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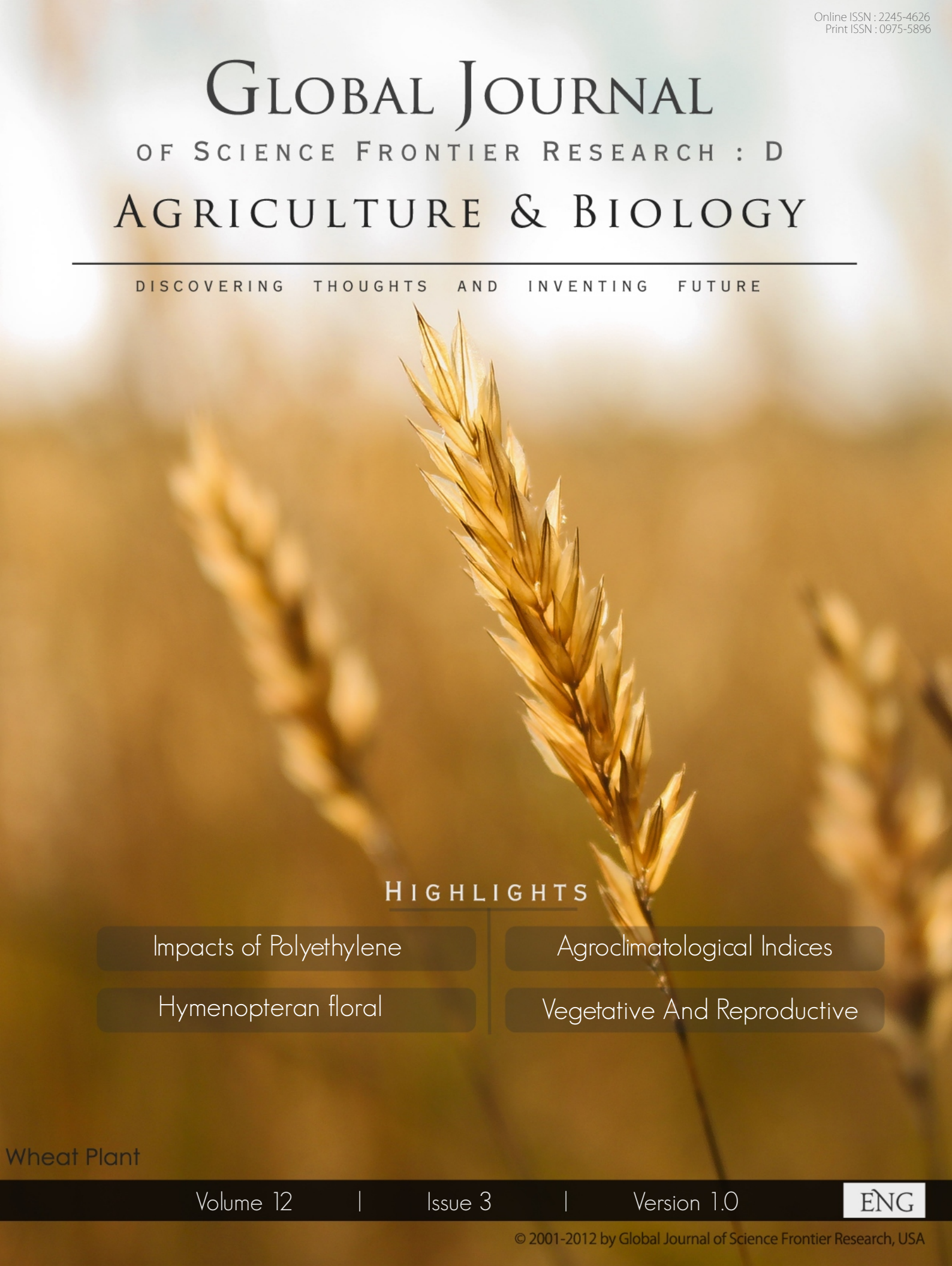

HIGHLIGHTS

- Impacts of Polyethylene
- Agroclimatological Indices
- Hymenopteran floral
- Vegetative And Reproductive

Wheat Plant

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Environmental Impacts of Polyethylene Generation and Disposal in Akure City, Nigeria

By A. O. Akinro, O. B Ikumawoyi, Olotu Yahaya & M.M. Ologunagba
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Abstract - The environmental impact and seasonal variation of polyethylene (cellophane) generation and disposal in Akure City, Nigeria was investigated. Five daily markets, were randomly selected for data collection. In each market, two areas: one in the raw food section and the other in the processed food items section, each measuring 30 metres by 100 metres were demarcated for investigation. The result showed that polyethylene is generated more during the dry season months than the wet season months. The result also showed that table water sachet topped the list of cellophane wastes generated. This is because; it is cheap and consumed throughout the year with very little seasonal variation. Types of cellophane generation at home and market also displayed a very interesting pattern. The study showed that in the market, polyethylene for assorted items was the least (51,000), followed by biscuits (50,863), ice cream sachets (81,526) and table water sachets (96,853).

Keywords : *cellophane, pollution, environmental, impact, campaign, enlightenment.*

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Environmental Impacts of Polyethylene Generation and Disposal in Akure City, Nigeria

A. O. Akinro[α], O. B Ikumawoyi[σ], Olotu Yahaya[ρ] & M.M. Ologunagba[ω]

Abstract - The environmental impact and seasonal variation of polyethylene (cellophane) generation and disposal in Akure City, Nigeria was investigated. Five daily markets, were randomly selected for data collection. In each market, two areas: one in the raw food section and the other in the processed food items section, each measuring 30 metres by 100 metres were demarcated for investigation. The result showed that polyethylene is generated more during the dry season months than the wet season months. The result also showed that table water sachet topped the list of cellophane wastes generated. This is because; it is cheap and consumed throughout the year with very little seasonal variation. Types of cellophane generation at home and market also displayed a very interesting pattern. The study showed that in the market, polyethylene for assorted items was the least (51,000), followed by biscuits (50,863), ice cream sachets (81,526) and table water sachets (96,853). On the other hand, the trend showed that, at home, polyethylene for assorted items was the highest (98,361kg), closely followed by biscuit wrapper (45,263), ice cream wrappers (35,514) and table water sachets (25,360). Cellophane waste poses various threats to public health and adversely affects flora and fauna as well as the environment especially when it is not appropriately collected and disposed. It is advocated that aggressive campaign and enlightenment of the masses on the threats posed by cellophane pollution should be carried out to prevent further damage to the environment.

Keywords : cellophane, pollution, environmental, impact, campaign, enlightenment

I. Introduction

Human activities generate many by-products which are generally seen as useless and discarded as wastes (Palmer, 1998). These massive amounts of wastes subsequently find their ways into the ground, air and water every year (Day, 1998). Increasing population growth accompanied by rapid urbanization and industrialization has resulted in dramatic increases in the volume of wastes generated by modern societies. Increase in economic activities and food consumption by humans and changing lifestyles generate a massive volume of domestic wastes which creates a critical problem in the developed and developing countries of the world (Palmer, 1998).

Solid waste management has emerged as a major environmental threat for cities in developing countries worldwide. In a survey released by UNDP in 1997, 151 mayors from around the world ranked solid waste disposal problem as their second most urgent urban challenges surpassed only by unemployment and followed by urban poverty (Agagu, 2008).

Solid waste management has gained notoriety in Nigeria today because of its visibility and the embarrassment it has constituted to the image of the nation (Agagu, 2008). Only few state capitals in Nigeria have been able to put in place fairly sustainable urban waste management programmes. It is therefore a common site to find mountains of waste scattered all over our cities for days or even weeks with no apparent effort displayed at getting rid of them, even with the attendant risk of air and ground-water pollution (Fig. 1).

Fig. 1 : Refuse mountain in a typical Nigerian City.

Considerable percentage of urban waste in developing countries is deposited either on the roads, or road sides, unapproved dump sites, in water ways drainage system, or in open sites which adversely affect environmental friendliness. In fact, solid waste poses various threats to public health and adversely affects flora and fauna as well as the environment especially when it is not appropriately collected and disposed (Geraldu, 1995). Besides the above mentioned effects of solid wastes, they result in emission of toxic chemical to the atmosphere and to the soil whenever they are degraded or burnt. The trees absorb these toxins through their root system which retards growth rates and consistently results to death (Addison *et al.*, 1991).

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Until recently, polyethylene (cellophane) papers do not have serious negative environmental problem in the developing countries simply because of the subsistent pattern, small scale agricultural and industrial production and, consequently, low quantity of waste generation. Besides, when generated, land was generously available for the disposal of waste. Hence simple disposal techniques such as return to land use of adjacent field, and indiscriminate burning and dumping were adopted for waste disposal (James, 1991; George *et al*., 1993). Unfortunately, these techniques could no more accommodate the present waste disposal problems because of rapid population growth and industrialization which are the two major factors competing for land (John and Williams, 1993). The two major factors have greatly increased the volume of polyethylene (cellophane) generation. If this is the present situation, it would mean that the coming generation will have to face and contend with unprecedented environmental problems and challenges.

In traditional African Society, with lower population figures, the native leave was sufficient for all that the individual needed to wrap (Jimoh, 2002). But the challenges of ever increasing population have made Nigerians to learn how to use the fairly improved means of wrappers such as the polyethylene bags. Polyethylene (cellophane) papers are currently being used in all forms and shades in Nigeria as wrappers ranging from biscuit, ice cream, table water, salt, and tapes (audio and video) to mention but a few. Cellophane bags are used virtually in all shopping centers, homes, markets, restaurants and farms in Nigeria (Ogunna, 1999). Polyethylene materials, which are derived from ethylene polymers, are products of the polymers industry at present. They posses certain qualities and properties which make them readily usable. These include high tensile, stiffness, compressive strength and impact resistance (Aziegbe, 2007). The high physical strength and properties are reproducible and predictable as well. They also retain their physical and chemical properties over a wide range of environmental conditions such as heat, cold and chemicals. They can resist mechanical stress for a very long period of time. Flame retardness is not an essential requirement but it has become an added asset lately. They are not biodegradable since they are unaffected by heat, cold and chemicals (Obediah, 2001). Polyethylene is found in the entire streets, nooks and crannies of Ondo State. They therefore pose serious environmental problems to inhabitants especially where solid wastes are deposited in both urban and rural areas. Urban waste disposal is the responsibility of various municipalities, local government and/or city co-operations (Ramasastry, 1988). In most developing nations, urban waste disposal systems are anything but functioning. Where they function however, they are grossly inadequate despite today's technological know-how and renewed efforts towards effective waste disposal. A lot of studies abound that focus attention on solid waste generation and disposal in Nigeria cities. Examples include Adedibo (1983) study of Ilorin and Offa, Kwara State; Adefemi and Awokunmi, (2009) study of Ado-Ekiti, Ekiti State and Fasinminrin, (2004) study on Akure, Ondo State. Studies of waste generation and disposal with a focus on the Nigeria landscape include Onokerhoraye (1984); Omuta (1988); and Oyinlola (2001). A central theme that runs through these studies cited is that they examined generally, solid waste generation and disposal systems. However, there are few research works on the environmental impact of polyethylene generation and disposal in Nigeria. Aziegbe, (2007) examined the seasonality and environmental impacts of polyethylene generation and disposal in Benin City, Nigeria. His work was however site specific. Till date, there is not known any research work with focus on the generation and disposal of polyethylene papers and its environmental impact status within the contexts of aesthetics and environmental in Ondo State and with particular attention to Akure City, Nigeria. This knowledge gap specifically represents the focus of this study. Essentially therefore, this paper investigates the seasonal variation in the generation and disposal of polyethylene papers in Akure municipal with a view to comparing the quantity of polyethylene generated and disposed off both at homes and market centers, and, also examines the risks posed by polyethylene to human health and environment.

II. Material and Methods

a) *Study Area*

The study area is Akure Municipal, the capital of Ondo State in South west Nigeria which lies at latitude 7 ° 16' North and longitude 5° 13' East. Akure has a population of about 483,300 out of the 140,003,542 inhabitant of Nigeria (Population census, March 2006 estimate). Akure has a land area of about 2,303 sq km and is situated within the Western upland area. The area has a general elevation of between 300 -700 meters above mean sea level. The average annual growth rate according to the 2004 estimate was 2.4%. Akure has been steadily increasing in population thereby putting pressure on the natural resources both land and water.

Akure city enjoys tropical climate with two distinct seasons. These are the wet season (April-October) and the dry season (November-March). It lies in the rain forest zone with mean annual rainfall between 1300mm-1600mm and with average temperature between 27.5^0-32.5^{0}C (Akinro and Olawale, 2007). The relative humidity ranges between 85% and 100% during the rainy season and less than 60% during the harmattan period. The relatively high temperature of Akure, no doubt, permits the demand for cold sachet water, ice cream as well soft drinks (minerals of all kinds) particularly during the dry season period.

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The technique adopted for this study is largely quantitative and it utilizes data that is collected through household/market interview and administration of questionnaires using standard quantitative technique. Quantitative research allowed the selection of a representative sample from among the population to be investigated, which then allows an analysis that generate inferences for the entire population under investigation (New man, 2000).

Nine daily markets (Table 1) were randomly selected for data collection. In each market, two areas measuring 30 metres by 100 metres were demarcated in such a manner that one was in the raw food section and the other in the processed food items (provision stores) section.

Table 1: Names of Markets and Location

S/No.	Name of Market	Location
1	Oja Oba	Oba Adesida Road
2	Isolo Market	Isolo
3	Isikan	Isikan
4	Ilisa	Oke-lisa
5	NEPA	Adekunle Ajasin/Hospital Rd
6	Iloro	Oke-Aro
7	Mojere Spare Parts Market	Ilesa Rd
8	Araromi	Araromi
9	Maronu	New Stadium

In the Mojere market where there was no foodstuff section, the same two areas with the same dimension indicated earlier on were equally demarcated. In each market, one of the sanitation personnel was made to sweep the demarcated areas daily and was instructed to always sort the cellophane from other wastes. These were stored in special refuse collection bins, and were measured weekly. Furthermore, for the purpose of determining and comparing the amount of cellophane generated at homes and in the markets, 400 waste paper baskets were distributed to 200 respondents approached to participate in this study. Each participant was given 2 waste paper baskets. While one of these baskets was to be placed and monitored in the markets, the other is to be used at homes. For the purpose of standardization, the number of those in each store or household divided the cellophane generated. Data were collected from January 2009 to December 2009. The data were analysed using statistical inferences.

III. Results and Discussions

The monthly distribution of cellophane in all the markets combined is shown in Table 2. The pattern displayed showed a rise in cellophane generation and disposal from January to April, which had the highest peak of 18.8 kg. Thereafter, there is a gradual declining trend until August (9.2 kg), which experienced the least generation and disposal. The rise in trend continued again until the month of December, which had the second peak (15.1 kg). Seasonal variation showed that cellophane generation was generally high during the dry season months of November to March with the highest occurring in March (23.6 kg). There was a decline in the amount of polyethylene generated in the wet season

Table 2 : Variation in polyethylene generation and disposal

Month	Seasonal basis	Market basis
January	18.2	13.5
February	20.4	14.7
March	23.6	15.4
April	19.7	18.8
May	16.3	13.1
June	17.5	10.6
July	17.2	9.5
August	16.5	9.2
September	15.4	11.4
October	14.5	12.7
November	16.8	13.2
December	17.2	15.1

months of April to October with the lowest occurring in the month of October (14.5 kg). This is in agreement with the works of Akitikpi (1999) who reported similar result for Warri when he observed that solid waste generation is higher during the dry season than in the wet season.

The mean cellophane generated and disposed from the sampled markets in Akure is shown in Table 3. Mojere spare parts market generated the highest cellophane among the sampled markets with 58.60±7.8 kg per day. This was closely followed by Oja –Oba with 53.21±8.3 kg of cellophane per day. Maronu market had the least weight of cellophane generation and disposal with a mean value 32.65±1.4 kg per day.

Table 3 : Cellophane generated on market basis

S/No.	Name of Market	Cellophane generated (kg)	Standard Deviation	Rank
1	Oja Oba	53.21	8.3	2
3	Isolo Market	48.63	4.5	3
4	Isikan	45.14	5.1	4
5	Ilisa	43.22	4.8	5
6	NEPA	40.91	3.7	6
7	Iloro	38.74	4.3	7
8	Mojere	58.60	7.8	1
9	Araromi	36.74	2.6	8
10	Maronu	23.65	1.4	9

A similar pattern of monthly distribution of polyethylene was noticed in these markets. Some market like Mojere, Oja-Oba and Isolo Market are mostly affected by seasonal variation. All the markets recorded the peak of polyethylene generation in the month of

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March (Table 2) but the least generation and disposal did not take place in a single month. While the least disposal occurred in the month of May in Araromi and Iloro markets, it was August and October in NEPA and Ilisa markets respectively. Mojere spare parts market ranked first in waste generation. The reason that could be responsible for this is that the market population comprised of mainly men who depend almost entirely on food items wrapped with polyethylene. Another reason may be because the market also serves as the motor park for transporters to Ibadan, Ilorin and other parts of Nigeria. Maronu and Araromi markets which recorded low cellophane generation are more of foodstuff markets where women traders dominate. Though, they use a lot of polyethylene in the sales of their foodstuff, most of these polyethylenes are not deposited in the markets but are taken home. Moreover, most women cook their food at home and bring them to the market in plastic food containers thus reducing the rate of consuming cellophane wrapped foods in the market.

The polyethylene collected were sorted and counted. The result shows that table water sachet topped the list, followed by cream and biscuit wrappers (Fig. 1).

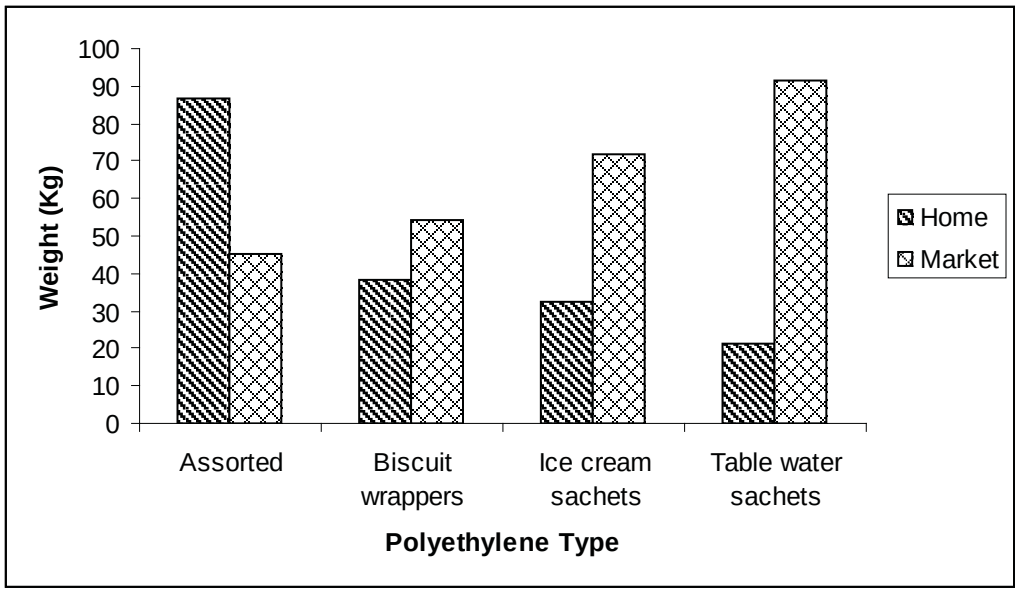

Fig.1: Comparison between polyethylene wastes generated at home and market.

