systems in Senegal most farmers rely on chemical weed control followed by hand weeding (Rood, 2004). For effective and safe herbicide use, the appropriate product, application equipment and application rates are important (Zimdahl, 2013).

Moreover, herbicide application requires good timing with respect to crop and the growth stage of weeds (Jamala, *et. al.*, 2011), weather conditions (Haeefe 2000) and flooding. Interactions between flooding and herbicides tend to be product specific (Sabair, 2008).

Herbicide Resistant Rice Technologies

Rice varieties with resistance against post-emergence non-selective or broad-spectrum herbicides could facilitate improved weed management in some situations (Johnson & Kent, 2002).

Types of Herbicides

The use of herbicides is sometimes the only practical and selective method of managing certain weeds. Herbicidal applications are usually cost-effective control methods in bush land areas, particularly when funding is scarce. In many cases, a weed is only susceptible to 1 specific herbicide, and it is important to use the correct product and application rate for control of that particular weed, (Khush, 1997). Common mistakes include incorrect identification of the weed, or using inappropriate products chosen solely on price (Khush, 1997). In most cases, weeds must be actively growing to be vulnerable to herbicide treatments.

There are 5 types of herbicides:

- **Broad spectrum** - these work on a wide variety of weeds
- **Selective** - these work on a narrow range of weeds
- **Contact** - these destroy weed tissue at or near the point of contact (they do not spread around the weed), and require even coverage in their application
- **Systemic** - these move through the weed's circulation system, and can be injected into the weed
- **Residual** - these can be applied to the soil and destroy by root uptake. They remain active in the ground for a certain length of time, and can control germinating seedlings.

Weed Control Using Cultural Method

Cultural weed control includes non-chemical crop management practices ranging from variety selection to land preparation to harvest and postharvest processing. Cultural weed control is a part of integrated weed management which involves the integrated use of cultural, manual, and/or mechanical control methods (Bailey, 2004). The following are the ways for central practical to control weeds

1. **Timing:** Weeds need to be controlled from planting until the crop canopy closes

2. **Land preparation and leveling:** Use land preparation to control growing weeds and to allow weed seeds to germinate. Kill newly emerging weeds by repeat tillage at adequate (~10-day) intervals.
3. **Reduce weed entry into fields:** Prevent the introduction of weeds into fields by: 1) use clean good quality seed; 2) keep seedling nurseries free of weeds to make sure weeds are not planted with the rice seedlings; 3) keep irrigation channels and field bunds free of weeds to prevent weed seeds or vegetative parts entering the fields; 4) use clean equipment to prevent field/crop contamination; and 5) rotate crops to break weed cycles.
4. **Fallow management:** Kill weeds in fallow fields (e.g., use tillage) to prevent flowering, seed-set and the build-up of weed seeds in the soil (Remember: “one year of seeds, seven years of weeds”).
5. **Crop-weed competition:** Select a weed-competitive variety with early seedling vigor, and high tillering to suppress weeds. Transplanted crops tend to have fewer weeds and less yield loss than direct seeded crops. Transplant healthy, vigorous seedlings that can better compete with weeds in early stages. Maintain an adequate plant population that closes its canopy by maximum tillering to shade out weeds. Apply Nitrogen (N) fertilizer just after weeding to minimize rice-weed competition for N.
6. **Water management:** Water is the best control for weeds. Many weeds cannot germinate or grow under flooded conditions (e.g. most grasses and some sedges). Maintain a 2-5 cm water level in the field to minimize weed emergence and lower weed pressure. If water is sufficient, fields can be continuously flooded from the time of transplanting to when crop canopy covers the soil completely. Good land leveling is critical to avoid high spots where weeds can become established (Adakayi, 2000).

Biological Method of Weed Control

Biological weed control has recently received renewed interest because it is an

environmentally compatible method of weed control without residue and pollution problems. However, biological weed control has its weaknesses and is not suitable for all weed problems. Undoubtedly, with continued interest and research support, the general assumption that biological weed control is used only as a last resort where chemical and other methods have failed will be proven incorrect, Duke, (2008). Biological control agents are generally most effective when established in gullies and rocky knolls of hills. These areas are usually inaccessible and too costly to spray so they can provide a safe haven for agents to retreat to from pastures when there is too much disturbance, such as grazing.