Table water sachet topped the list because; it is consumed throughout the year with very little seasonal variation. Again, the studied markets have no public portable water system where the traders can get their drinking water. As a result, majority of them depend on the sachet water on a daily basis. Some traders who take their drinking water to the market from home soon discover that the water become too warm and unfit for consumption in the afternoons particularly on sunny days. Consequently, they resort to the cold sachet water that is being hawked all over the market. Ice cream wrappers exhibited the highest variation in this study. Their generation and disposal are readily compared both during the dry months and the heart of the wet season.

Polyethylene for assorted items also exhibited high seasonal variation. This implies that its demand and consumption is almost uniform throughout the year. Dede (2000) reported similar finding for Ibadan. She noted that among the non-biodegradable solid wastes generated, cellophane is mostly affected by seasonality. This kind of seasonality impact was reported for sachet water and newspaper in Warri (Odjugo, 2004).

Polyethylene generations are not restricted to markets and streets alone but are also generated at homes. Consequently, this study attempted to make some kind of comparison between the nature of polyethylene waste generated at home and, in the market. The same monthly pattern of generation was out-rightly higher for markets than homes. The possible reason could be that, at home most food is served with plates instead of wrappers. This has a way of reducing drastically the amount of cellophane generated as compared to the markets where most of the cooked food or snacks are served in polyethylene. Types of cellophane generation at home and market also displayed a very interesting pattern (Fig. 1).

Observations among polyethelene types generated in the market revealed that Table water sachets top the list with about 91.5 kg. This was closely followed by Ice cream sachets (71.8 kg), Biscuit wrappers (45.5 kg) and assorted polyethylene types (45.2 kg respectively in that other. Whereas, the trend of polyethelene types generated and disposed at home showed that polyethylene for assorted items was the highest (86.7 kg), closely followed by biscuit wrapper

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(38.4 kg), ice cream wrappers (32.6 kg) and table water sachets (21.3 kg) respectively in that order. Cellophane for assorted items ranked lowest in the market because they are used in wrapping items in the market but disposed off at home having removed the contained items for cooking or storage. The generation of table water sachets was lowest at home but highest in the market. This is so because most homes have refrigerator where they can store water for it to get cool/cold. This finding is in agreement with Aziegbe's (2007) study in Benin, Edo State, Nigeria. Further analysis showed that an individual generated and disposed 0.16 ton of cellophane annually (Table 4).

Table 4 : Measured and Estimated amount of polyethylene generated in Nigeria.

Category	Estimated Population	Weight of Polyethylene (tons)
Individual*	Individual	0.16
Akure City**	483,300	7,539
Ondo State**	4,475,316	69,815
Nigeria**	140,003,542	2,184,055

* = Measured ** = Estimated

Source : Fieldwork, 2008

Using this individual mean, estimates were computed for Akure City, Ondo State, and Nigeria (the entire country). Akure City with estimated population of 483,300 (National Census, 2005) generated 7.5 thousand tones of cellophane. Ondo State on the other hand with 4.5 million people in the same year, generated about 70 thousand tones of cellophane, while the entire country with estimated population 140 million generated 2.2 million tones of cellophane. With these figures, one can begin to imagine the number or volume of cellophane being generated and disposed in Nigeria from environmental perspective.

Table 5 : Preference for Polyethylene over other wrapping Material

respondents	%
Polyethylene	78
Newspaper	13
Leaves	9

The questionnaire survey further reveals that 78% of the respondents prefer the use of polyethylene as wrappers to newspapers and natural leaves (Table 5). This is because they are cheaper and have high aesthetic value. About 13% and 9% showed preference for local newspaper and leaves as media for wrapping. The respondents who showed interest in newspaper as wrappers fell into the group of petty traders such as fast food sellers on the road sides. Those who showed preference for leaves were mainly were mainly the aged ones. The group identified added taste and aroma as reasons for their choice of local leaves. They also see the leaves as medicinal. It should be noted that much as these respondents would want to use local leave as wrappers, they also see the need for modern wrapping materials like cellophanes, newspapers, old textbooks and magazines among others. Basically, all the respondents agreed that they use the polyethylene for wrapping fish, crayfish, meat, boiled and raw rice, beans, eggs and numerous form of processed food. About 94% agreed that they use larger cellophane to carry goods from the market and shopping centers, to raising seedlings and flowers. On the frequency of using cellophane before disposal, all the respondents agreed that they use it for a number of times so long as the cellophane is in good condition. On the question as to why cellophanes are disposed off indiscriminately by the respondents, the most outstanding reasons given include lack of waste bins in private and public places/vehicles; poor attitude of Nigerians towards waste disposal and environmental sanitation, no adequate punishment for environmental violators/abusers. Personal observation and experience reveal that virtually every Nigerian is guilty of this indiscriminate waste disposal since both the educated and illiterate, rich or poor, old or young throw away any waste anywhere and anytime he is done with the content.

IV. Environmental Problems of Cellophane and Management

The environmental problems associated with cellophane are numerous and varied. For example, a glass bottle thrown into the sea takes 1000 years to decompose. In contrast, paper tissues decompose in only three months. A cigarette butt pollutes the soil or sea for upward of 5 years; plastic bags take 10 to 20 years; nylon papers (where polyethylene belongs) take 30 – 40 years; cans, 500 years; and polystyrenes, 1000 years (Awake, 2002). Nylon or cellophane is non biodegradable but its strength while in water or soil deteriorates with time. During the deterioration period, the chemicals with which, the cellophane is composed are gradually released and thus polluting the soil or water for upward of 40 years.

With this in mind, and going by the volume of cellophane dumped into our water bodies, and land, one became worried with the magnitude of environmental pollution in Nigeria in the coming years. One is not particularly certain, when exactly, the use of cellophane started in this country but, what cannot be disputed is that its usage and the concomitant environmental pollution has been on steady rise since the 1970s when rapid urbanization, bludgeoning socialization, serious cultural integration and technological development resulted in a shift in the average Nigeria life style. This shift in life style from the traditional to the Western ways of living and feeding, together with the placement of aesthetics over and above the use of natural leaves as wrappers, accounted for some of the basic reasons for the continued

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patronage and use of polyethylene in Nigeria. Since polyethylene is not recycled in Nigeria or adequately disposed off, they are ever present on the landscape not-with-standing whether it is rural or urban. The environment is therefore, filthily coloured with all shades of polyethylene resulting in a drastic reduction of environmental aesthetics. This form of eyesore resulting largely from environmental abuse and degradation is worst in urban areas. The polyethylene is also capable of holding rain for days, weeks and months. These small pools of water are usually breeding ground for mosquitoes thereby increasing the incidence of malaria in Nigeria.

Presently, the type and magnitude of soil and water pollution in Nigeria is not fully known. However, there is the fear that if the situation is not checked immediately, chances are that our environment will become seriously unsustainable in the future. To guide against this, it is suggested that appropriate measures be put in place to properly dispose the non-biodegradable items.

In furtherance of these measures, it is advocated that aggressive campaign and enlightenment of the masses on the dangers of cellophane be carried out. This can be achieved through public lectures, jingles and adverts as the case may be. Hopefully, this approach will change their current attitude as it pertains to indiscriminate disposal of cellophanes. Government should provide public waste bins in strategic positions along the streets, and other public places. These waste bins should be collected and adequately disposed off regularly.

More personnel should be employed in the Ministry of Environment. Environmental Health Officers and equipments should be strengthened to be able to meet the demand of the present environment within the context of waste disposal. Currently, manpower and equipment are grossly inadequate in this ministry. People who are found to be physically abusing the environment should be arrested, charged and punished if found guilty. The hitherto monthly environmental sanitation programme as presently practiced in the State should be reinvigorated. It is equally advocated that the recycling aspect of the cellophane should be seriously considered. The government can do this by contracting cellophane collection and disposal out rightly. If this is done, and the people are aware that they will be paid for used cellophane, they will definitely be encouraged to preserve the ones used. This will create a means of sustainable employment for the women, children and the generally unemployed. Besides, our environment will be the better for it in terms of pollution and degradation.

V. Conclusion

Polyethylene generation was found to be higher during the dry season months (November – March) than the wet season months (April – October) with the least in the month of June. None foodstuff markets dominated by male traders who depend solely on wrapped food items with polyethylene had the highest cellophane generation. Cellophane generation was also higher in the markets than at homes. This is so because at homes, most food is served with plates and the consumption of table water and ice cream are considerably reduced. A larger proportion of the respondents prefer the use of polyethylene as wrappers, to newspaper and local natural leaves because of its cheapness, neatness and readily availability. Generally, respondents use polyethylenes for shopping, raising young seedlings, flowers and as, traveling bags. Some of the reasons given for improper disposal of polyethylene include environmental care-free attitude of Nigerians, non-availability of refuse bins in public and private places, as well as no punishment for environmental abusers and violators. Polyethylene is a major source of environmental degradation in Nigeria, and this form of environmental abuse is worst in the urban areas. The water held by cellophane serves as breeding ground for mosquitoes thereby increasing the incidence of malaria, which is the leading killer disease in Nigeria today. For a cleaner and sustainable environment therefore, massive awareness campaign and enlightenment about the danger cellophane poses to our environment should be vigorously carried out. Government should provide public waste bins in strategic positions for the collection of wastes.

The Ministry of Environment should employ more personnel. The government and individuals should look at recycling option of polyethylene

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Demand Analysis for Frog Meat in Ondo State, Nigeria

By Omoniyi, L.O , Ajibola M.E. & J.O. Bifarin
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Abstract - This study examined the demand for frog meat in Ondo State, Nigeria. A random sampling technique was used to select 100 consumers of frog meat. The tools of analysis were descriptive statistics like percentage, frequency distribution and tables; Regression analysis was also used to estimate the demand for frog meat and determine factors that influences same. The result of the analysis showed that 74% of the respondents are above 40 years of age, 82% married, 67% had family size of at least 6 and 76% claimed that frog meat is generally acceptable. The demand functions shows that the independent variables specified in the model accounted for 58.8% of the variability observed in the demand for frog meat. Furthermore, age (x_1), family size (x_4) and level of acceptability (x_8) were significant at 5% level, implying that they have important implications for the demand for frog in the study area. This study recommends the heed for the populace to be educated on importance and nutritional implications of the consumption of frog meat.

Keywords : *Demand, frog meat, Ondo State, Nigeria.*

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I. Introduction

Frogs are classified as amphibians. Amphibians are essentially a tropical group and well represented in Nigeria *(Oldham 2000)*. They are the first group of vertebrate animals to make a serious attempt at life on land. Their history is long and complex.

Few people realize how ancient frogs are, for 190 years, the ancestors of modern frogs have roamed (if not rule) the earth looking much the same as they do today. The secret of their success is their amazing adaptability *(Bay, 2002)*.

They can, in general, move, feed and breathe equally well on land and in fresh water. But nearly all amphibians return to water to breed.

Like all amphibians, frogs are cold-blooded meaning that their body temperature changes with the temperature of the environment. When temperature drops, some frogs dig and burrow underground or in the mud at the bottom of the ponds. *(Larrea, 2001)*. Frogs like to be near ponds which have plenty of algae and plant near the edge usually with shallow edges so that they can easily climb out. In general, the common frogs seems to prefer ponds which have water flowing in and out of them *(Hughes, 1981)*.

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Human population is growing very rapidly, creating a significant and increasing demand for additional animal protein. This demand can only be met most easily by rapidly increasing source of animal protein which include frog production. While the demand for frog is growing in some countries like United States, Australia, Bangladesh and Costa Rica, the production of frog in Nigeria is not yet popular.

The demand for frogs is of vital importance to man, most especially in developing countries like Nigeria where other animal protein from chevon, pork, poultry meat and eggs are limited in supply due to low level of animal husbandry or because their cost price is becoming too expensive to afford. Therefore, frogs could become an eminent source of protein to the populace in substitution for other forms of animal protein.

Frog culture is an important economic activity in Thailand with high demand for the product in foreign market such as Malaysia, Singapore, Hong Kong, Japan, Germany and France *(Akasay, 1994)*. In Laos, there is an increasing demand for consumption in the family, household and local markets. There are restaurants in Vientiane that buy frog on a regular basis for their customers *(Bounsong, 2001)*.

The demand for frog product is lower in Nigeria compared to other countries like India and France because the production of frog is yet to be popular in Nigeria, high prices of the little available product and the low income of the people especially in the rural areas. The availability of bush meat couple with the low literacy level is also responsible for the low demand of the product.

The major sources of frog meat for consumption are through aquaculture and the wild. Aquaculture frog legs are lighter in color and milder in taste than those from the wild. They are also cleaner. This is not a major issue as wild frog legs are susceptible to contamination with Salmonella *(Zancanaro, 1999)*. As one of the world's poorest and most densely populated country, Bangladesh emerged suddenly and dramatically as a major producer of Shrimp, frog legs and fish for export. Bangladesh has earned foreign currency by exporting frog legs *(Russell et al, 1996)*.

The study area is Akure South Local Government area of Ondo State. It has an area of

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2,303km. The LGA has Akure as the main town with some communities such as Oda, Ilekun, Ipinsa etc.

The climate of the area is tropical rain forest with raining spanning from March/April to October/November followed by a dry season of four to five months. The major occupation of the people is farming. Apart from farming, the people also engage in other occupations like civil service and trading. 100 consumers of frog meat were randomly selected in Akure metropolis and data were collected using structured questionnaire. The questionnaire elicited information on the socio-economic characteristics, source of frog meat, factors affecting the demand for frog meat and the level of acceptability among them.

The data collected were analyzed using descriptive statistical looks like percentage, frequency distribution and tables Regression analyses was used to estimate and the demand for frog meat and determine the factors that affect same.

The hypothesized demand equation is a stated below:

$$Y = f(x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, e_i)$$

and the explicit model presented in the linear form thus

where $Y = B_o + B_1x_1 + B_2x_2 + B_3x_3 + R_4x_4 + B_5x_5 + B_6x_6 + R_7x_7 + B_8x_8 + e_i$

Y = quantity of frog meat purchased.
x_1 = taste
x_2 = gender
x_3 = age
x_4 = marital status
x_5 = level of education
x_6 = family size
x_7 = religion
x_8 = level of acceptability
e_i = error term.

II. Discussion

Table 1 shows that 74% of the respondents are above 40 years of age. This may imply that relatively elderly people consume frog meat. Also from Table 2, 58% of the respondents were females, meaning that the decision taking as regards food items to purchase may be in the domain of the women folks. Furthermore, 82% of the respondents (Table 3) were married, implying that frog meat could be a cheap source of animal protein necessary for family sustenance.

From Table 4, 67% of the respondents had family size of at least 6 thus meaning that frog meat is a delicacy cherished by families. Furthermore, Table 5 reveals that 93% of the respondents can at least read and write; and this may have broaden their outlook to life thus appreciate the nutritive value of frog meat. Also, Table 6 shows that majority (72%) of the respondents are of Christian faith. This could be a reflection of the admixture of the people's religious inclinations is the study area though it was claimed that some Islamic sects viewed frog meat as 'haram' or unclean, and not to be taken.

Table 7, shows that 99% of the respondents affirmed that frog meat is palatable. This may be the reason for the respondents preference for frog meat. Also, Table 8 revealed that 74% of the respondents claimed that frog meat is acceptable thus implying that frog meat is a potential source of animal protein for the people.

Table 9 shows the demand function for frog meat. From the result, it could be deduced that the specified independent variables in the linear regression model, accounted, for 58.8% of the variability of the demand for frog meat. Also Age (x), family size (x_4), and level of acceptability (x_8) were variables that are significant at 50% level. This implies that these variables has important implications for the demand for frog meat in the study area.

The positive signs associated with Age (x_1), family size (x_4) and level of acceptability (x_8) implies that the higher values of these variables the higher the demand. This conforms with a prior expectations since it had earlier been established that (74%) elderly people consume frog meat hence that older the respondents the higher the demand for the commodity. Also the higher the family size the higher the demand for frog meat since it had been inferred that frog meat could be of cheap source of animal protein. Furthermore, obviously the higher the level of acceptability of frog meat the higher the level of demand.

III. Conclusion and Recommendation(s)

This study examined the demand for frog meat in Ondo State, Nigeria. Frogs could become an eminent source of protein to the populace in substitutions for other forms of animal protein which had limited supply due to low level of animal husbandry thus their cost price becoming too expensive to afford.

In the study area, Age (x_1), family size (x_4) and level of acceptability (x_8) were variables that has important implications for demand for frog meat. Based on these findings, it is therefore recommended that the populace should be educated on the importance and nutritional implications of frog meat.

Table 1: Socio-economic Characteristics

Age	Frequency	Percentage (%)
20-39 years	26	26.0
40-59 years	49	49.0
- 60 years	25	25.0
Total	100	100.0

Table 2

Gender		
Male	42	42.0
Female	58	58
	100	100.0

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Table 3

Marital Status		
Single	10	10.0
Married	82	82.0
Widow	3	3.0
Divorced	5	5.0
	100	100.0

Table 4

Family size		
1-5	33	33.0
6-10	52	52.0
11-15	10	10.0
16-20	5	5
	100	100.0

Table 5

Level of education		
No. formal education	7	7.0
Adult education	9	9.0
Primary education	2	2.0
Secondary education	28	28.0
Tertiary education	54	54.0
	100	100.00

Table 6

Religion		
Christian	72	72.0
Muslim	25	25.0
Traditional worship	3	3.0
	100	100.00

Table 7

Taste		
Very palatable	46	46.0
Palatable	53	53.0
Not Palatable	1	1.0
	100	100.0

Table 8

Level of acceptability	Frequency	Percentage (%)
Highly accepted	49	49.0
Moderately accepted	3	3.0
Accepted	22	22.0
Not accepted	26	26.0
	100	100.00

Table 9 : Regression Analysis Result of demand for frog meat.

Factors	Estimated Coefficient	Standard error
Constant	10.567	
Age	0.778*	0.521
Gender	-1.470	2.163
Marital status	0.163	0.086
Family size	5.894*	2.088
Level of education	1.229	0.963
Religion	0.443	0.828
Taste	-1.971	4.133
Level of Acceptability	*6.337*	0.850
R^2	0.588	
$\acute{R}^2$	0.522	
F statistics	10.822	

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Effect of Settlement Patterns on Cassava Production in Delta State, Nigeria

By Ofuoku,A.U. & Ebewore,S.O
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Abstract - This study investigated the effect of settlement patterns on cassava production in Delta State, Nigeria. A sample size of 250 cassava farmers was used for this study. Data were collected with use of questionnaire and analyzed with the use of descriptive statistics such as frequency counts, percentages and mean derived from four Point Likert-type scale.The relationship between cassava production and the distances from the farmers' home to their farms was tested with the use of Pearson's Product Moment Correlation (PPMC). The study revealed that the majority of farmers (77.2%) live in nuclear settlements, and as such affect their output, due to trekking long distances to their farms and lesser energy was used in the farm work, inadequate access to markets, and high cost of transporting farm produce, were major challenges facing the farm settlers. It was found that the farmers no longer practice dual residence due to security reasons. It is recommended that farmers should practice dual residence in order to have enough time for their crops and to reduce stress and waste of time during farming season. Extension agents should take into cognizance the settlement patterns of the farmers and design ways on how farm innovations can be disseminated to them.

Keywords : *Rural settlement patterns, cassava production,farmers, Delta State, Nigeria.*

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Keywords : Rural settlement patterns, cassava production,farmers, Delta State, Nigeria.

I. Introduction

Settlement pattern refers to the manner that a population distributes itself within the geographical space it occupies (Ekong 2003). According to Adeleke and Leong (1978). It is a unit or organized group of men, women, and children making a living out of their surrounding environment.

When it is conceptualized with specific relation to the rural people, it is said to be how the people locate themselves in relations to their farms. A settlement pattern refers to the way that buildings and houses are distributed in a rural settlement. Settlement pattern are of interest to geographers; historians and anthropologist, for the insight they offer in how a community has developed overtime (Ehow, 2010) andto the rural sociologist, how the community interact with their envroment-social,physical,biological and economic.

According to Ekong (2003), the settlement pattern of any group of persons can be influenced by a number of factors such as the natural physical condition like topography, soil type, availability of water, type of vegetation, e.t.c.

Social conditions like the need for defence against external aggression, type of family organization, economic arrangement particularly in the case of feudalistic landlords and self relationship, e.t.c and the nature and organization of the prevailing agricultural economy, i.e. whether nomadic permanent or semi-permanent type of farming is practiced.

There are two major types of settlements take the patterns of compact, cluster or nucleated villages and the scattered or dispersed settlements. With the discovery of river course and construction of new roads another pattern of settlement has emerged. This is referred to as linear or line settlement. This comprises of a number of houses located in a linear or river course (Ekong, 2003).

One of the advantages of nucleated settlement, as stated by Ekong (2003) is easier transmission of information on innovations to a large number of people within a short time. Adeyafa (1972), Alao (1974), Lapido (1978) as cited by Ekong (2003), however stated that farmers have to travel long distances to get to their farm. This is a situation that does not encourage mixed farming. They were also of the view that dual residence in the case of nucleated settlement splits farmer's loyalty to the development of his place of residence makes farmers difficult to locate as a results of uncertainty of their movements between the two residence and waste of farmer's time and money in commuting between residence in the settlement and on the farm.

As far as dispersed settlement is concerned Ekong (2003) opined that as people live in relatively isolated homestead, it is move difficult to bring them together for meetings and information on innovations tend to diffuse slowly. In linear settlements, as the people build on both side of the roads or river courses, they use the land behind as farms.In consideration of the above mentioned facts , the question now is about the type of settlement that are prevalent in this contemporary times Vis-à-vis farming.

Settlement patterns affect farming activities, (Ekong,2003). Most farmers, from observations are into cassava production, especially the small holder farmers who are known to be the ones that feed the nation. About 75% of the Nigeria population is made up of farmers. In spite of the stated facts, there is the extant problem of insufficient supply of cassava products as food and industrial raw material.

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This study will help to as an eye opener to unveil the effect of settlement pattern, in Delta State, Nigeria on farm output. The result will be useful in the planning of extension activities to the farmers in Delta and other States of the nation and other developing countries, of the world. It is hoped that the information from this study will be used for every stage of extension service delivery.

II. Objectives of the Study

The main objective of this study was to ascertaining the present day settlement patterns of rural communities in relation with cassava production among farmers in Delta State, Nigeria. Specifically the studywass to:

i. identify the type of settlement pattern prevalent in the rural settlements in the study area,
ii. ascertain the average distance between the farmers' home and their farms
iii. determine the perceived cassava production level among settlers in the study area,and
iv. identify the perceived challenges they have with respect to their settlement patterns in relation to their farming activities.

III. Hypothesis

Ho : The distance between farmers' settlement and their farms has no significant effect on cassava output.

IV. Methodology

The study area is Delta State, Nigeria. Delta State, lies roughly between longitude 5^0 00E and 5^0 45E of the Greenwich meridian and latitude 5^0 00N and 6^0 30E of the equator. The total area of the study is 17,698 Sq km , one third of this area is swampy and water logged. It has common boundary with Edo State in the North, Ondo State towards the North-west, Anambra State towards the Eastern part on the South by Bayelsa State.

The Atlantic Ocean forms the South western boundary (Ministry of Agric and Natural resource, 2000). The state is divided into 25 local government areas. It has an estimated population of 4,098,391 (National population census, 2006).It is demarcated into three agricultural zones-Delta North, Central and South Agricultural Zones.

Random sampling method was used to select respondents from among the cassava farmers registered with the three (3) DTADP zonal head quarters, ten registered farmers in each of the 25 local government areas were randomly selected to have a sample size of 250 respondents. Questionnaire was employed to collect data from the respondents. Each of the selected farmers was visited and questionnaires were shared to the respondents through "person – to – person" contact by field extension agents that were used as enumerators.

Objectives were addressed with the use of frequency counts and percentages and with the use of means derived from 4 point likert's type scale of very strong effect, (4) strong effect (3), weak effect (2) and very weak effect (1).

The hypothesis (Ho) was addressed with the use of Pearson Product Moment Correlation. The formula is stated as below:

$$r = \frac{xy - \frac{(x)(y)}{n}}{\sqrt{\left[\frac{x^2}{n} - (x)^2\right]\left[\frac{y^2}{n} - (y)^2\right]}}$$

Where:

n = Total number of respondents
$\sum$ = Summation
Y = Output of the farmers
X = Distance

V. Type of Settlement Patterns of the Respondents

Table 1.indicates that most 77.2% of the respondents dwell in nuclear/cluster settlement. The implication of this is that farmers embark on long distance, to their farms. It is expected that farm output may be affected by the settlement pattern.According to Ekong (2000) farmers output are affected due to the long distance to their farms.These settlements transformed into nucleation as a result of human need to communicate with others through social and religious activities. Kirch *et al.,* (2004) State that environmental variables strongly suggest that distribution of human settlements is primarily by a few key parameters affecting the productivity of crops.

Table 1 : Distribution of Settlement patterns of respondents

Type of Settlement	No of Respondents	Percentages (%)
Nuclear/cluster	193	77.2
Line/linear	39	15.6
Dispersed	18	7.2

Source: Field Survey, 2011

Distance between farmers' settlements and farms

Table 2 shows that farmers who live in nuclear settlement (0.8%) linear settlements (4.4%) and dispersed settlement (6.0%) trekked rode less 1km to their farms.

Those that live in nuclear settlements (26.6%), linear settlements (2.4%) travelled distances of 4 – 5km on foot or bicycle to their farms, but in dispersed settlement there were no such distance. Farmers (14.4%) in nuclear settlement travelled >5km distances on bicycle to their farms, unlike those in linear and dispersed settlements. The implication is that farmers' settlement patterns will influence their productivity. Kirch *et al.*, (1997) opines that human settlements are influenced by level of technology, sociological and economic factors. Most of the respondents live in nuclear settlements because of these factors that are prevalent in the various nuclear settlements. Bartle (2007) suggests that as settlements became nucleated,

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the lands closest to the residences could no longer sustain the population for food and the distance to farm became longer. Aydinlioglu (2010) reports that in Rough Cilicia ,in 2009, rural communities became nucleated and the farm land thus became far away from the settlements. This causes farmers to travel varied long distances to their farms. Organization of American States (OAS)(2001) considers the distance between settlements and farms as a limitation to agricultural development. The afore mentioned references and the results are enough indicators that there is a relationdhip between distance to farm and productivity.

Table 2 : Typologies of settlement patterns in relation to their distances from farms.

Distance (km)	Nuclear/ cluster	Linear/ line	Dispersed/ scattered
<1	2 (0.8)	11 (4.4)	15 (6.0)
1 – 2	20 (8.0)	17 (6.8)	3 (1.2)
3 – 4	61 (24.4)	5 (2.0)	0 (0)
4 – 5	74 (26.6)	6 (2.4)	0 (0)
>5	26 (14.40)	0 (0)	0 (0)

Figures in parenthesis ( ) are percentages
Source: Field survey, 2011

The perceived average quantity of cassava produced by the Respondents yearly

Table 3 indicates that 36% of the farmers produced 1000-2000kg of cassava yearly, and 27.2% of farmers produced 2001-3000kg of cassava yearly. This implies that majority of the cassava farmers' production level were still mainly on subsistence scale. In another way, the level of output may have been affected by the distance related challenges. Organization of American States (OAS)(2001) considers the distance between settlements and farms as a limitation to agricultural development.

Table 3 : The level of quantity of cassava produced by the farmers

Quantity (kg)	No of Respondents n = 250	Percentages (%)
500 – 999	20	8
1000 – 2000	90	36
2001 – 3000	68	27.2
3001 – 4000	43	17.2
Above 4000	29	11.6

Source: Field Survey, 2011

The challenges of settlement pattern in relation to farming activities of the Respondent

Table.4 shows that in nuclear settlements, the most important problem is that of long distance (mean= 2.95) from their homes to farms. Most of their useful time and energy are spent on long treks or bicycle rides to their farms. This affects the farm output in terms of the volume of work done which later translates, into low output.

The most important challenge experienced by those in linear settlement were destruction of crops by human activities (means = 2.74). Their farms are always, not far from their homes. This exposes their farms to frequent human activities which lead to easy destruction of crops. The same piece of land is farmed every year. This results to soil nutrient depletion; this is congruent with Ekong (2003) who suggests that farmers' crops in linear settlements are prone to human and animal destruction, while their soils are easily depleted.

In dispersed settlements the most important problem is that of theft of farm produce (mean = 3.44). This supports an earlier observation in settlement patterns in Nigeria.

Table 4 : The distribution problem of settlement patterns in relation to farming activities of the Farmers

Settlement patterns and problems	Very serious (4)	Serious (3)	Fairly serious (2)	Not a problem (1)	Total score	Mean (X)
Nuclear settlement (n=193) long distance from farm	60 (240)	67 (201)	63 (126)	3 (3)	570	2.95
Dual residence	50 (200)	71 (213)	59 (118)	13 (13)	544	2.82
Outbreak of disease	57 (228)	77 (231)	52 (104)	7 (7)	578	2.68
Linear/line settlement (n=39)						
Destruction of crops by animals	5 (20)	21 (63)	9 (18)	4 (4)	105	2.69
Destruction by human activities	3 (12)	12 (36)	15 (30)	9 (9)	87	2.74
Soil nutrient depletion	9 (36)	14 (48)	9 (18)	5 (5)	107	2.74
Scattered (Dispersed settlement (n=18)						
Inadequate access to information	6 (24)	9 (27)	3 (6)	0 (0)	57	3.17
Theft of farm produce	11 (44)	5 (15)	1 (20)	1 (91)	62	3.44
Long distance from market	8 (320	4 (12)	2 (4)	1 (1)	49	2.72
Accessibility of road	5 (20)	8 (24)	4 (8)	1 (7)	53	2.94
Inadequate supply of water of crops	9 (36)	3 (9)	2 (4)	4 (4)	53	2.94

Values in parentheses are products ot scale and frequency for different level of problems
Cut-off mean=2.50
Source: field survey, 2011.

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Effect of distance to farm on cassava production of the respondents

Table 6 indicates that the greatest effect of distance on cassava output as perceived by the farmers in nuclear settlements was low output followed by high cost of transporting produce to market for sales. Among the linear settlers, the greatest effect was less cost of input due to nearness to market and high of output due to nearness of farm, to their homes. This positive effect is to the advantage of the farmers. The most important effects of distance on cassava production in dispersed settlement were less cost of input and high output due to the proximity of farm to their homes much time and energy are saved.

Table 6 : Distribution of influence of distance between homes and the farm.

	Effects	Nuclear/cluster n=193	Linear n=39	Dispersed n=18	Total n=250
1	High output due to farm's closeness to home	13 (6.7)	20 (51.3)	8 (44.4)	
2	Low output due to loss time	91 (47.2)	0(0)	0(0)	
3	High cost of transport to market	69 (35.8)	5 (12.8)	6 (33.3)	
4	Less cost of input due to nearness to farm and market	20 (10.4)	14 (35.9)	4 (22.2)	

Figures in parenthesis ( ) are percentages
Source: field survey, 2011.

Test of hypothesis

Ho : The distance between farmers' settlement and their farms has no significant relationship with their cassava output

VI. Result

The result of hypothesis tested showed a perfect negative correlation between the farmers settlement patterns and their cassava output (r = - .989) at 0.01 level of significance. The null hypothesis which states that there is no significant relationship between farmers' settlement pattern and cassava yield is thus rejected. The implication is that the farther the farms are from the farmers homes, the lower the yields obtained.

This is attributed to the fact that movement to farms reduces the man hour spent on farming activities. Moreover, much energy is expended on movement to their farms thereby, depleting the energy they would use for farming operations. This is more so as farmers no longer stay on their farms for security reasons. This mostly applies to farmers who live in nuclear settlements, mean while, most of the farmers in the study areas live in nuclear settlement. This is congruent with Ekong (2003), AOS (2001) that stated that distance of farms from farmers' homes affects their farm outputs.

Table 7 : Relationship between distances and cassava output the farmers

	Distance to farm	Quantity of cassava	Decision
Distance	1.000	-.989**	Significant
Output of cassava	-.989**	1.000	

***Correlation is significant at 0.01 level.*

VII. Conclusion and Recommendations

From the results of the study it can be concluded that majority of farmers live in nuclear settlements and as such affect their output, due to long trekking and riding of bicycle from their home to farms, inadequate access to market and high cost of transporting farm produce, were the major problems facing farm settlers. It was found that farmers no longer practice dual residence due to security reasons.

Based on the findings the following recommendations are made:

- Extension agents should convince the farmers to practice dual residence in order to have enough time to the crops and to reduce stress and waste of time during farming season
- Extension agents should take into cognizance the settlement patterns of the farmers and design ways on how farm innovations can be disseminated to them.

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Hymenopteran Floral Visitors as Recorded from an Agro-Ecosystem Near Bikaner, Rajasthan

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Abstract - Hymenoptera is one of the most diverse orders of insects, including over 115,000 described species. Some are phytophagous (plant-feeding), while others are herbivorous, predatory, or even parasitic. Hymenoptera distribution is often dependent on their food supply for eg., bees pollinate flowers and require habitats with flowering plants. Hymenoptera are important to the balancing and functioning of most ecosystems on the planet. These are also one of the most beneficial insects for the human economy. Not only do bees pollinate many of our crops, but they also produce goods such as wax any honey. Parasitic wasps are often the most successful way to control pest insects as biological control agents. The present study was therefore planned to observe and document hymenopteran pollinators existing in the vicinity of Bikaner (Rajasthan) and to monitor some of their activities. Thirteen species of hymenopterans belonging to seven families were found to visit the flowers of various crops cultivated in the agro-ecosystem during the present study.

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HYMENOPTERAN FLORAL VISITORS AS RECORDED FROMAN AGRO-ECOSYSTEM NEAR BIKANER, RAJASTHAN

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Hymenopteran Floral Visitors as Recorded from an Agro-Ecosystem Near Bikaner, Rajasthan

Harshwardhan Bhardwaj[α], Parul Thaker[α] & Meera Srivastava[α]

Abstract - Hymenoptera is one of the most diverse orders of insects, including over 115,000 described species. Some are phytophagous (plant-feeding), while others are herbivorous, predatory, or even parasitic. Hymenoptera distribution is often dependent on their food supply for eg., bees pollinate flowers and require habitats with flowering plants. Hymenoptera are important to the balancing and functioning of most eco-systems on the planet. These are also one of the most beneficial insects for the human economy. Not only do bees pollinate many of our crops, but they also produce goods such as wax any honey. Parasitic wasps are often the most successful way to control pest insects as biological control agents.

The present study was therefore planned to observe and document hymenopteran pollinators existing in the vicinity of Bikaner (Rajasthan) and to monitor some of their activities. Thirteen species of hymenopterans belonging to seven families were found to visit the flowers of various crops cultivated in the agro-ecosystem during the present study. Maximum floral visitors (13 spp. belonging to 7 families) were documented on marigold, followed by mustard (9 spp. belonging to 5 families), ridged gourd (7 spp. belonging to 5 families), bottle gourd (6 spp. belonging to 4 families), brinjal (4 spp. belonging to 2 families), pumpkin (3 spp. belonging to 3 families), radish (5 spp. belonging to 3 families). Most number of hymenopteran species were documented during the month of January (12) followed by December (10), February (10), November (9), September (8) and October (7).The major hymenopteran visitors observed during the present study were *Apis mellifera, Scolia specifica* and *Xylocopa fenestreta*.

I. Introduction

Pollinators, including insects play a crucial role in reproduction of flowering plants and in the production of most fruits and vegetables.The relationship between pollinators and flowering plants is one of the mutually beneficial relationships in the natural world. Without the assistance of pollinators, most plants cannot reproduce. Different pollinators prefer different types of flowers. Studying the relationships between flowers and their pollinators is thus very useful to help maintain endangered species. The loss of a pollinator could cause the collapse of an ecosystem. Pollinators are also required for the successful proliferating communities and wildlife habitats. Estimates suggest that approximately 73 percent of the world's cultivated crops are pollinated by some varieties of bees, 19 percent by files, 6.5 percent by bats, 5 percent by wasps, 5 percent by beetles, 4 percent by birds and 4 percent by butterflies, indicating that most of the plat species rely on insects for pollination. Looking into the importance of insect pollinators, agricultural practices must be designed to incorporate the protection and sustainable management of pollinators.

Over the last few decades the perception has been growing among pollination biologists that pollinators have declined in numbers resulting in decreased seed and fruit set in the plants that they service.Threats to pollinators include habitat reduction, use of pesticides and other agrochemicals, invasive species, fungal, protozoan and bacterial diseases, modern agricultural practices etc.

Hymenoptera is one of the most diverse orders of insects, including over 115,000 described species. Some are phytophagous (plant-feeding), while others are herbivorous, predatory, or even parasitic. Hymenoptera distribution is often dependent on their food supply for eg., bees pollinate flowers and require habitats with flowering plants. Hymenoptera are important to the balancing and functioning of most eco-systems on the planet. These are also one of the most beneficial insects for the human economy. Not only do bees pollinate many of our crops, but they also produce goods such as wax any honey. Parasitic wasps are often the most successful way to control pest insects as biological control agents.

The present study was therefore planned to observe and document hymenopterans as pollinators existing in the vicinity of Bikaner (Rajasthan) and to monitor some of their activities.

II. The Study Area

The state of Rajasthan is the largest state of Indian republic located between 23°3' to 20'13 N latitude and 69°30' to 78°17'C longitudes and the area under study falls in the Indian desert near Bikaner situated in Western Rajasthan along the international border. The agro-ecosystem Vallabh Garden Agriculture Farm surveyed during the present study lies 10 km away from Bikaner, at Gharsisar village. It is a crop field where seasonal crops are grown. It is irrigated by sewage water.

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III. Methodology

The crop field comprised of different crops during the study period. As the study concentrated on hymenopteran pollinators, therefore, the flowering period in different crops was also recorded. The flower status whether solitary or in the form of inflorescence and the colour and size of flowers were also documented. It was also noted that whether the flowers released scent or not. Visit of a particular hymenopteran species to a specific flower was documented and expressed as number of visits/man/h.The hymenopteran insect visitors to different flowering crops were surveyed and collected every week from September 2008 to February 2009. For the study, the field area was divided into five stations from where the hymenopteran visitors on flowers were collected. Sweep net was used for insect collection. The hymenopterans collected by the above method were transferred to killing bottles, killed and preserved. Large winged hymenopteran were put to dry preservation by pinning them in insect boxes, while smaller insects were preserved in 70% alcohol.The fauna were sorted out group wise and help from the Section of Entomology, Department of Agriculture, Bikaner and Desert Regional Station of the Zoological Survey of India, Jodhpur was also taken for identification and for confirmation. Besides, the reference collection in the Department of Zoology, Dungar College was also consulted.