Summary

Rice has become an important strategic and daily staple food crop in Nigeria. The potential land area for rice production in Nigeria is between 4.6 million and 4.9 million ha. Out of this, only about 1.7 million ha—or 35 per cent of the available land area—is presently cropped to rice. The main production ecologies for rice in Nigeria are rainfed lowland, rainfed upland, irrigated lowland, deep water and mangrove swamp. Of these, rainfed lowland rice has the largest share of the rice area (50%) and rice production. New high-yielding lowland varieties of the rice are undergoing agronomic evaluation in Nigeria and several other countries. Small-scale farmers with farm holdings of less than 1 ha cultivate most of the rice produced in Nigeria. However, rice productivity and production at the farm level are constrained by several factors. These constraints include insufficient appropriate technologies, biotic factors, poor supply of inputs, ineffective farmer organizations and groups, low yield and poor milling quality of local rice varieties, poor marketing arrangements, inconsistent agricultural input and rice trade policies, poor extension systems and environmental constraints. These environmental constraints include poor drainage and iron toxicity in undeveloped lowland swamps, poor maintenance of developed lowland swamps, drought, deficiencies of N and P, insufficient rain for

rained lowland, rice production, and poor soil management practices.

Conclusion

This study reveals that though several inter-related social, economic and cultural factors review in farmers of weed control method, among some particular factors affecting adoption of some weed control methods are; insufficient funds, inadequate technical support and supplies, an insufficient cost-benefit ratio to cover the investment risk, and a preference for traditional methods. Hence farmers, improved weed control measures which build on traditional practice and which are compatible with farmer resources.

Control of weeds during land preparation is crucial to reduce the amount of weed pressure in the field. Land preparation should start 3–4 weeks before planting. Ploughing destroys weeds and remaining stubble from the previous crop. Weeds should be allowed to grow before the next cultivation. In addition, a level field helps retain a constant water level that controls weeds.

Recommendations

- Weed management in rice will only be improved if farmers take into consideration the ecology of major weeds and their interaction with rice. Reduction of inputs for weed control will only be possible if there is a sustainable reduction of weed seed bank.
- Weed ecology requires further research. Extension workers and farmers should be trained in these aspects within the ongoing IPM programmes on rice. Weed ecology elements should be an essential part of the IPM curriculum in farmers' field training.
- There are several new developments in weed control (e.g. use of green manure and intercropping) which require implementation as part of an integrated approach, taking account of the available data on weed ecology.
- Breeders and weed scientists should work closely together to develop new rice cultivars and look for the possibilities of producing either all elopathic or highly competitive rice varieties that are able to compete with weeds. This should be another important element in the development of integrated weed management in rice.
- Problems of herbicide resistance will only be reduced by preventing this phenomenon. To this end, it is necessary to design and implement appropriate measures, including information on cases of resistance of particular herbicides in rice in other countries. Labelling of herbicides with their mode of action would help farmers to reduce the possibilities of resistance. Farmers should also be trained in the correct use and handling of herbicides.
- Due to the potential risk of transfer of the resistance trait from transgenic herbicide-resistant rice to weedy rice, it is not advisable to use such cultivars. At present, farmers simply cannot afford to take a risk which may create more problems than benefits. Although science may develop some procedures to prevent this phenomenon in the future, it is clear that at present there are no solutions available.
- Agricultural extension agencies should take note of the information needs of rice farmers particularly in areas of pesticides, fertilizers, and improved farm implements and try to step up their services in these areas of need.
- Farmers' adult literacy education programme is required to help them acquire basic skills and abilities to seek and receive needed agricultural information through modern communication channels such as mass media, extension agents, e.t.c.
- Government should encourage and assist rice farmers by giving them special attention in terms of access to needed farm inputs. New farming implements which will reduce drudgery and are affordable should be made available to them and at appropriate time and seasons.
- Rice farmers should be considered in terms of granting loans to help boost their production capacity to ensure food security not only in their domain but in Nigeria as a nation.

- Finally, ICT-based agricultural information delivery support system should be developed to encourage modern production technology adoption by farmers.