IV. Observations and Results

During the study period the crops cultivated in the agro-ecosystem included marigold, bottle gourd, ridged gourd, pumpkin, mustard, radish and brinjal. Crops, their flowering period and floral characteristics have been presented in Table 1.

a) Crops and their hymenopteran visitors

The flowers of marigold (*Tagetes erecta*), a member of family Compositae, were visited by all the 13 species documented during the present study. *Apis mellifera* were the major forms (57.20%) followed by *Polistes sp.* (9.55%), *Scolia specifica* (9.00%), *Xylocopa fenestreta* (6.23%), *Megachile* sp. (4.70%), *Sphex sp.* (4.15%), *Polistes carolina* (3.87%), *Pompilus* sp. (1.80%), Potter wasp (1.38%), *Coelioxys capitatus* and *Xylocopa virginica* (0.96% each), *Bembix* sp. and *Xanthopimpla stemmator* (0.27% each). *Lagenaria siceraria or* bottle gourd flowers were visited by six species viz *S. specifica* (37.42%), *Polistes sp.* (22.08%), *X. fenestrata* (20.85%), *X. stemattor* (13.49%), *A. mellifera* (4.90%), and *X. virginica* (1.22%). One of the major cucurbit crops cultivated in the agro-ecosystem studied was *Luffa cylindrica* from the flowers of which eight insect species were collected viz., *A. mellifera* (35.96%), *X. fenestreta* (27.19%), *S. specifica* (16.66%), *Polistes sp.* and *Sphex sp.* (7.01% each), *P. carolina* (3.07%), *X. virginica* (2.19%) and *X. stemattor* (0.87%).Yet another vegetable species cultivated in the agricultural field was pumpkin *Cucurbita maxima*.The flowers of pumpkin were visited by three species viz *A. mellifera* (94.64%), *S. specifica* (3.57%) and Potter wasp (1.78%).Of the total thirteen species documented during the present study, nine species viz., *Bembix* sp. (33.61%), *A. mellifera* (22.68%), *Megachile* sp. (19.32%), *Polistes sp.* and Potter wasp (5.78%), *S. specifica* (4.95%), *X.virginica* (4.20%), *X.fenestreta* (1.68%) and *Sphex sp.* (1.65%) were found to visit the mustard flowers (*Brassica campestris)* belonging to family Brassicaceae. *Solanum melongena* belonging to family Solanaceae was visited by five species viz. *X.fenestrete* (40.00%), *A.mellifera* (24.00%), *X. viriginica* (16.00%), *S.specifica* (12.00%) and *C.capitatus* (8.00%).The flowers of radish *Raphanus sativus* were visited by five species viz. *A. mellifera* (40.62%), *Megachile* sp. (34.37%), *Polistes sp.* (15.62%), *C. capitatus* (6.25%) and *X. fenestreta (*3.12%).

b) Preference and rhythmicity of hymenopteran visitors

During the present study insect species belonging to following hymenopteran families were reckoned from the agro-ecosystem studied:

c) Apidae

This family was represented by three species which included *A. mellifera*, *X. fenestreta and X. virginica*. *A. mellifera* was documented throughout the period of study as presented in Table 2. It was found to visit the flowers of all the crops cultivated in the agriculture field and has been presented in Table 3. *A. mellifera* was found to prefer the capitulum of *T. erecta* on which its visits ranged from 40 v/m/h in the month of October to 121 v/m/h in the month of November. It was documented as a rare form on flowers of *Lagenaria* in the month of September, making only 8 visits /m/h. The flowers of *Luffa* were also frequented by this bee during September (10v/m/h) and October (72v/m/h). On flowers of *Cucurbita* it was noted in the months of November and December, visiting them at the rate of 35 and 18v/m/h, respectively. During January and February they were also documented on flowers of mustard making 6 and 12v/m/h respectively. The bee was also observed on *Solanum* making 5v/m/h and 1 v/m/h in November and December respectively, whereas on radish it was found to visit the flowers at the rate of 5v/m/h and 8v/m/h in the months of January and February respectively (Table 4.).

X. fenestreta was also observed throughout the study period as presented in Table 2. It was found to visit the flowers of all crops cultivated in the agriculture field except *Cucurbita* during the period of study and has been presented in Table 3. *X. fenestreta* was found to prefer the flowers of *Luffa* on which its visits ranged between 30-32 v/m/h in the month of September and October, and documented as a rare form on flowers of radish in the month of January making only 1v/m/h. The

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head of *Tagetes* were also visited by the bee making 29v/m/h, 12v/m/h and 4v/m/h in the months of December, January and February respectively. On flowers of *Lagenaria* it was noted in the months of September, October and November, visiting them at the rate of 5v/m/h, 17v/m/h and 12v/m/h respectively. The bee was a rare visitor to the flowers of *Brassica* crop making 2v/m/h in the month of February. On the flowers of *Solanum* it was documented during November and January making 2 v/m/h and 8 v/m/h and respectively. Over all, on keen observation it was noted that when the flowering period of *Luffa* was going on, the insect preferred it more, but afterwards it shifted to the capitulums of *Tagetes* and flowers of *Lagenaria* (Table 5.).

Another species, *X. virginica* was also observed throughout the study period as presented in Table 2. It was found to visit the flowers of all crops, except *Cucurbita* and *Raphanus* cultivated in the agriculture field during the period of study and has been presented in Table 3. *X. virginica* was found to prefer the flowers of *Luffa* on which it was observed to visit 5v/m/h in the month of September. It rarely visited the head of *Tagetes* making a single visit in the month of February, and 4 and 2v/m/h in the months of November and January respectively. This bee rarely visited the flowers of *Lagenaria only* at the rate of 2v/m/h in the month October. On *Brassica* flowers, the bee was noted to make 2 and 3 v/m/h in the months of December and February respectively. On flowers of *Solanum* the insect was observed to visit 4v/m/h in the month of January (Table 6.).

d) Vespidae

This family was represented by three species which included *Polistes sp.*, *P.carolina* and an unidentified species of potter wasp. *Polistes sp.* was documented through out the study period as presented in Table 2. It was found to visit the flowers all crops except *Cucurbita* and *Solanum* present in the agriculture field during the study period as presented in Table 3. *Polistes sp.* was found to prefer the capitulum of *Tagetes* on which its maximum visits were noted in the month of November making 38 v/m/h, while in October, December, January and February the visits were 14, 8, 2 and 7v/m/h respectively. It was found rarely on the flowers of *Raphanus* making 2v/m/h in the month of February and 3v/m/h in the month of January. The flowers of *Lagenaria* were visited by this wasp, making 24 v/m/h in September while 12 v/m/h in October. On *Luffa* flowers, the wasp was observed only in September making 16v/m/h. On the flowers of *Brassica* the insect visits were observed to be 4v/m/h and 3v/m/h in the months of January and February respectively. It was further noted that *Polistes sp.* preferred the flowers of *Lagenaria* the most, but as soon as the flowering period of this crop ended the preference shifted towards the flowers of *Tagetes* (Table 7.). *P.carolina* was rarely documented during the study period as presented in Table 2. It was found to visit only the head of *Tagetes* and flowers of *Luffa* crop present in the agriculture field as presented in Table 3. *P.carolina* was found to prefer the heads of *Tagetes* on which its visits ranged from 7v/m/h in the month of October to 21v/m/h in the month of November. The wasp made its least visits on the flowers of *Luffa* making 2v/m/h in the month of September and on the same crop 5v/m/h was noted in the month of October (Table 8.).

Potter wasp belonging to family Vesipidae which was rarely documented in the agriculture field as presented in Table 2 was found to visit only the flowers of *Tagetes, Cucurbita and Brassica* as presented in Table 3. This species was found to prefer the flowers of *T. erecta* on which its visits ranged from 7v/m/h in the month of December to 2v/m/h and 1 v/m/h in the months of November and January respectively. It was documented rarely on the flowers of *Cucurbita* in the month of December making only 1 v/m/h. On the flowers of *Brassica* it was seen to make 3v/m/h in the month of January and 4v/m/h in the month of February (Table 9.).

e) Megachilidae

This family was represented by two species which included *Megachile* sp. and *Coelioxys capitatus. Megachile* sp. was rarely documented during the study period as presented in Table 2. It was found to visit the flowers of only three crops *viz., Tagetes, Brassica and Raphanus* cultivated in the agriculture field during the period of study, as presented in Table 3. This member was found to prefer the flowers of *Tagetes* on which its visits ranged from 16v/m/h in the month of January to 18v/m/h in the month of February. It was found rarely on the flowers of *Raphanus* in the month of February making 4v/m/h where as on same flowers 7v/m/h were noted in the month of January. The flowers of *Brassica* were also frequented by this member, making 12v/m/h in the month of January and 11v/m/h in the month of February (Table 10.). Another member belonging to the same family which was observed during the study period was *Coelioxys capitatus* which was also rarely documented during the study period as presented in Table 2. It was found to visit the flowers of three crops namely, *Tagetes, Solanum* and *Raphanus* as presented in Table 3. *C. capitatus* was observed to prefer the flowers of *Tagetes* on which its visits in the month of February were 5 visits /m/h, where as it was rarely documented on the same crop and on flowers of *Raphanus* in the months of December to February. During February they were also documented on flowers of *Solanum*, making 2v/m/h (Table 11.).

f) Scoliidae

Scolia specifica was the only wasp representative of this family documented from the crop field. It was observed nearly in all the months of study,

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as presented in Table 2. It was found to visit the flowers of all the crops except *Raphanus* and has been presented in Table 3. *S.specifica* was found to prefer the flowers of *Luffa* on which its visits were noted to be 38v/m/h in September. On flowers of *Cucurbita* it was documented as a rare form making only 2v/m/h in the month of December. The capitulum of *Tagetes* was also frequented by this wasp, visits ranging from 32v/m/h during October to 2v/m/h in the month of February. The flowers of *Lagenaria* were also visited by this wasp making 35v/m/h during September and 26v/m/h during October respectively. On flowers of *Brassica* it was noted in the month of February, visiting them at the rate of 6v/m/h, while on flowers of *Solanum* making 3v/m/h in the month of November. Overall, it was noted that it highly preferred to visit the flowers of *Lagenaria and Luffa* (Table 12.).

g) Sphecidae

Two members belonging to this family documented from the study area were *Sphex sp*. and *Bembix sp.* Former was documented throughout the study period where as the latter was noted only during January and February as presented in Table 2. Both the species were found to visit the flowers of two crops namely *Tagetes and Brassica* while *Sphex* sp. also visited the flowers of *Luffa*, cultivated in the crop field during the study period and has been presented in Table 3. *Sphex sp*. was found to prefer the flowers of *Tagetes* on which its visits ranged from 1-18 v/m/h, maximum visits were noted in the month of November. The flowers of *Luffa* were also frequented by this wasp making 4v/m/h during September and 12v/m/h during October. On flowers of *Brassica* it was noted only in the month of January, visiting them at the rate of 2v/m/h. It was further noted that with the end of flowering period of *Luffa* in November the insect diverted towards the head of *Tagetes* (Table 13.). *Bembix* sp. belonging to this family was rarely documented as presented in Table 2. It was found to visit only the head of *Tagetes* and flowers of *Brassica* crop cultivated in the agriculture field during the study period as presented in Table 3.This species was found to prefer the flowers of *Brassica* on which its visits ranged from 27v/m/h in the month of January to 13 v/m/h in the month of February. It was documented as a rare form on heads of *Tagetes* in the month of January making only 2 visits /m/h (Table 14.).

h) Pompilidae

Only one member *Pompilus* sp. belonging to this family was reckoned during the present study.This member was a rare visitor, documented only during three months as presented in Table 2. It was found to visit the head of *Tagetes* crop only and has been presented in Table 3. The visits ranged from 1 to 7v/m/h from November to January (Table 15.).

i) Ichneumonidae

Xanthopimpla stemattor was only representative of this family documented from the crop field, as presented in Table 2. Occurrence of this wasp was documented on the flowiers of three crops which were *Tagetes, Lagenaria and Luffa* as presented in Table 3. *X.stemattor* was found to prefer the flowers of *Lagenaria* on which its visits were noted to be 22v/m/h in the months of September, while on *Luffa* it made only 2v/m/h in the same month. It was rarely found on flowers of *Tagetes* making single visit v/m/h in the months of December and January (Table 16.).

V. Discussion

a) The hymenopteran visitors

Thirteen species viz., *Apis mellifera, Xylocopa fenestreta and Xylocopa virginica* belonging to family Apidae; *Polistes sp., P.carolina* and an unidentified species of Potter wasp belonging to family Vespidae; *Coelioxys capitatus* and *Megachile sp.* of the family Megachilidae; *Scolia specifica* belonging to family Scoliidae; *Sphex sp.* and *Bembix sp.* belonging to family Sphecidae; *Pompilus sp.* belonging to family Pompilidae; and *Xanthopimpla stemattor* belonging to family Ichneumonidae were documented on the flowers of various crops present in the agro-ecosystem during the present study.

Apis mellifera was one of the major forms reckoned throughout the study period in large numbers. It was found to visit the flowers of all the crops cultivated in the agro- ecosystem. Overall, in relation to crops, the honeybee *A. mellifera* preferred flowers of marigold followed by ridged gourd, mustard, pumpkin, bottle gourd, radish and brinjal.

The number of flowers visited/minute by any bee species depends upon a number of factors including floral structure (Free 1970) instinctive foraging behavior, length of proboscis (Inouye, 1980), corolla depth (Gilbert, 1980), type and quantity of floral rewards (Rao & Suryanarayana, 1990; Rao, 1991), besides density of flowers and hour of the day. The present findings also get support from the work of Omar (1988) who reported *A. mellifera* as pollinator of *C. sativum*. Maria & Zenon (2004) and Bruce et al. (2002) reported *Tagetes* to be visited by honeybee *Apis* which also corroborate the present findings. Agarwal & Rastogi (2008) also noticed hymenopterans on the flowers of *L. cylindrica*. Morimoto et al. (2004) observed honeybee *A. mellifera* as active floral visitor of *L. siceraria*. Alan & Bradley (1966) and Agbagwa et al. (2007) considered *A. mellifera* as natural pollinator of pumpkin. Singh et al. (2006) reported that most of the insect pollinators of *Brassica* crops belong to *Apis* species. *A. mellifera, A. dorsata* and *A. cerena* as floral visitors of mustard were also observed by Povada et al. (2004). Partap (1999) suggested *A. cerena* and *A. mellifera* as the most practical pollinators for mustard crop. Honeybees are efficient pollinators of *B. campestris* were also observed

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by Langride & Goodmen (1975); Mohar & Jay (1988) and Perveen et al. (2000) and therefore, support the present findings. *A. mellifera* as important pollinator of brinjal has been suggested by Partap (1999), Hiwkawa (2004) and Miyamoto (2006).

During the present study bees were observed during November – December which is in conformation with earlier study of Sekhar & Gowda (2006) who also noted bees on brinjal flowers from November to July. According to Tootland & Mathews (1998) flower density was much more important than temperature, humidity, time of day and season in explaining variation in bee numbers, total numbers of flowers visited, the number of flowers visited by individual bees and the total number of visits / flowers. *A. mellifera* was documented throughout the study period, it showed a great increase in the month of November and this trend was noticed upto December. In January and Februray it was noted in less number. Grombene – Guaratini et al. (2004) while studing the reproductive biology of *Bidens* (Asteraceae) suggested that the composition of the pollinator community changes during a year and between sites, hymenopterans being one of the most frequent visitors of this species. During the present study also honeybees were documented on marigold flowers a member of Asteraceae, from October to February, major visits being during November, December and January, and during rest of the months they shifted to other crops. Sekhar & Gowda (2006) noted bees from June to December on sunflower, on *Bidens* from January to May and on *Aster* during September and October. Singh et al. (2006) suggested most of the insect pollinators of *Brassica* crops belong to *Apis* species. They observed an average of 15.04, 7.71 flower visits/minute by *A. mellifera* and *A. dorsata* respectively.

Heithans (1974) observed a positive relationship between bee and floral abundance. Change in major weather factors such as temperature and RH might be responsible for the difference in visitation rate of honeybee was suggested by Selva Kumar et al. (1996). Bee foraging activity is highly influenced by prevailing weather factors have also been reported by Szabo (1980), Sihag & Abrol (1986), Abrol (1987). This could be true for the present study also.

Xylocopa fenestreta and *X. virginica* were the two carpenter bees documented during the present study on the eleven crops cultivated in the field, pumpkin was not visited by these species, while mustard, marigold, bottle gourd and ridged gourd flowers were visited by both the species. *X.virginica* species was rarely documented on the flowers of *Tagetes*. Earlier *X. fenestreta* as flower visitor of *Helianthus annuus* a member of Asteraceae was reported by Singh et al. (2000). The present findings also get support from the work of Carrek & Williams (2002) who found 16 families of Hymenoptera to visit the flowers of *Tagetes*. On flowers of *Luffa, X. fenestreta* was observed as a major visitor, while, *X. virginica* as a rare form. During the present study, *X. fenestreta* was collected from the umbels of radish and mustard flowers. The present findings are in conformation with the reports of Thapa (2006) and Hannan (2007) who also reported *Xylocopa* as insect pollinators of *Brassica. X. virginica* as floral visitors of *Delphinium* by Macior (1975), *Xylocopa basilis* and *X. fenestreta* as pollinators of *Alfalfa* were reported by Ahmed (1976); *X. virginica* as pollinator of milkweed by Kephart (1983), Ivey et al. (2003); *X. aestuans* as visitor of *Acacia* by Stone et al. (2003), *X. aestuans* as visitors of *Justicia* by Sheikh (2005), *X. aestuans* as visitors of Teak by Tangmitcharoen et al. (2006).

Overall, the choicest flower of *Xylocopa sp.* based on the present observations could be concluded as *Luffa cylindrica*, a yellow and scentless flower, probably high in pollen content. According to Martin (1993) *Xylocopa spp.* are common visitors of *Acacia* flowers, transport large pollen loads, move large distances between plants. Lane (1996) also considered *Xylocopa* as efficient pollinators and reported that *Xylocopa* have a tendency to collect pollen and nectar simultaneously. Amoako & Yeboah (2000) found *Xylocopa* to be an important pollinator of *S. melongena* and *Xylocopa darwini* was noted as visitor of *Lecocarpus pinnatifidus* (Asteraceae) by them. Two solitary bees including *Xylocopa caffra* were identified as effective pollinators of *Solanum melongena* in Kenya by Herren& Ochieng (2008).

Xylocopa fenestreta was noted throughout the study period. It was noted on the flowers of *L. siceraria*, *C. maxima, R. sativus* and *S. melongena*. Except *Luffa,* on all flowers its visitation was noticed to range between 1–29v/man/h. On *Luffa* flowers it was noted in good numbers making 30-32 visits/man/h from September to October. *X. virginica* was noted on the flowers of *Tagetes, Lagenaria, Luffa, S.melongena* and *Brassica* and its visitation was from 1 to 5 visits man/h. On *Luffa* it was noticed only during September. Somanathan & Borges (2002) found that the number of carpenter bees visiting a tree per minute and number of flowers visited per visiting bout were positively related to the size of the floral display.

Polistes sp., P.carolina and potter wasp were the three members belonging to family Vespidae which were documented on the flowers of various crops cultivated in the agro-ecosystem during the present study. All the three wasps were found in good numbers to visit the flowers of *Tagetes.* Flowers of *Luffa cylindrica* were visited by *Polistes sp. and P.carolina*. Only *Polistes sp.* was found to visit the flowers of *L. siceraria*, *R. sativus* and *B. campestris* while flowers of *C. maxima* were visited by *Potter wasp* but *S. melongena* flowers were visited by none of them. The present findings get support from the earlier reports by different workers who suggested *Polistes spp.* as flower visitors. These include Defni & Ducas (1986) who recorded *Polistes gellicus* as pollinator of *Urginea maritima* (Liliaceae), Hannan (2007)

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who found *Polistes* to visit *Sesamum* flowers. Tangmitcharoen et al. (2006) noted *P. stigma* as potential pollinator of teak flowers or inflorescence. Milk weed has been found to be pollinated by *Polistes* as reported by Kephart (1983), Ivey et al. (2003) and Robert et al. (1994). During the present study while *Polistes sp.* was noticed nearly throughout the study period, *P.carolina* was found during September to November. Both the wasps were found in good numbers in the month of November. The population density of *Polistes sp.* was also found to be high in the months of September, October and November. According to Martin (1993) *Polistes sp.* are very common floral visitors of *Acacia* with little pollen movement. Valdivia & Niemeyar (2006) also reported *Polistes buyssoni* as diurnal floral visitor. Wasp as a floret visitor of Asteraceae was documented by Tooker & Hanes (2000). Patt (2000) found that umbels such as coriander, dill, fennel, caraway are very attractive beneficial insects like wasp. Dunne (2001) also observed that lovage attracts wasps. Visitation rate of *P.carolina* was noticed from 1–21 visits/man/h. The flowers of *Luffa* were visited by the wasp during September and October. The highest visits were noticed to be 21visits/ man/h on *Tagetes* and minimum of 2visits/man/h on the flowers of *Luffa*. While *Polistes sp.* visited 1–38 visits/man/h on different crops and peak visitation was noticed in the month of November on the flowers of *Tagetes.*

Scolia specifica a member of family Sphecidae was also a major wasp found to visit flowers of various crops cultivated in the agro-ecosystem during the present study. It was found to prefer flowers of *Lagenaria,* followed by *Tagetes, Luffa, Brassica, Solanum and Cucurbita*. *S. duvia* as insect pollinator of milk weed, *Scolia sp.* as flower visitors of *Sesamum* and *S. ruficeps* as potential pollinators of teak flowers were suggested by Ivey et al. (2006) respectively, which corroborate the present findings. It was noted throughout the study period. Its maximum numbers were noted in the month of September when it visited the flowers of *Luffa* at the rate of 469 visits / man/ h. According to Martin (1993) members of family Scoliidae are common, patrolling underneath flowering plants. Yamazaki & Kato (2003) also reported scolid wasp as a good pollinator of some plants in the grassland ecosystem. Reddi & Reddi (1983) observed *Scolia cruenta* as pollinators of *Jatropha gossypiifolia* (Euphorbiaceae).

Sphex sp. and *Bembix sp.* belonging to family Sphecidae were collected from different flowers during the present study. *Sphex sp*. was found to visit flowers of *Luffa, Tagetes* and *Brassica,* whereas *Bembix sp.* visited only the Head of *Tagetes* and flowers of *Brassica.* Thapa (2006) also reported *Sphex sp.* as pollinator of various crops. Kephart (1983), Robert et al. (1994) and Ivey et al. (2003) reported *Sphex sp.* as pollinator of milkweed. Visitation rate of *Sphex sp.* was noticed to be between 1–18 visits / man / h on different crops throughout the study period.

Coelioxys capitatus and *Megachile sp.*, members belonging to family Megachilidae were collected from different flowers during the present study. *C. capitatus* was found to visit flowers of *Tagetes, R. sativus,* and *S. melongena* where as *Megachile sp.* preffered the head of *Tagetes* and flowers of *Raphanus* and *Brassica*. Peak visitation of *Coelioxys* was observed on the flowers of *T. erecta* in the month of February and it was noted as 5 visits/man /h. On the flowers of *Lagenaria, Luffa, Cucurbita* and *Brassica* it was never documented during the present study. Tybirk (1992) also observed *Coelioxys* as the pollinators of African *Acacias* which supports the present findings.

Pompilus sp., another hymenopteran belonging to family Pompilidae was documented visiting only the capitulum of *T. erecta* cultivated in the agriculture farm during the present study. It was noted from November to January. Its visits on the head of *Tagetes* ranged from 1-7 visits/m/h. *Pompilus sp*. as a floret visitor of Asteraceae was documented by Tooker & Hanes (2000) which gives support to the present study.

Xanthopimpla stemattor, another hymenopteran belonging to family Ichneumonidae was documented visiting flowers of different crops cultivated in the agricultural farm during the present study. It was documented from September to January. In September it was found to visit the flowers of *L.siceraria* at the rate of 19–22 visits/man/h. Although it was also noticed on flowers of *Luffa* and *Tagetes*, but on these it was a rare form.

According to Roubik (1989) hymenopterans are responsible for 67–93% of the floral visits. Total pollination activities, over 80% are performed by insects, and bees contribute nearly 80% of the total insect pollination and therefore, they are considered the best pollinators, supporting the present findings. Sievers (1948) also reported hymenopterans as visitors of chervil flowers. Hymenopterans as pollinators of plants belonging to family Asteraceae were noted by Noronha & Gottsberger (1980); Arroyo et al. (1982); Sazima & Machado (1983); Abbot & Irwin (1988); Herrera & Iwata (1990). Hymenopterans were noted as pollinators of carrot an umbelliferous plant by Ahmed & Aslam (2002). Hymenopterans were noted on the heads of *Mikania* by Cerena (2004).

b) The hymenopteran visitors in relation to crops

Marigold (Tagetes erecta)

During the present study marigold heads, were visited by thirteen species belonging to seven families. *A. mellifera* were the major visitors while, the others which included *S. specifica, Sphex sp., Polistes sp., P. carolina, X. fenestreta, X. virginica, C. capitatus, Xanthopimpla stemattor, Bembix sp., Potter wasp, Megachile sp. and Pompilus sp.* were rare visitors. The

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present findings are in conformation with the work of Gange & Smith (2005) who suggested hymenopterans as pollinators of *T. erecta*. Maria & Zenon (2004) in their study also found that the *Tagetes* was visited by hymenopterans including *A. mellifera.* Ten bumble bee species were reckoned by Lall (2003) visiting *T. patula*. Honeybee *Apis* and wasp *Helictus* on flowers of *T. erecta* were also noted by Bruce et al. (2002) which corroborate the present findings. In a study done by Singh et al. (2000) on *Helianthus annuus,* a member of Asteraceae, the honeybees *A. mellifera, A. dorsata* and *A. florea* were found to constitute 42.2% of the total insects visiting the capitula. They also documented *X. fenestreta* as the flower visitor of *H. annuus.* Radford et al. (1979) also reported *A. mellifera* as the most frequent floral visitor to flowering sunflower while, Panda et al. (1996) observed *A.cerena* and *A.dorsata* besides, *A. mellifera* as predominant visitors to sunflowers. Puskadija et al. (2005) also noted honeybees as visitors of sunflower head. The present findings also get support from the earlier work of Carrek & Williams (2002) who found sixteen families of hymenoptera including bumble bees to visit the flowers of *Tagetes*. Five hymenopteran floral visitors to heads of sunflower were observed by Nderitu et al. (2008), while, Arya et al. (1994) noted twelve bee species visiting sunflower. According to several other authors (Noronha & Gottsberger, 1980; Arroyo et al., 1982; Sazima & Machado, 1983; Abbot & Irwin, 1988; Herrera, 1990; Iwata, 1990 & 1992) the members of Asteraceae are pollinated by several insect groups and Hymenoptera is also one of them. Honeybees *Apis mellifera* were found to produce at least 150% more seeds in family Asteraceae as reported by Mamood et al. (1990). Cerana (2004) noticed hymenopterans on heads of *Mikania* while, Roitman (1999) documented them on capitula of *Grindelia covasii,* both belonging to Asteraceae. Thapa (2006) has also reported honeybees as good pollinators of various Asteraceae plant like *Cynara scolymus, Cichorium intiybus, Helianthus annuus* etc. Wasp as a floret visitor of Asteraceae was documented by Tooker & Hanes (2000) which gives support to the present study wherein, five wasp species were documented.

c) Bottle gourd (Lagenaria siceraria)

During the present study six species belonging to four families were found to visit the flowers of bottle gourd.The flowers were visited by six species viz. *A. mellifera, X. fenestreta, X.virginica, X.stemattor, Polistes sp.* and *S. specifica.* Earlier Morimoto et al. (2004) also observed honeybee *A. mellifera* as active flower visitors of *L. siceraria* in Kenya which is in support of the present findings. Fomekong et al. (2008) also reported *A. mellifera* to be a pollinator of cucurbitaceous plant. *A. mellifera* as a dominant species visiting flowers of Cucurbitaceae was also reported by Rust et al. (2003). In all, 43 species of bees were collected from the flowers of *E. elaterium* a member of Cucuritaceae, of which 33 bee species were found to carry pollen. The present findings also get support from the findings of Valdivia & Niemeyer (2006) who also documented *A. mellifera* and *Polistes buyssoni* to visit flowers of cucurbit *Escallonia myrtoidea.* Besides these, 16 other hymenopteran species were reported to visit these flowers by them. While studying the pollination ecology of *Citrullus lanatus* a cucurbit, Njorage et al. (2004) found that this species depends heavily on *A. mellifera* for pollination. Other pollinators identified were *Xylocopa* bees, halicted bees and hypotrigona bees which corroborate the present findings.

d) Ridged gourd (Luffa cylindrica)

Of the total number of species documented during the present study, eight species viz., *S. specifica, A. mellifera, X. fenestreta, X. virginica, Sphex sp., X. stemattor* and *Polistes sp.* belonging to five different families were found to visit the flowers of ridged gourd during the present study. The present findings are in conformation with the studies done by Agarwal & Rastogi (2008) who also noticed hymenopterans on the flowers of *Luffa cylindrica.* Singh et al. (2000) also recorded members belonging to family Braconidae on cucurbit plant *Luffa cylindrica.* The members of Formicidae on *Luffa* were documented by Okoli et al. (2008). Thapa (2006) reported hymenopterans like bumble bee *Bombus,* golden wasp *Vespa magnifica* and oriental wasp *Vespa orientalis* as pollinators of sponge gourd. Earlier Baskaran & Eswaran (2004) also observed *Apis dorsata* and *A. florea* as pollinators of another gourd *Momordica charantia* which corroborate the present findings.

e) Pumpkin (Cucurbita maxima)

During the present study, three species belonging to three families were observed on flowers of pumpkin during the present study.The hymenopterans visiting the flowers of pumpkin were *S. specifica, A. mellifera* and Potter wasp. Earlier most of the authorities have considered honeybees to play a major role in pollination of *Cucurbita,* which include the works of Pammel & Bach (1894), Jones & Rosa (1928), Jones & Emsweller (1934), Whitaker & Davis (1962), Battaglini (1969), Langridge (1952), Nevkryta (1953), Robinson (1952), Sandulac (1959), Verdieva & Ismalilova (1960) and Wolfenbarger (1962), while, Michel Bacher et al. (1964) and Hurd (1966) gave credit to both honeybees as well as wild bees and thus support the present findings. Alan & Bradley (1966) have also considered bumble bees, carpenter bees, squash bees and honeybees including *A. mellifera* as natural pollinators of pumpkin. Canto Aquliar & Parra – Ptavla (2000) evaluated the pollination efficiency of *Peponapis limitaris* and *A. mellifera* in *Cucurbita moschata* in Mexico and found that *P. limitaris* to be more efficient than *A. mellifera.* Thapa (2006) has also reported *A. cerena* and *Helophilus trivittatus* as insect visitors of *C. maxima* which corroborate the present findings. Agbagwa *et al.,* (2007) also considered *A. mellifera* to play an essential

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role in pollination of *C. moschata* in Nigeria. Fomekong et al. (2008) reported *A. mellifera* to be a pollinator of Cucurbitaceae plant.

f) Mustard (Brassica campestris)

Nine species belonging to five families were documented on the flowers of *Brassica campestris* during the present study.These were *A. mellifera, X. fenestreta, X. virginica, Polistes sp., S. specifica, Sphex sp., Bembix sp.,* Potter wasp *and Megachile sp.* of which, *Apis mellifera* was the most frequent visitor. The present findings are in conformation with the earlier reports of Singh et al. (2006) who also found that most of the insect pollinators of *Brassica* crops belonged to *Apis* species. In another study, *A. florea* was noted to out number the visitation on *Brassica* followed by *A. mellifera* and *A. dorsata* by Singh et al. (2004). Jhajj et al. (1996) also found the foraging frequency of various bee species as *A. mellifera > A. dorsata > A. florea* on raya and brown sarson. A total of 859 flower visitors on mustard were observed by Poveda et al. (2004), most abundant of which were the honeybees *A. mellifera, A. dorsata, A. cerena. Xylocopa* and *Megachile sp.* have been reported to be flower visitors of *Brassica* by Hannan (2007) which also supports the present observations. According to Partap (1999), *A.cerena* and *A. mellifera* are the most practical for mustard crop pollination. Langridge & Goodman (1975) also reported honeybees as efficient pollinators of *B. campestris*. Perveen et al. (2000) also suggested *A. mellifera* to cause a significant increase in quantity and quality of *B. campestris* in Pakistan. Honeybees as important pollinators of *B. napus* and *B.rapa* was observed by Pritsch (2000), while, Mohar & Jay (1988) observed honeybees to visit and pollinate *B. campestris* more as compared to *B. napus*. Honeybees are attracted towards mustard flowers and are of great benefit to *B. hirta* and *B. juncea* was suggested by Free & Spancer (1963). An increase in the yield of rape and white mustard due to honeybee *A.mellifera* was noted by Kontensky (1959). Manning & Boland (2000) also emphasized on the significance of *A. mellifera* in pollination of *B. napus* in Western Australia. Thapa (2006) reported *A. mellifera, A. cerena, A. dorsata, Bombus sp., Xylocopa, Sphex sp.* and *Chlorion sp.* as insect pollinators of *B. campestris* which corroborate the present findings.

g) Brinjal (Solanum melongena)

The flowers of *S. melongena* were found to be visited by five species belonging to three families viz. *A. mellifera, S. specifica, X. fenestreta, X. virginica and C. capitatus* during the present study which gets support from the observations of Miyamoto (2006) who also observed *A. mellifera* as pollinators of egg plant. According to Partap (1999) *A. cerena* and *A. mellifera* are most practical for brinjal crop pollination. Bumble bees *Bombus terrestris* have been suggested to be effective pollinators of *S. melongena* by Buczkowska et al. (2000) and Kowalska (2003), while, Hikawa (2004) suggested *A. mellifera* to be economically important pollinator as compared to *B. terrestris*. *A. mellifera* and *B. terrestris* as pollinators of *S. melongena* was also reported by Vanden (1994). Wild bees can be equal or better pollinators than *A. mellifera* for important agricultural crops such as Solanaceae was suggested by O' Toole (1993). Two solitary bees *Xylocopa caffra* and *Macronomia rufipes* were identified as effective pollinators of egg plant by Gemmill – Herren& Ochienj (2008). Amoako & Yeboah – Gyan (2000) found *A. mellifera* and *Xylocopa* to be important pollinators of *S. melongena*. Thapa (2006) reported *Bombus sp., Chlorion sp., Vespa magnifica, V. orientalis, Xylocopa sp.* and *Polistes sp.* as floral visitors of brinjal which support the present findings in a way that, both honeybee and wasps were documented on flowers of brinjal.

h) Radish (Raphanus sativus)

The flowers of *R. sativus* were found to be visited by five species viz., *A. mellifera, X. fenestreta, Polistes sp., Megachile sp. and C. capitatus* belonging to three different families. The present findings are in conformation with the studies done by Free & Williams (1973) who also noticed bumble bees visiting Brussels sprout flowers of family *Brassicaceae* comprising 98% of visitors in Egypt (Hussein and Abden- Aal, 1982) and 99% in New Zealand (Forster et al.; 1973). Eariler most of the authorities have considered honey bees to play a major role in pollination of radish, which include the works of Raula (1972), Dhaliwal and Sharma (1973), which support the present findings. From Indian sub-continent *A. cerena, A.dorsata and A. florae* are all important visitors on *Brassica olererecea*, a member of *Brassicacea* as reckoned by Singh et al. (2004). Thapa (2006) has also reported *A. mellifera, A. cerena, A. dorsata, Xylocopa and Sphex sp.* as insect pollinators of *R. sativus*. Singh et al. (2006) recorded that most of the insect pollinators of *Brassica* crops belong to *Apis* species which also supports the present observations. Conner and Rush (2008) also reported about the effect of flower size and number on *A. mellifera* visitation on wild radish. Bumble bees preffered white coloured flowers of wild radish was reported by Key (1978) which corroborate the present findings.

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Table1: Crops cultivated in Vallabh Garden Agriculture Farm, Bikaner and their floral characteristics

Crop	Botanical Name	Family	Inflorescence	Scent	Colour	Self or Cross pollination	Flowering period
Marigold	*Tagetes erecta*	Compositae/ Asteraceae	Head or Capitulum	Scented	Yellowish orange	Self/Cross	October to February
Bottle gourd	*Lagenaria siceraria*	Cucurbitaceae	Solitary	Scentless	White or Creamish	Cross	September to October
Ridged gourd	*Luffa cylindrica*	Cucurbitaceae	Solitary	Scentless	Yellow	Cross	September to October
Pumpkin	*Cucurbita maxima*	Cucurbitaceae	Solitary	Scentless	Yellow	Cross	November to December
Radish	*Raphanus sativus*	Brassicaceae	Racemose	Aromatic	Purplish white	Self/Cross	January to March
Mustard	*Brassica campestris*	Brassicaceae	Corymbose raceme	Aromatic	Yellow	Self/Cross	January to February
Brinjal	*Solanum melongena*	Solanaceae	Solitary	Scentless	Purple	Cross	November to December

Table 2 : Hymenopteran floral visitors observed in Vallabh Garden Agriculture Farm, Bikaner (September 2008 - February 2009)

Hymenopteran visitors	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
FAMILY: APIDAE						
Apis mellifera	++	++++	++++	++++	+++	+++
Xylocopa fenestreta	++	++	++	++	++	+
Xylocopa virginica	+	+	+	+	+	+
FAMILY: VESPIDAE						
Polistes sp.	++	++	++	+	+	++
Polistes Carolina	+	++	++	-	-	-
Potter wasp	-	-	+	+	+	+
FAMILY: MEGACHILIDAE						
Megachile sp.	-	-	-	-	++	++
Coelioxys capitatus	-	-	-	+	+	+
FAMILY: SCOLIIDAE						
Scolia specifica	+++	+++	++	+	+	+
FAMILY: SPHECIDAE						
Sphex sp.	+	++	++	+	+	+
Bembix sp.	-	-	-	-	++	++
FAMILY: POMPILIDAE						
Pompilus sp.	-	-	+	+	+	-
FAMILY: ICHNEUMONIDAE						
Xanthopimpla stemattor	++	-	-	+	+	-

0-10 = +, 10-50 = ++, 50-100 = +++, 100-200 = ++++.