References

- Abeysekera & Anuruddhika, S. K. 2001. Management of *Echinochloa* spp. in rice in Sri Lanka. Paper presented at the FAO workshop on *Echinochloa* spp. Control, Beijing, China, 13 pp.
- Abouziena, H. F. *et al.*, 2009: Comparison of some new natural product herbicides for weed control at two growth stages. *Weed Technol.*, v. 23, n. 3, p. 431-437.
- Adakayi, P.E., 2000. Climate. In: Geography of Abuja Federal Capital Territory, Dawan, PD. Famous/Asanlu Publishers, Ivlinna, Niger State, Nigeria, pp: 9-23.
- Ajah, J. and J.N. Nmadu, 2012. Socio-economic factors influencing the output of small-scale maize farmers in Abuja, Nigeria. *Kasetsart J. (Soc. Sci.)*, 33: 333-341
- Akande, T. (2002): An Overview of the Nigerian Rice Economy, NISER Monograph Series No. 11. Nigerian Institute of Social and Economic Research (NISER) Ibadan
- Akinbile, C.O., 2010. Behavioural pattern of upland rice agronomic parameters to variable water supply in Nigeria. *J. Plant Breed. Crop Sci.*, 2: 73-80
- Akpokodje, G, Lançon, and O, Erenstein, (2001): Nigeria's rice economy: State of the art. Paper presented at the NISER/WARDA Nigerian Rice Economy Stakeholders Workshop, Ibadan, 8-9 November 2001. Bouake: WARDA.
- Awotodunbo A. A. and Bello F. G. (2011), Appraisal of weed management effectiveness in North Eastern Nigeria: A study of Leventis Foundation trained farmers *International Journal of Agricultural Economics & Rural Development* - 4 (2): 2011
- Babar, S. R.; Velayutham, A. 2012: Weed management practices on weed characters, plant growth and yield of rice under system of rice intensification. *Madras Agric. J.*, V. 99, n. 1-3, p. 46-50,.
- Bailey, S.W. (2004). Climate change and decreasing herbicide persistence. *Pest Management Science*, 60(2), 158-162.
- Baker, B.; Brown-Rosen, E. 2007: Crop protection product formulation for the organic market. In: FELSOT, A. S.; RACKE, K. D. (Ed.). Crop protection products for organic agriculture: environmental, health, and efficacy assessment. Oxford: Oxford University Press.
- Basoru, OJ. and JG. Fasakin, 2012. Factors influencing rice production in Igbemo-Ekiti Region of Nigeria. *J. Agric. Food Environ. Sci.*, 5: 1-9.
- Bingaman, B. R.; Christians, N. E. 1995: Greenhouse screening of corn gluten meal as a natural control product for broadleaf and grass weeds. *Hort Science*, v. 30, n. 6, p. 1256-1259.
- Bond, W.; Turner, R. J.; Grundy, A. C. 2016: A review of non-chemical weed management. 2003. Disponible: <<http://www.organicweeds.org.uk>>.
- Cho, D.S. and H.C. Moon (2002). *From Adam Smith to Michael Porter: Evolution of Competitiveness Theory*, World Scientific, Singapore
- Danbaba, N., J.C. Anounye, A.S. Gana and ME. Abo, 2013. Grain physiochemical and milling