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Table 3 : Hymenopteran visitors on flowers of different crops in Vallabh Garden Agriculture Farm, Bikaner

Hymenopteran visitors	*Tagetes erecta* (marigold)	*Lagenaria siceraria* (bottle gourd)	*Luffa cylindrica* (ridged gourd)	*Cucurbita maxima* (pumpkin)	*Brassica campestris* (mustard)	*Solanum melongena* (brinjal)	*Raphanus sativus* (radish)
Family : Apidae							
Apis mellifera	+++	+	++	++	++	+	+
Xylocopa fenestreta	++	++	++	-	+	+	+
Xylocopa virginica	+	+	+	-	+	+	-
Family : Vespidae							
Polistes sp.	++	++	+	-	+	-	+
Polistes carolina	++	-	+	-	-	-	-
Potter wasp.	+	-	-	+	+	-	-
Family : Megachilidae							
Megachile sp.	++	-	-	-	++	-	+
Coelioxys capitatus	+	-	-	-	-	+	+
Family: Scoliidae							
Scolia specifica	++	++	++	+	+	+	-
Family: Sphecidae							
Sphex sp.	++	-	+	-	+	-	-
Bembix sp.	+	-	-	-	++	-	-
							....
Family: Pompilidae							
Pompilus sp.	+	-	-	-	-	-	-
Family: Ichneumonidae							
Xanthopimpla stemattor	+	++	+	-	-	-	-

+=1 to 10 visits/m/h, ++=11 to 50 visits /m/h, +++=51 to 100 visits /m/h,

Table 4 : Occurrence (No./man/h) of *Apis mellifera* (Family: Apidae) on flowers of different crops in Vallabh Garden Agriculture Farm, Bikaner

S. No.	Crop	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
1	*Tagetes erecta*	-	40	121	117	92	43
2	*Lagenaria siceraria*	8	-	-	-	-	-
3	*Luffa cylindrica*	10	72	-	-	-	-
4	*Cucurbita maxima*	-	-	35	18	-	-
5	*Raphanus sativus*	-	-	-	-	5	8
6	*Brassica campestris*	-	-	-	-	6	21
7	*Solanum melongena*	-	-	5	1	-	-

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Table 5 : Occurrence (No./man/h) of *Xylocopa fenestreta* (Family: Apidae) on flowers of different crops in Vallabh Garden Agriculture Farm, Bikaner

S. No.	Crop	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
1	*Tagetes erecta*	-	-	-	29	12	4
2	*Lagenaria siceraria*	5	17	12	-	-	-
3	*Luffa cylindrica*	32	30	-	-	-	-
4	*Cucurbita maxima*	-	-	-	-	-	-
5	*Raphanus sativus*	2	-	-	-	1	0
6	*Brassica campestris*	-	-	-	-	-	2
7	*Solanum melongena*	-	-	2	-	8	-

Table 6 : Occurrence (No./man/h) of *Xylocopa virginica* (Family: Apidae) on flowers of different crops in Vallabh Garden Agriculture Farm, Bikaner

S. No.	Crop	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
1	*Tagetes erecta*	-	-	4	-	2	1
2	*Lagenaria siceraria*	-	2	-	-	-	-
3	*Luffa cylindrica*	5	-	-	-	-	-
4	*Cucurbita maxima*	-	-	-	-	-	-
5	*Raphanus sativus*	-	-	-	-	-	-
6	*Brassica campestris*	-	-	-	2	-	3
7	*Solanum melongena*	-	-	-	-	4	-

Table 7 : Occurrence (No./man/h) of *Polistes sp.* (Family: Vespidae) on flowers of different crops in Vallabh Garden Agriculture Farm, Bikaner

. No.	Crop	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
1	*Tagetes erecta*	-	14	38	8	2	7
2	*Lagenaria siceraria*	24	12	-	-	-	-
3	*Luffa cylindrica*	16	-	-	-	-	-
4	*Cucurbita maxima*	-	-	-	-	-	-
5	*Raphanus sativus*	-	-	-	-	3	2
6	*Brassica campestris*	-	-	-	-	4	3
7	*Solanum melongena*	-	-	-	-	-	-

Table 8 : Occurrence (No./man/h) of *Polistes carolina* (Family: Vespidae) on flowers of different crops in Vallabh Garden Agriculture Farm, Bikaner

S. No.	Crop	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
1	*Tagetes erecta*	-	7	21	-	-	-
2	*Lagenaria siceraria*	-	-	-	-	-	-
3	*Luffa cylindrica*	2	5	-	-	-	-
4	*Cucurbita maxima*	-	-	-	-	-	-
5	*Raphanus sativus*	-	-	-	-	-	-
6	*Brassica campestris*	-	-	-	-	-	-
7	*Solanum melongena*	-	-	-	-	-	-

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Table 9 : Occurrence (No./man/h) of Potter wasp (Family: Vespidae) on flowers of different crops in Vallabh Garden Agriculture Farm, Bikaner

S. No.	Crop	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
1	*Tagetes erecta*	-	-	2	7	1	-
2	*Lagenaria siceraria*	-	-	-	-	-	-
3	*Luffa cylindrica*	-	-	-	-	-	-
4	*Cucurbita maxima*	-	-	-	1	-	-
5	*Raphanus sativus*	-	-	-	-	-	-
6	*Brassica campestris*	-	-	-	-	3	4

Table 10 : Occurrence (No./man/h) of *Megachile sp.* (Family: Megachilidae) on flowers of different crops in Vallabh Garden Agriculture Farm, Bikaner

S. No.	Crop	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
1	*Tagetes erecta*	-	-	-	-	16	18
2	*Lagenaria siceraria*	-	-	-	-	-	-
3	*Luffa cylindrica*	-	-	-	-	-	-
4	*Cucurbita maxima*	-	-	-	-	-	-
5	*Raphanus sativus*	-	-	-	-	7	4
6	*Brassica campestris*	-	-	-	-	12	11
7	*Solanum melongena*	-	-	-	-	-	-

Table 11 : Occurrence (No./man/h) of *Coelioxys capitatus* (Family: Megachilidae) on flowers of different crops in Vallabh Garden Agriculture Farm, Bikaner

S. No.	Crop	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
1	*Tagetes erecta*	-	-	-	1	1	2
2	*Lagenaria siceraria*	-	-	-	-	-	-
3	*Luffa cylindrica*	-	-	-	-	-	-
4	*Cucurbita maxima*	-	-	-	-	-	-
5	*Raphanus sativus*	-	-	-	-	1	1
6	*Brassica campestris*	-	-	-	-	-	-
7	*Solanum melongena*	-	-	-	-	-	2

Table 12 : Occurrence (No./man/h) of *Scolia specifica* (Family: Scoliidae) on flowers of different crops in Vallabh Garden Agriculture Farm, Bikaner

S. No.	Crop	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
1	*Tagetes erecta*	-	32	21	5	5	2
2	*Lagenaria siceraria*	35	26	-	-	-	-
3	*Luffa cylindrica*	38	-	-	-	-	-
4	*Cucurbita maxima*	-	-	-	2	-	-
5	*Raphanus sativus*	-	-	-	-	-	-
6	*Brassica campestris*	-	-	-	-	-	6
7	*Solanum melongena*	-	-	3	-	-	-

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Table 13 : Occurrence (No./man/h) of *Sphex sp.* (Family: Sphecidae) on flowers of different crops in Vallabh Garden Agriculture Farm, Bikaner

S. No.	Crop	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
1	*Tagetes erecta*	-	1	18	3	7	1
2	*Lagenaria siceraria*	8	-	-	-	-	-
3	*Luffa cylindrica*	4	12	-	-	-	-
4	*Cucurbita maxima*	-	-	-	-	-	-
5	*Raphanus sativus*	-	-	-	-	-	-
6	*Brassica campestris*	-	-	-	-	2	-
7	*Solanum melongena*	-	-	-	-	-	-

Table 14 : Occurrence (No./man/h) of *Bembix sp.* (Family: Sphecidae) on flowers of different crops in Vallabh Garden Agriculture Farm, Bikaner

S. No.	Crop	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
1	*Tagetes erecta*	-	-	-	-	2	-
2	*Lagenaria siceraria*	-	-	-	-	-	-
3	*Luffa cylindrica*	-	-	-	-	-	-
4	*Cucurbita maxima*	-	-	-	-	-	-
5	*Raphanus sativus*	-	-	-	-	-	-
6	*Brassica campestris*	-	-	-	-	27	13
7	*Solanum melongena*	-	-	-	-	-	-

Table 15 : Occurrence (No./man/h) of *Pompilus* sp. (Family: Pompilidae) on flowers of different crops in Vallabh Garden Agriculture Farm, Bikaner

S. No.	Crop	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
1	*Tagetes erecta*	-	-	5	7	1	-
2	*Lagenaria siceraria*	-	-	-	-	-	-
3	*Luffa cylindrica*	-	-	-	-	-	-
4	*Cucurbita maxima*	-	-	-	-	-	-
5	*Raphanus sativus*	-	-	-	-	-	-
6	*Brassica campestris*	-	-	-	-	-	-
7	*Solanum melongena*	-	-	-	-	-	-

Table 16 : Occurrence (No./man/h) of *Xanthopimpla stemattor* (Family:Ichneumonidae) on flowers of different crops in Vallabh Garden Agriculture Farm, Bikaner

S. No.	Crop	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
1	*Tagetes erecta*	-	-	-	-	1	1
2	*Lagenaria siceraria*	22	-	-	-	-	-
3	*Luffa cylindrica*	2	-	-	-	-	-
4	*Cucurbita maxima*	-	-	-	-	-	-
5	*Raphanus sativus*	-	-	-	-	-	-
6	*Brassica campestris*	-	-	-	-	-	-
7	*Solanum melongena*	-	-	-	-	-	-

Shaded a rea in tables indicating crop period

Shaded area in tables indicating flowering period.

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Survey of Weeds as a Source of Pharmaceuticals from Mohol Tahasil

By Dalave S.C , Auti S.G & B.J. Apparao
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Abstract – Weeds are considered as unwanted plants. However some weeds posses valuable pharmaceutical importance. Number of researchers combined this fact with an ethnobotanical approach. The present work reports, pharmaceutically important weeds from the common fields (Sorghum, Sugarcane, Maize, Wheat, Pulse Crop and waste land) of Mohol Tahasil of Solapur district, Maharashtra state. 21 valuable weed species were collected from different fields of Mohol Tahasil and identified for their pharmaceutical source using standard literature and herbal pharmacopoeias. Ethnomedicinal and weed survey in this area was not much explored and hence the present investigation was taken up.

Keywords : *Weeds, Pharmaceutical aspects.*

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Dalave S.C[α], Auti S.G[σ], & B.J. Apparao[ρ]

Abstract - Weeds are considered as unwanted plants. However some weeds posses valuable pharmaceutical importance. Number of researchers combined this fact with an ethnobotanical approach. The present work reports, pharmaceutically important weeds from the common fields (Sorghum, Sugarcane, Maize, Wheat, Pulse crop and waste land) of Mohol tahasil of Solapur district, Maharashtra state. 21 valuable weed species were collected from different fields of Mohol tahasil and identified for their pharmaceutical source using standard literature and herbal pharmacopoeias. Ethnomedicinal and weed survey in this area was not much explored and hence the present investigation was taken up.

Keywords : *Weeds, Pharmaceutical aspects.*

I. Introduction

Weeds are considered as unwanted plants nevertheless number of researchers proved the valuable aspects of some weed species. Natural products can be important source for new pharmaceuticals (Abelson, 1990). The role of weed in the present pharmacopoeia has been overlooked; weeds are an important source of medicines for indigenous peoples and have a highly significant over representation in indigenous pharmacopoeias in relation to other types of plants (Stepp and Moerman, 2001).

Mohol tahasil is the semi-irrigated area of Solapur district with an annual rainfall 500 mm and temperature ranges from 18^0 C to 41^0C. Sorghum, Maize, Wheat, Pulses and sugarcane are the common crops of the Mohol tahasil.

II. Material and Methods

Monthly visit to selected field crops were made during the period of July. 2005 to July 2006. For the survey 100 fields were selected to study the weeds flora. Weed plant species having high frequency in a crop were collected to know the botanical name, family and common names. The collected plant specimens were identified with the help of flora of presidency Bombay (Cooke T. 1903- 1908). Information on the medicinal uses and local names of the plants gathered was confirmed with scientific literature mentioned in Useful Plants of India (Ambasta et al., 1994), Medicinal Plants (Jain S.K. 1968), Database on medicinal Plants Used in ayurveda (Sharma *et al*) and herbal pharmacopoeias. Photographs of plants have been taken during the field survey.

III. Results and Discussion

As many as 21 species showed the higher frequency in maximum crops. The pharmaceutical status was confirmed with the help of methods mentioned in methodology. Botanical names and crop wise distribution are as per described in table-1.

Table -1 : List of weed species in different crops and wastelands.

Sr. No	Weed Species	Sorghum	Maize	Wheat	Sugarcane	Pulses	Waste lands / Road side
1.	*Acacia arabica.* L.	— —	— —	— —	— —	— —	*
2.	*Achyrathus aspera* L.	*	**	**	— —	*	**
3.	*Argemone maxicana*	— —	*	**	*	*	*
4.	*Barleria prointis*	— —	— —	— —	— —	— —	*
5.	*Boerhivia diffusa* Linn.	**	**	**	— —	**	**
6.	*Calotropis gigantean L.*	*	— —	— —	— —	— —	*
7.	*Celocia argentiana* L.	*	— —	*	— —		*
8.	*Commelina benghalensis* L.	*	*	*	*	*	— —
9.	*Cynadon dactylon* L.	*	— —	— —	— —	*	**
10.	*Cyperus rtundus* L.	**	— —	*	— —	— —	**
11.	*Datura metal* L.	— —	— —	— —	— —	— —	**
12.	*Euphorbia geniculata* L.	*	— —	*	**	— —	*
13.	*Euphorbia hirta*	**	*	*	*	*	— —
14.	*Phylanthus amarus.* Schum. & Thonn.	*	*	— —	*	*	*

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15.	*Portulaca oleraceae* L.	— —	— —	*	*	— —	*
16.	*Sesbania grandiflora* L.	— —	— —		*	— —	*
17.	*Solanum nigrum* L.	*	**	*	*	*	**
18.	*Solanum xanthocarpum* L.	— —	— —	— —	— —	*	**
19.	*Tinospora quardifolia* (Willd)	— —	— —	— —	*	— —	*
20	*Tribulus terestis.* L.	*	— —	— —	— —	*	*
21.	*Withania somnifera.* L. Dunal	— —	— —	— —	— —	— —	*

∗ Present, ∗∗ Present in high frequency, −− absent

In the present survey we have reported crop wise distribution of the common weeds. All the observed 21 weeds showed the source of pharmaceutical in various remedies of the ayurveda and unnani system of medicine.

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Relative Performance of Three Sweet Potato Varieties in Sole and Intercrop Systems in Southern Guinea Savanna Ecology of Nigeria

By Egbe,O.Moses
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Abstract – A field experiment was conducted in 2009 and 2010 at the Teaching and Research Farm of the University of Agriculture, Makurdi, Benue State, Nigeria. The purpose of the experiment was to investigate the yield and yield components of newly introduced sweet potato varieties under various planting patterns with pigeonpea. Neither fertilizer nor insecticide was applied. This was done in accordance with standard practices of organic sweet potato production. The experiment was a 3 x 5 split plot set out in a randomized complete block design with three replications. Each component crop was planted at a population of 33,000 plants per ha-1 in both sole and intercropping systems. Planting pattern did not exert any significant effects on the fresh fodder weight and number of saleable tubers of sweet potato. Sole cropped sweet potato produced significantly higher number of branches per plant, tuber length and weight than row- and strip-intercropped treatments.

Keywords : *sweet potato, pigeonpea, planting pattern, productivity.*

GJSFR-D Classification : *FOR Code: 820215, 820602*

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Keywords : sweet potato, pigeonpea, planting pattern, productivity.

I. Introduction

Sweet potato (*Ipomea batatas* (L.) Lam) has a long history to stave off famine – especially as a cheap source of calories (Adam, 2005). It feeds millions of people in the developing world and it is especially popular among farmers with limited resources. The production, marketing and utilization of sweet potato have expanded in the last decade to almost all ecological zones in Nigeria (NRCRI, 2009). Presently, 381,000 – 510,000 ha of land are subjected to sweet potato cultivation in Nigeria with an annual production figure of 3.46 million metric tonnes (NRCRI, 2008). Estimated yields of sweet potatoes in the research fields varied from 40 to 70 t/ha for improved varieties, while in multilocational trials yields averaged 23.5t/ha across seasons and locations (Tewe *et al.*, 2003).

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Today, Nigeria is the largest producer of sweet potato in Africa and the second largest in the world after China. In Benue State, Nigeria, approximately 212,840 ha was subjected to sweet potato production with a mean yield of 9.80 t/ ha in 2008 (BNARDA, 2008).

Sweet potatoes are usually consumed without special processing. The fresh tuber is boiled, roasted, baked, or fried as chips, which may be sold as snacks or salted and eaten as potato crisps in most parts of Nigeria. Sweet potatoes are fed to livestock or processed industrially into alcohol, starch, noodles, candy, desserts and flour. Orange flesh sweet potatoes are rich in B – carotene (precursor for vitamin A). Sweet potatoes are now being used in Africa to combat a widespread vitamin A deficiency in 250,000 – 500,000 children. About two-thirds of the children developing xerophthalmia, resulting from lack of vitamin A, die within a year of losing their sight. The strategy of increasing orange flesh sweet potato consumption helps to alleviate vitamin A deficiency (Anderson *et al.*, 2007).

Intercropping sweet potato with pigeonpea will not only ensure better environmental resource utilization, but should also provide better yield stability, reduce pests and diseases and diversify rural income. Some yield advantages have been derived from sweet potato intercropping with okra (Njoku *et al.*, 2007) and sweet potato with pigeonpea (Egbe and Idoko, 2009). Intercropping sweet potato with pigeonpea is presently not popular but it has enormous potential in the Southern Guinea Savanna ago-ecological zone of Nigeria to ensure the supply of dietary carbohydrate, protein, fats, vitamins and minerals (calcium, magnesium, copper, iron and zinc) for the rural household (Egbe, 2005). Recently, several improved varieties of sweet potato have been introduced into the cropping systems of smallholder farmers in Benue State, particularly from International Institute of Tropical Agriculture (IITA), Ibadan and the National Root Crops Research Institute (NRCRI), Umudike. Farmers in Benue State who intercrop or mix sweet potato with pigeonpea do so in highly variable planting patterns with resultant low productivity. The study reported here was undertaken to document the influence of cropping systems on the yield and yield components of newly introduced sweet potato varieties with a view to improve

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the productivity of sweet potato/pigeonpea intercropping in Benue State and enhance food security of the region. The work also sought to evaluate the suitability of these newly introduced sweet potato varieties to sole, row- and strip-intercropping systems usually adopted by farmers in Benue State and in the Southern Guinea Savanna agro-ecological zone of Nigeria.