- qualities of rice (*Oryza sativa* L.) cultivated in Southeast, Nigeria. *J. Applied Agric. Res.*, 5: 61-71
- Daramola B. (2005): Government Policies and Competitiveness of Nigerian Rice Economy. A Paper presented at the 'Workshop on Rice Policy & Food Security in Sub-Saharan Africa' organized by WARDA, Cotonou, Republic of Benin, November 07-09.
- David E. Johnson (2017) Weed Management in Small Holder Rice Production in the Tropics Natural Resources Institute University of Greenwich Chatham, Kent, UK. <https://ipmworld.umn.edu/johnson>
- Duke, S.O., & Powles, S.B. (2008). Glyphosate: A once-in-a-century herbicide. *Pest Management Science*, 64(4), 319-325.
- Edoka, M.H., S.O. Adejoh and M.K. Ibrahim, 2009. The role of women in rice production in Idah local government area of Kogi State, Nigeria. Proceedings of the 43rd Annual Conference on Agricultural Society of Nigeria, October 19-23, 2009, Abuja, pp: 648
- Ekeleme, F., A.Y. Kamara, L.O. Omoigui, A. Tegbaru, J. Mshelia and J.E. Onyibe, 2008. Guide to Rice Production in Borno State, Nigeria. IITA, Ibadan, Nigeria.
- Ekong, E.E., 2003. **An Introduction to Rural Sociology**. 2nd Edn., Dove Educational Publishers, Uyo, Nigeria.
- FAO 2017. Nigeria at a Glance retrieved from <http://www.fao.org/nigeria/fao-in-nigeria/nigeria-at-a-glance/en/> 12/17/17 6:50pm
- FAO. 2008. *Summary of the Workshop on Echinochloa Control*, Institute of Plant Protection, Beijing, China, 27 May. Available at www.fao.org/WAICENT/FAOINFO/AGRICULT/AGP/AGPP/IPM/Weeds/Default.htm.
- Ginigaddara GAS, Ranamukhaarachchi SL (2009) Effect of conventional, SRI and modified water management on growth, yield and water productivity of direct-seeded and transplanted rice in central Thailand. *Aust J Crop Sci* 3(5):278-286.
- GLOVER, D. 2011: A system designed for rice? Materiality and the invention/discovery of the system of rice intensification. *East Asian Sci. Technol. Soc.*, v. 5, n. 2, p. 217-237.
- Haefele, S.M., Johnson, D.E., Diallo, S., Wopereis, M.C.S., Janin, I., 2000. Improved soil fertility and weed management is profitable for irrigated rice farmers in Sahelian West Africa. *Field Crop*.
- Jamala, G.Y., H.E. Shehu and AT. Crarba, 2011. Evaluation of factors influencing farmers adoption of irrigated rice production in Fadama soil of North Eastern Nigeria. *J. Develop. Agric. Econ.*, 3: 75-79
- Johnson, D.E., & Kent, R.J. (2002). The impact of cropping on weed species composition in rice after fallow across a hydrological gradient in West Africa. *Weed Research*, 42(2), 89-99.
- Khush, G.S. (1997). Origin, dispersal, cultivation and variation of rice. *Plant Molecular Biology*, 35(1-2), 25-34.
- Kraehmer, H.; Baur, P. Weed anatomy 2013. London: Wiley-Blackwell, 504 p.
- Mahadi MA, Dadari SA, Mahmud M, Babaji BA 2006. Effect of pre-emergence herbicides on yield and yield components of rice. *J Food Agric Environ* 4(2): 164-167.

- NAERLS and NPFS, 2011. Agricultural performance survey of 2011 wet season in Nigeria. National Agricultural Extension and Liaison Services, Ahmadu Bello University and National Programme for Food Security, pp: 1-17
- NPC, 2006. Population and housing census enumerators manual. Federal Republic of Nigeria, National Population Commission, Nigeria, pp: 1-16.
- Nwajiuba, C.U. and A.O. Ejiogu, 2008. Short-run analysis of food and fuel prices in Nigeria 1990-2006: Implications for food security. Proceedings of the 10th Annual Water Distribution Systems Analysis Conference, August 17-20, 2008, Kruger National Park, South Africa, pp: 476-491.
- Nwalieji, U. and EA. Onwubuya, 2013. Adaptation practices to climate change among rice farmers in Anambra State of Nigeria. *J. Agric. Extension*,
- Odoemenem, I.U. and Inakwu, J.A. (2011): "Economic Analysis of Rice Production in Cross River
- Okonji, C.J; KA. Okeleye, S.O. Oikeh, S.G. Aderibigbe, FE. Nwilene, O. Ajayi and A.A. Oyekanmi, 2012. Rice yield and yield components as influenced by phosphorus and nitrogen application rates in the moist savanna of West Africa. *J. Agric. Sci. Technol*, 2: 1214-1223.
- Onwueme, I.C. and TD. Sinha, 1991. Field Crop Production in Tropical Africa. Technical Centre for Agricultural and Rural (Joperation (CTA) Ede, The Netherlands, Pages: 480
- Rood, M. A. 2004: Long-haul organic. *Rice J.*, v. 105, n. 1, p. 12-17.
- Sabair, G., 2008. Nigerian spends one hundred billion yearly to import rice. Nigerian Tribune Newspaper, November 25, 2008
- Sinha SK and Talati J (2007) Productivity impacts of the system of rice intensification (SRI): A case study in West Bengal, *India. Agr Water Manag* 87: 55-60.
- Sopeña, F. M. C.; Morillo, E. 2009: Controlled release formulations of herbicides based on micro-encapsulation, Literature Review. *Cien. Invas. Agr.*, v. 35, n. 1, p. 27-42.
- United States Department of Agriculture (USDA) Foreign Agricultural Service *World Agricultural Production Circular Series* WAP 12-17 December 2017
- WARDA, 2001. West Africa rice development association. Strategic Plan 2008-2010
- ZePu Zhang. 2001. Weed management in rice in China. Summary presented at FAO Workshop on *Echinochloaspp.* Control, Beijing, China, 27 May.
- ZimdahL, R. L. 2013: Fundamentals of weed science. 4ed. New York: Academic Press.