II. Materials and Methods

A field experiment was conducted for two cropping seasons (2009 and 2010) at the Teaching and Research Farm of the University of Agriculture, Makurdi [Latitude 07^0 45/ - 07^0 50/ N, Longitude 08^0 45/ - 08^0 50/ E,elevation 98 m] in Benue State, located in the Southern Guinea Savanna of Nigeria. The site used for the experiment had been cropped to pigeonpea for two years; it received 1402.50 mm of rain in 2009 and 1115.30 mm in 2010. The soil was classified as Dystric Ustropept (USDA).The same site was used for the experiment in each year. Eight core samples of soil were collected from different parts of the experimental field from a depth of 0-30 cm and bulked into a composite sample and used for the determination of the physical and chemical properties of the soil (see Table 1) before planting. The soil samples were air-dried at room temperature for one week, ground (using mortar and pestle) to pass through a 0.3 mm screen for chemical analysis. Mechanical analysis was carried out by the hydrometer method described by Bouyoucos (1962). Soil pH was obtained using a 1:2.5 soil-water ratio. Total organic carbon was determined by the use of an improved chromic acid digestion and spectrophotometric method (Heanes, 1984) and organic matter was estimated by multiplying the organic carbon figure by 1.724. Available phosphorus was determined by using Bray1 procedure (Bray and Kurtz, 1945). Nitrogen in soil was estimated by phenols colour formation method (Chaykin,1969) after micro-Kjeldahl digestion;exchangeable potassium and calcium were determined using the methods described by Jou (1983). Magnesium was assessed using the methodology developed by Tel and Rao (1982). Effective cation exchangeable capacity (ECEC) was obtained by the summation method.

Table 1: Physical and chemical properties of the surface soil (0-30 cm) at the experimental site in Makurdi in 2009 and 2010.

	Makurdi	
Parameter	2009	2010
Sand (%)	68.00	68.20
Silt (%)	13.20	16.20
Clay (%)	18.60	15.60
Textural class	Sandy loam	Sandy loam
pH (H_2O)	6.40	6.25
Organic matter (g kg^{-1})	4.25	3.73
Total N (g kg^{-1})	1.91	1.70
Available P (cmol kg^{-1} soil)	8.88	7.33
Ca^{2+} (cmol kg^{-1} soil)	3.55	2.8
Mg^{2+} (cmol kg^{-1} soil)	2.13	1.25
K^+ (cmol kg^{-1} soil)	0.44	0.41
Na^+ (cmol kg^{-1} soil)	0.19	0.17
ECEC (cmol kg^{-1} soil)	4.87	5.21

The plot was ploughed, harrowed and ridged before laying the experiment as a 3 x 5 split plot set out in a randomized complete block design with three replications. The main plot treatments comprised of three planting patterns: (i) sole cropping (sweet potato, pigeonpea *var. igbongbo*) (ii) row intercropping (sweet potato + pigeonpea) and (iii) strip intercropping (sweet potato + pigeonpea). The sub – plot treatments comprised of five improved sweet potato varieties obtained from the National Root Crops Research Institute, Umudike [TIS 87/0087, TIS 86/0356, TIS 2532.OP.1.13, 440293 (orange flesh) and 199004-2]. TIS 87/0087, though improved, was used as the local check in this study, because it had proved superior to other varieties of sweet potato in previous work (Egbe and Idoko, 2009) and it is already being grown by many farmers in the region. The gross plot was made up of four ridges,4 m long (16 m^2),while the bordered area had two ridges 3 m long (6 m^2).The experiment was planted on 25th July, 2009 and 30th July, 2010. Sweet potato cuttings measuring 25 cm with at least four nodes were planted at the crest of ridges at a spacing of 1 m x 0.3 m (33,000 plants per hectare – sole cropping, row intercropping and strip intercropping). Strip-intercropped plots had a ratio of 2 ridges of sweet potatoes: 2 ridges of pigeonpea. The pigeonpea (*var.igbongbo*) seeds used for the study were obtained from the local market in Otobi. Sole, row- and strip-intercropped pigeonpea was planted at a spacing of 1 m x 0.3 m with two seeds per hole and later thinned to 1 plant/stand (33,000 plants/ha) at 10 days after planting. While row-intercropped pigeonpea was sown by the side of the ridge, sole and strip-intercropped pigeonpea was planted at the crest of the ridge. Weeding was done at three weeks after planting (w.a.p.) and at 6 w.a.p.using traditional hand hoes.

Neither fertilizer nor insecticide was applied. This was done in accordance with standard practices of organic sweet potato production (Adam, 2005). It was expected that residual nitrogen (N) from previous pigeonpea (fixation and decomposition of leaf litter) and from the current crop would suffice. Residual benefits of pigeonpea to cassava had been reported to give higher fresh tuber yields than fallow plots in both sole and

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intercropping systems irrespective of NPK;15:15:15 fertilizer rates (0,45,90 kg/ha)used (Egbe et al.,2011). Muktar et al. (2010) had also indicated that N requirement for commercial sweet potato production in Nigeria was fairly low. Pigeonpea can fix up to 164.82 kg N/ha (Egbe, 2007) and can increase the available phosphorus pool in the cropping systems in which it is grown (Ae *et al.*, 1990).

At harvest, the following parameters were measured from the net plot :

(a) Sweet potato component: Number of branches/plant, number of saleable tubers/plant, weight of saleable tubers (weight of tuberous root ≥ 100g, devoid of insect and disease attack as well as harvest injuries), tuber length, tuber circumference at the widest point and fresh fodder weight.

(b) Pigeonpea component: Number of pods/plant, seeds/pod (average of five plants per plot), pod weight and grain yield.

Intercrop advantage was calculated by determining: Land equivalent ratio (LER) (Ofori and Stern, 1987). LER = (Yab/Yaa) + (Yba/Ybb),where *Y*aa and *Y*bb are yields as sole crops of sweet potato and pigeonpea, respectively and *Y*ab and *Y*ba are yields as intercrops of sweet potato and pigeonpea, respectively. Values of LER greater than 1 are considered advantageous. Land equivalent coefficient (LEC),a measure of interaction concerned with the strength of the intercrop relationship was also calculated: LEC = La x Lb, where, La = LER of main crop (sweet potato) and Lb = LER of intercrop (pigeonpea) (Adetiloye *et al.*,1983). For a two-crop mixture the minimum expected productivity coefficient (PC) is 25%, i.e. a yield advantage is obtained if LEC value exceeds 0.25. Also, the competitive ratio (CR) (Putnam *et al.*, 1984), the number of times by which one component crop is more competitive than the other was computed. Ra = La/Lb x zba/*z*ab, where R*a* is the competitive ratio of crop *a* and L*a* and L*b* are the LERs of crops a and b respectively, zba is the proportion of crop *a* in the ab intercrop and z*a*b is the proportion of crop *b* in the ab intercrop. If R*a* < 1, there is a positive benefit and the crop can be grown in association; if Ra > 1, there a negative benefit. The reverse is true for Rb. Area x Time equivalent ratio (ATER) (Hiebisch and Mc Collum, 1987),the ratio of number of hectare-days required in monoculture to the number of hectare-days used in the intercrop to produce identical quantities of each of the components was calculated: ATER = (Rya x ta) + (Ryb x tb)/ T, where, Ry = relative yield of species 'a' or 'b' i.e., yield of intercrop/yield of monocrop,t = duration (days) for species 'a' or 'b' and T = duration (days) of the intercropping system. Values of ATER greater than 1 are considered advantageous (Ofori and Stern,1987).

Year x treatment interactions were not significant, so data for both years were pooled together and analyzed. Data collected were analyzed using GENSTAT Release 11.1 (PC/Windows) (2008.VSN International Ltd., London) and the least significant difference (LSD) test at 5% probability level was used to compare the treatment means.

III. Results

The main effects of planting patterns on some of the parameters (number of branches and saleable tubers per plant, fresh fodder weight, tuber length, circumference and saleable weight) was significant($P \leq 0.05$),but planting pattern x variety interaction effects on the various parameters of sweet potato intercropped with pigeonpea in Makurdi were not. Table 2 presents the results of the main effects of planting pattern on the number of branches and saleable tubers per plant, fresh fodder weight, tuber length, circumference and weight of sweet potato intercropped with pigeonpea. Planting pattern did not exert any significant effects on the fresh fodder weight and number of sale able tubers of sweet potato, but sole cropped sweet potato produced significantly higher number of branches per plant and saleable tuber weight than both row-intercropped and strip-intercropped treatments. Tuber length of sole cropped sweet potato was significantly higher than that of row intercropping, but it was not significantly different from that produced by strip-intercropped treatment. Tuber circumference of sole cropping was significantly lower than that of strip-intercropping, but it was statistically at par with that produced by row intercropping. Percentage reduction in saleable tuber yield of sweet potato varied from 47.07% (strip – intercropping) to 49.11% (row – intercropping).

Table 2 : Effect of cropping systems on number of branches and tubers per plant, fresh fodder weight, tuber length, circumference and saleable weight of sweet potato intercropped with pigeonpea in Makurdi.

Parameter	Sole cropping	Row- intercropping	Strip-intercropping	Mean	FLSD(0.05)
Branches/plant	5.47	3.60	5.00	4.69	0.15
Fresh fodder weight (t/ha)	1.77	1.12	1.66	1.52	ns
Tubers/plant	2.93	2.13	2.33	2.46	ns
Tuber length (cm)	21.80	15.20	16.50	17.33	5.44
Tuber circumference (cm)	22.90	20.60	24.41	22.64	2.23
Saleable tuber weight (t/ha)	11.20	5.70	6.60	7.83	3.65
Percentage Saleable tuber weight reduction (%)	0.00	49.11	41.07		

FLSD: Fisher's Least Significant Difference Test

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The main effect of variety on the number of branches and tubers per plant, fresh fodder weight, tuber length, circumference and weight was significant. Table 3 shows the effect of variety on the tuber yield and other yield components of sweet potato intercropped with pigeonpea in Makurdi. Mean number of branches per plant of sweet potato varieties was 4.69. TIS 2532.OP.1.13 had significantly fewer branches/plant than TIS 87/0087, but the number of branches/plant of TIS 2532.OP.1.13 was not significantly different from those produced by 440293. TIS 87/0087 and TIS 2532.OP.1.13 consistently had significantly more number of tubers/plant, fresh fodder weight, tuber length, circumference and saleable tuber weight than all other varieties, except TIS 86/0356, which obtained similar number of tubers and tuber circumference. The length of tuber of TIS 86/0356 was significantly lower than that of TIS 2532.OP.1.13. TIS 87/0087 and TIS 2532.OP.1.13 produced similar saleable tuber weights (14.20 t/ha and 16.00 t/ha, respectively) and these were significantly higher than the saleable tuber weights produced by TIS 86/0356, 440493 and 199004-2. The latter variety gave the lowest number of tubers per plant, fresh fodder weight, tuber length, circumference and saleable tuber weight.

Table 3 : Influence of variety on the number of branches and tubers per plant, fresh fodder weight, tuber length, circumference and weight of sweet potato in Makurdi.

Variety	Branch/plant	Tubers/plant	Fresh fodder	Tuber length(cm)	Tuber circumference (cm)	Saleable tuber weight (t/ha)
TIS 87/0087(check)	5.56	3.33	2.43	20.90	24.00	14.20
TIS 86/0356	4.89	3.22	1.31	17.70	21.10	5.40
TIS 2532.OP.1.13	4.33	3.00	2.40	29.10	25.80	16.00
440293	3.67	1.56	1.05	12.40	19.90	2.50
199004-2	5.00	1.22	0.40	9.20	12.30	1.20
Mean	4.69	2.47	1.51	17.86	20.62	7.86
FLSD (0.05)	0.80	1.21	0.68	7.05	6.89	7.11

FLSD : Fisher's Least Significant Difference Test

Sweet potato varieties did not influence the number of pods produced per plant of intercropped pigeonpea (Table 4). Sole crop pigeonpea gave highest number of seeds per pod. There was, however, no significant difference between sole pigeonpea and pigeonpea row – intercropped with TIS 86/0356 or strip – intercropped with TIS 87/0087, 440293 and 199004-2. Intercropping reduced the pod weight and grain yield of pigeonpea when compared to the sole crop treatment (Table 4). Sole crop pigeonpea produced the highest pod weight (3.00 t/ha) and grain yield (2.61 t/ha), while row-intercropped pigeonpea with 440293 had the lowest pod weight (1.53 t/ha) and grain yield (1.22 t/ha).

Table 4 : Number of pods per plant, seeds per pod, pod weight (t/ha) and grain yield of sole and pigeonpea intercropped with sweet potato in Makurdi.

Cropping systems	Pods/plant	Seeds/pod	Pod weight (t/ha)	Grain yield (t/ha)
Sole pigeonpea	107.70	5.33	3.00	2.61
TIS 87/0087 row - intercropped with pigeonpea	90.70	4.00	1.56	1.28
TIS 86/0356 row – intercropped with pigeonpea	107.20	5.00	1.58	1.47
TIS 2532.OP.1.13 row – intercropped with pigeonpea	93.70	4.33	1.92	1.58
440293 row – intercropped with pigeonpea	96.50	4.00	1.53	1.22
199004-2 row – intercropped with pigeonpea	91.30	4.00	1.56	1.28
Mean (row-intercropping)	95.88	4.27	1.63	1.37
TIS 87/0087 strip - intercropped with pigeonpea	92.70	5.00	1.75	1.56
TIS 86/0356 strip – intercropped with pigeonpea	105.00	4.33	1.94	1.86
TIS 2532.OP.1.13 strip – intercropped with pigeonpea	107.70	4.33	2.11	1.83
440293 strip – intercropped with pigeonpea	101.70	5.00	1.97	1.58
199004-2 strip – intercropped with pigeonpea	94.70	5.00	2.03	1.78
Mean (strip-intercropping)	100.36	4.73	1.96	1.72
Grand Mean	99.00	4.58	1.90	1.64
FLSD (0.05)	ns	0.61	0.28	0.32

FLSD : Fisher's Least Significant Difference Test

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There were no significant differences between the various treatments in LER (land equivalent ratio) and LEC (land equivalent coefficient) produced by intercropped sweet potato with pigeonpea in Makurdi (Table 5). All intercrop combinations had LER figures above unity, except row - and strip - intercropped TIS2532.OP.1.13. Also, LEC values were greater than 0.25 in all intercrop situations, except in row - and strip - intercropped TIS2532.OP.1.13. Row – intercropped 199004-2 had the highest LER (1.97) and LEC (0.75) figures, while row – intercropped TIS 2532.OP.1.13 had the lowest LER (0.97). Strip –inter cropped TIS 2532.OP.1.13 also had the lowest LEC value (0.18). Mean LER and LEC figures obtained were 1.33 and 0.43, respectively. Under row intercropping, competitive ratio values of sweet potato (CRPOT) were higher than 1.00, only in TIS 2532.OP.1.13 and TIS 87/0087. In strip-cropping, only TIS 2532.OP.1.13 gave a competitive ratio value of sweet potato above 1.00. Competitive ratio figures of pigeonpea (CRPPEA) were above unity when row – intercropped with all other sweet potato varieties, except TIS 2532.OP.1.13. Under strip – intercropping, only pigeonpea combined with 440293 had CRPPEA value higher than 1.00.Only row- intercropped TIS 87/0087 had CRPOT (1.13) and CRPPEA (1.14) at par, all other varieties had increased CRPOT with concomitant decreased CRPPEA and vice versa. In general, there was no significant difference between CRpot and CRPPEA (Table 5). ATER (Area x Time equivalent ratio) values were greater than 1.0 in row- and strip-intercropped TIS 86/0356, row-intercropped 199004-2 and strip-intercropped 440293; all other treatments gave ATER figures of less than 1.00.

Table 5 : Land equivalent ratio (LER), land equivalent coefficient (LEC), competitive ratio of sweet potato (CRPOT) and competitive ratio of pigeonpea (CRPPEA)of intercropped sweet potato with pigeonpea in Makurdi.

Treatment	LER	LEC	CRPOT	CRPPEA	ATER
TIS 87/0087 row - intercropped with pigeonpea	1.08	0.29	1.13	1.14	0.88
TIS 86/0356 row – intercropped with pigeonpea	1.74	0.66	2.19	0.52	1.44
TIS 2532.OP.1.13 row – intercropped with pigeonpea	0.97	0.22	0.61	3.19	0.86
440293 row – intercropped with pigeonpea	1.12	0.33	1.14	0.91	0.91
199004-2 row – intercropped with pigeonpea	1.97	0.75	2.80	0.38	1.45
Mean	1.38	0.45	1.57	1.23	1.10
TIS 87/0087 strip - intercropped with pigeonpea	1.24	0.39	0.73	0.35	0.99
TIS 86/0356 strip – intercropped with pigeonpea	1.36	0.45	0.77	0.33	1.19
TIS 2532.OP.1.13 strip – intercropped with pigeonpea	0.98	0.18	0.28	1.74	0.90
440293 strip – intercropped with pigeonpea	1.79	0.74	1.15	0.30	1.39
199004-2 strip – intercropped with pigeonpea	1.05	0.25	0.37	0.87	0.91
Mean	1.28	0.40	0.66	0.72	1.08
FLSD (0.05)	ns	ns	1.02	2.14	ns
Paired t-test (0.05) CRPOT vs CRPPEA			-0.32ns		

ns: not significant at 5% probability level

IV. Discussion

The rainfall received during the experimental periods of both 2009 and 2010 was considered adequate for crop growth and development. The non-significant effect of planting pattern on the fodder weight and number of saleable tubers per plant suggest that these traits might be under strong genetic control as opposed to planting environment. Anshebo *et al.* (2004) had reported that high heritability estimates were noticed for vine traits (length of vine, number of branches per plant and weight of foliage) of sweet potatoes in Madras, India. The higher number of branches per plant, tuber length and weight of sole cropped sweet potato as compared to intercropping (row- and strip- intercropping) can be attributed to greater availability of growth resources (light,water,soil nutrients,etc.) to sole crop plants than those intercropped with pigeonpea. Sharing of growth resources among components crops under intercropping can limit growth and accumulation of dry matter compared to sole cropping where competition exists (Dasbak and Asiegbu, 2009). Egbe and Idoko (2009) had observed depressive effects of pigeonpea on yields of sweet potato varieties at Otobi and associated such responses to decline of photosynthesis due to decreased solar radiation by shading of the sweet potato by the taller pigeonpea component. The superior performance of TIS 87/0087 (check) over all other varieties of sweet potato, except TIS 2532.OP.1.13, could imply that this variety was more suitable than the other varieties for cultivation with or without pigeonpea in Makurdi environment. Only this variety (TIS 87/0087) and TIS 2532.OP.1.13 had tuber yields above the mean yield (9.80 t/ha) of sweet potato in Benue State. TIS 2532.OP.1.13 should be cultivated in sole rather than intercropping for higher productivity. The orange flesh variety (440293) had about 25% of the current average yield of sweet potato in the State, making it difficult as a choice variety for adoption by farmers in the region. The reduction in the pod weight and grain yield of intercropped pigeonpea as compared with its sole might be ascribed to underground

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competition for soil growth resources (water and soil nutrients) between the intercrop components. It is known that competitive reactions reduce yields in intercropped crop species as compared to sole cropping (Egbe, 2005). TIS 87/0087 and the other varieties, except TIS 2532.OP.1.13, gave LER values above unity and LEC figures beyond 0.25, indicating intercrop advantages. These intercrop advantages may have arisen from the high yields of the pigeonpea component which made up for the reduction in the sweet potato yield. This may be a case typifying a "competition-recovery production principle" as proposed by Zhang and Li (2003), where after a dominant/base species is harvested, the subordinate/intercrop species has a recovery or complementary process so that the final yields remain unchanged or even increase compared with corresponding sole species. ATER values indicated yield advantages only for intercropped TIS 86/0356, 199004-2 and 440293. It showed that 19-39% hectare-days could be saved under strip intercropping and 44-45% under row intercropping. Strip intercropping of these three sweet potato varieties with pigeonpea could therefore be an alternative production system for sweet potato growers. Intercrop productivity measures (LER, LEC, CR, ATER) used in this study indicated poor performance of TIS 2532.OP.1.13, although it gave comparable saleable tuber yield with TIS 87/0087. This result was at variance with the findings of Njoku *et al.* (2007), who had identified TIS 2532.OP.1.13 to give remarkable yields when intercropped with okra in southeastern Nigeria. The high productivity indices of the orange flesh variety (440293), despite its low saleable tuber yield may be indicative of its ability to tolerate shading under intercropping with pigeonpea.

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Determinants of Climate Change on Cassava Production in Oyo State, Nigeria

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Abstract – The study examined the determinants of climate change on cassava production in the study area. To achieve this main objective, the study identified the socio economic characteristics of the cassava farmers; identified the constraints faced by farmers in cassava production and finally determined the coping strategies adopted by cassava farmers in adjusting to the impact of climate change in cassava production. A well structured interview schedule was used in collecting data for the study and the data collected were based on the stated objectives of the study. There are ten cells in the block. Simple random sampling technique was used in selecting 18 respondents from each cell making a total number of ninety (90) as the sample size. Results of findings revealed that the mean age of the cassava farmers was 53.22 and most of the farmers had 7 members in their household. About 72.2% of the respondents were male and most of them had one form of formal education or the other. The result of findings revealed that a significant relationship was found between change of farmland (.295*) and the determinants of climate change. The major constraints faced by farmers in cassava production were lack of storage system and problem of pests and diseases. Therefore, the study recommends that storage facilities should be provided by government to cassava farmers and the cost of pesticides should also be subsidized in order to boost cassava production.

GJSFR-D Classification : *FOR Code: 070306, 070106, 070108*

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Abstract - The study examined the determinants of climate change on cassava production in the study area. To achieve this main objective, the study identified the socio economic characteristics of the cassava farmers; identified the constraints faced by farmers in cassava production and finally determined the coping strategies adopted by cassava farmers in adjusting to the impact of climate change in cassava production. A well structured interview schedule was used in collecting data for the study and the data collected were based on the stated objectives of the study. There are ten cells in the block. Simple random sampling technique was used in selecting 18 respondents from each cell making a total number of ninety (90) as the sample size. Results of findings revealed that the mean age of the cassava farmers was 53.22 and most of the farmers had 7 members in their household. About 72.2% of the respondents were male and most of them had one form of formal education or the other. The result of findings revealed that a significant relationship was found between change of farmland (.295*) and the determinants of climate change. The major constraints faced by farmers in cassava production were lack of storage system and problem of pests and diseases. Therefore, the study recommends that storage facilities should be provided by government to cassava farmers and the cost of pesticides should also be subsidized in order to boost cassava production.

I. Introduction

Agriculture belongs to the main sector of Nigerian economy and it is characterized by a multitude of small scale farmers scattered over wide expanse of land area, with small holding ranging from 0.05 to 3.0 hectares per farm land, rudimentary farm systems, low capitalization and low yield per hectare. The roles of agriculture remain significant in the Nigerian economy despite the strategic importance of the oil sector. Agriculture provides primary means of employment for Nigerians and accounts for more than one–third of total gross domestic product (GDP) and labour force (FAO, 2005: World Bank, 2003). Agriculture in Nigeria is a major branch of the economy providing employment for 70% of the population. The sector is being transformed by commercialization at the small, medium, and large-scale enterprises levels. Major crops include beans, sesame, cashew nuts, cassava, cocoa beans, groundnuts, kolanut, maize(corn), melon, millet, palm kernels, palm oil, plantains, rice, rubber, sorghum, soybeans and yams (Olomola, 2007). Agriculture is the basic activity by which humans live and survive on the earth and assessing the impacts of climate change on agriculture is a vital task. In both developed and developing countries, the influence of climate on crops and livestock persists despite irrigation, improved plant and animal hybrids and the growing use of chemical fertilizers. The continued dependence of agricultural production on light, heat, water and other climatic factors, the dependence of much of the world's population on agricultural activities, and the significant magnitude and rapid rates of possible climate changes all combine to create the need for a comprehensive consideration of the potential impacts of climate on global agriculture (Rosenweig et al, 1990).

Cassava (manihot esculenta) is a native from South America that is extensively cultivated as an annual crop in the tropical and subtropical regions for its edible starchy tuber as root. Cassava has the ability to grow on marginal lands and its one of the most important staple food crops in Tropical Africa with its efficient production of food energy, year round availability and tolerant of extreme environmental stresses which makes it eminently suitable for farming and food system in Nigeria. Cassava production plays a key role in alleviating poverty in Nigeria, as it is virtually impossible that an average household will not consume cassava product in a day. Therefore, cassava is an important factor in food security, poverty alleviation, rural – urban drift and reducing unemployment among others (Okpukpara, 2006). The discovery and exploitation of petroleum, the black gold led to the decline in the importance attached to the golden crop cassava and other important agricultural produce. Nevertheless, Nigeria still has a high percentage in exportation of cassava (Adegeye, 1996). However, Oyo state being one of the cassava producing states in Nigeria is highly sensitive to variation in climatic factors most especially rainfall, temperature and sunshine duration. Several views have been expressed about the impact of irregularity of climate on cassava production. To achieve the main objective, the study identified the socio economic characteristics of cassava farmers, investigated the constraints faced in cassava production and determined the coping strategies adopted by cassava farmers in adjusting to the impact of climate change in cassava production. The study further determined the relationship between the coping strategies adopted in cassava production and effects of climate change in the study area.

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II. Methodology

The study was conducted in Ido Local Government Area of Oyo state. Historically, the local government was created in 1989 with the Administrative Headquaters located at Ido. It shares boundaries with Iseyin and Afijio Local Government Area to the North, Akinyele Local government Area to the east, Ibarapa East Local Government Area to the West. It also shares boundaries with Ogun State to the south. This Local Government Area has a land mass of 1,010,954 square kilometers with the 2010 estimated population of 117,129 using a growth rate of 3.2% from 2006 census. A population density of 116 persons per square kilometer.The residents of the local government area are mostly farmers, traders, transporters and civil servants. They are yorubas and other tribes from various parts of the country. Soil fertility in the area enhances the production of maize, cocoa, oil palm, cassava and vegetables. It has processing industry at Ilaju. The study population comprises of cassava farmers (men and women) in the study area. A simple random sampling tecnique was used in selecting the respondents for this study. Ido local government is a block under the Ibadan/Ibarapa agricultural zone of the Oyo State Agricutural Programme (OYSADEP). The block is made of up of ten(10) cells from which 50% was selected. Eighteen (18) respondents were selected using simple random technique, thus a total of 90 respondents constituted the sample size. The instrument for data collection was structured interview schedule. The dependent variable is the effect of climate change on cassava production while the independent variables were the coping strategies adopted such as irrigation system, fertilizer application, and change in planting date. Frequency, percentage and mean value were used as descriptive statistics while correlation coefficient was used to determine the relationship between the variables.

III. Data Analysis and Interpretation

a) Socio – economic characteristics of respondents

The result of the findings in (table 1) revealed that majority (27.70%) of the respondents were between ages 60 and 69. The mean age is 53.22 years. It is inferred that most of the cassava farmers are middle aged and therefore still have the strength to manage their farm effectively. The table also shows that majority (72.20%) of the cassava farmers were male while 27.80% were female. This is an indication that the male components were more involved in cassava production. 83.30% of the cassava farmers were married, while 16.70% were single. The high percentage of married people is an indication of more responsible adults in the study area. Going through the distribution of the educational level attained, one will see that tertiary education had the highest percentage (30.0%). Primary occupation of 64.40% was farming while 35.60% were generating their major source of income from other occupations. Table 1 further revealed that 61.90% had about 20 years experience in farming. 51.10% had between 6 and 10 members in their household. The mean household size is 6.46 which imply that most of the respondents have about seven members in their household as at the time the research was conducted. This might help in supplying household labour and thereby reducing the cost incurred on payment of labour. It was also revealed that 52.20% were involved in both commercial and subsistence farming and 24.30% of them earned between 151,000 – 200,000 naira in a year.

b) Constraints encountered by respondents.

It was revealed in table 2 that lack of storage facilities was ranked first among the constraints encountered with a weighted mean score of 1.41, followed by problem of pests and diseases (1.26) and poor transportation (1.00). Also, lack of subsidies ranked fourth (0.90), followed by lack of credit facilities (0.89) and labour availability (0.73). Government policy ranked seventh (0.58) and land tenure system ranked eighth (0.39).

c) Adoption of coping strategies

The results of the findings revealed that 83.3 per cent adopted change in planting date as their major coping strategy. Followed by fertilizer application (78.9%), adoption of new varieties and change in farm land with 68.9 per cent respectively. Others are improved farming practices (52.2%), marketing policy (27.8%) and post harvest technology (22.2%). This implies that most of the respondents employed change of planting date and fertilizer application as their major coping strategies in adjusting to the effects of climate change.

d) Determinants of climate change on cassava production

From result of the findings, it was observed that thin stem and tall plant (1.67) was the major determinant of climate change experienced in the study area followed by early growth slowdown (1.56), poor germination of tubers (1.31), leave turning colour (1.29), stunted growth (1.04), late maturity (0.82) and poor seed density (0.18).

e) Relationship between coping strategies adopted and effect of climate change

From the table below, a significant and positive relationship was found to exist between change in farm land and determinants of climate change at 0.01 level of significance ($r=0.295$, $P^{*}= 0.01$).This implies that adoption of change in farm land is positively related to determinant of climate change. That is the practice of shifting cultivation assisted in adjusting to the negative effects of climate change in the study area.

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IV. Conclusion and Recommendation

The study has shown that majority of the respondents were in their late ages and cassava farming was revealed as males' agricultural activity in the study area. The results of the findings also revealed that the large household size favoured the supply of labour for farming activities in the study area and most of the farmland in the study area was owned through inheritance. Lack of storage system and incidence of pests and diseases were still prevalent in the study area as change in planting date and fertilizer adoption were the major coping strategies adopted in the study area. The findings of the study also revealed that thin plant and tall stem were the most serious determinants of climate change on cassava production in the study area. A significant and positive relationship was found between change in farm land as a coping strategy and determinant of climate change in the study area. Therefore, the study recommends that farmers should be educated on the appropriate coping strategies to adopt during climate changes and effort should be geared towards increasing the technical manpower of farmers and also reduce the incidence of pest and diseases in the study area, which will amount to increase in level of production and in turn increase farmers income.

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Table 1 : Distribution of respondents by socio-economic characteristics of the respondents. N= 90

Age	Frequency	Percentage
20 – 29	2	2.20
30 – 39	14	15.50
40 – 49	18	19.90
50 – 59	19	21.00
60 – 69	25	27.70
70 and above	12	13.30
Sex		
Male	65	72.20
Female	25	27.80
Marital status		
Single	2	2.20
Divorced	3	3.30
Widow	10	11.10
Married	75	83.30
Level of education		
No formal education	18	20.00
Primary school incomplete	22	24.40
Primary school complete	7	7.80
Secondary school incomplete	11	12.20
Secondary school complete	5	5.60
Tertiary institution	27	30.00
Primary occupation		
Others	32	35.60
Farming	58	64.40
Household size		
0	3	3.30
1 – 5	33	36.60
6 – 10	46	51.10
11 – 15	8	8.90
Scope of production		
Subsistence farming	27	30.00
Commercial farming	16	17.80
Both	47	52.20

Source : Field Survey, 2011

Table 2 : Distribution of constraints encountered by respondents

Constraint	Serious constraints	Mild constraint	No constraints	Mean score	Weighted mean score	Rank
Lack of credit facilities	25(27.8)	30(33.3)	35(39.8)	80	0.89	5
Land tenure system	4(4.4)	27(30.0)	59(65.5)	35	0.39	8
Labour availability	11(12.2)	44(48.9)	35(38.9)	66	0.73	6
Lack of subsides	28(31.1)	25(27.8)	37(41.1)	81	0.90	4
Govt. Policy	8(8.9)	36(40.0)	46(51.1)	52	0.58	7
Problem of pest and disease	39(43.3)	35(38.9)	16(17.7)	113	1.26	2
Poor transportation	34(37.8)	22(24.4)	34(37.7)	90	1.00	3
Lack of storage system	53(58.9)	21(23.3)	16(17.7)	127	1.41	1
Others	5(5.6)	1(1.1)	84(93.3)	11	0.12	9

Source : Field Survey, 2011

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Table 3 : Distributions of respondents by coping strategies.

Coping strategies	Frequency*	Percentage
Improving farming practices	47	52.2
Changing planting date	75	83.3
Post harvest technology	20	22.2
Marketing policy	25	27.8
Fertilizer adoption	71	78.9
Changing farm land	62	68.9
Adoption of new varieties	62	68.9

**Multiple responses*

Source : Field Survey, 2011

Table 4 : Distribution of respondents by the determinants of climate change

Determinants	Serious effect	Mild effect	No effect	MS	WMS	Rank
Stunted growth	20 (22.2)	54 (60.0)	16 (17.8)	94	1.04	6
Poor seed density	13 (14.4)	47 (52.2)	30 (33.3)	73	0.18	7
Late maturity	14 (15.6)	46 (51.1)	30 (33.3)	74	0.82	5
Poor germination of tuber	42 (46.7)	34 (37.8)	14 (15.6)	118	1.31	3
Thin stem and Tall plant	22 (24.4)	61(67.81)	7 (7.8)	105	1.67	1
Early growth Slow down	27 (30.0)	50 (55.6)	13 (14.4)	104	1.56	2
Leaf turning Colour	34 (37.8)	48 (53.3)	8 (8.9)	116	1.29	4

Source : Field Survey, 2011

Table 5 : Summary of correlation analysis between coping strategies adopted and effect of climate change.

Variable	R value	Remark
Improving farming practices	.019	Not significant
Changing planting date	-.046	Not significant
Post harvest technology	.126	Not significant
Marketing policy	-.130	Not significant
Fertilizer adoption	-.080	Not significant
Changing farm land	.295**	Significant

*** Correlation significant at the 0.01 level*
Calculated from data 2011

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Yield Components and Gas Exchange Responses of Nerica Rice Varieties *(Oryza Sativa L.)* to Vegetative and Reproductive Stage Water Deficit

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Abstract – Kenya has got a rapidly increasing population which was estimated to be 36 million in the year 2009 with a growth rate of 2.7 per annum hence the need for diversified food production. Water deficit is one of the most environmental stresses affecting agriculture productivity. Drought may affect crop yield and gas exchange at any developmental stage while early reproductive stage is found to be one of the most susceptible phases of a crop to drought stress. NERICA (New Rice for Africa) are high yielding rainfed rice varieties with early maturity and has shown high potential to revolutionize rice farming even in Africa's stress afflicted ecologies. However, NERICA varieties vary in their response to water deficit. A pot experiment was conducted in 2009 at the Maseno University Botanic garden, to evaluate the responses of five NERICA varieties (NERICA1, NERICA 2, NERICA 3, NERICA 4 and NERICA 5) to water deficit during their vegetative or reproductive stage of their development. The response pattern of crop yield and gas exchange parameters to water deficit imposed at different growth stages might provide basis for selecting the most tolerant variety to water deficit in order to stabilize yield and solve food crisis.

Keywords : NERICA rice, relative water content, transpiration, stomatal conductance, Photosynthesis, flowering and yield.

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Yield Components and Gas Exchange Responses of Nerica Rice Varieties (*Oryza Sativa* L.) to Vegetative and Reproductive Stage Water Deficit

Sikuku P.A.[α], Onyango J.C.[σ] & Netondo G.W.[ρ]

Abstract - Kenya has got a rapidly increasing population which was estimated to be 36 million in the year 2009 with a growth rate of 2.7 per annum hence the need for diversified food production. Water deficit is one of the most environmental stresses affecting agriculture productivity. Drought may affect crop yield and gas exchange at any developmental stage while early reproductive stage is found to be one of the most susceptible phases of a crop to drought stress. NERICA (New Rice for Africa) are high yielding rainfed rice varieties with early maturity and has shown high potential to revolutionize rice farming even in Africa's stress afflicted ecologies. However, NERICA varieties vary in their response to water deficit. A pot experiment was conducted in 2009 at the Maseno University Botanic garden, to evaluate the responses of five NERICA varieties (NERICA1, NERICA 2, NERICA 3, NERICA 4 and NERICA 5) to water deficit during their vegetative or reproductive stage of their development. The response pattern of crop yield and gas exchange parameters to water deficit imposed at different growth stages might provide basis for selecting the most tolerant variety to water deficit in order to stabilize yield and solve food crisis. The treatments were; T_1-irrigating the pots with a litre of water after every two days (Control), T_2 -water deficit at vegetative stage in which water was withheld by irrigating the plants using one litre of water after every six days from 30-50 days after planting; T_3-water deficit at reproductive stage in which water was withheld by irrigating the plants using one litre of water after every six days from 51-71 days after planting. Water deficit caused a significant reduction in gas exchange parameters and yield more at the reproductive stage as compared to water deficit at vegetative stage. The results indicate that NERICA 2 and 4 were tolerant as compared to NERICA 1, 3 and 5 to water deficit occurring at vegetative stage or reproductive stage because their leaf relative water content, transpiration, stomatal conductance, photosynthesis and yield components were least affected.

Keywords : NERICA rice, relative water content, transpiration, stomatal conductance, Photosynthesis, flowering and yield.

I. Introduction

Agriculture is the mainstay of Kenya's economy and 80% of the rural population depends on agriculture (Irungu, 2009). Kenya has got a rapidly increasing population which was estimated to be 36 million in the year 2009 with a growth rate of 2.7 per annum hence the need for diversified food production (MOA, 2008). Water deficit is one of the most environmental stresses affecting agriculture productivity. Drought may affect crop yield and gas exchange at any developmental stage while early reproductive stage is found to be one of the most susceptible phases of a crop to drought stress (Liu *et al.*, 2003). Rice's susceptibility to water deficit is more pronounced at the reproductive stage and causes the greatest reduction in grain yield when stress coincides with the irreversible reproductive processes. According to Lanceras *et al.* (2004) stable and high yields of rainfed rice under drought conditions can be obtained by having appropriate phenology to avoid late season drought and Fukai *et al.* (1999) observed that ontogenic characters especially appropriate flowering time play an important role in drought avoidance of rainfed rice. Jongdee *et al.* (2002) pointed out that phenology is the most important factor. Timing, intensity and occurrence of water deficit have been associated with the delay of heading or flowering (Fukai *et al.*, 1999).

Water deficit during the vegetative stage may have relatively little effect on grain yield, perhaps owing to the compensatory growth or changed partitioning of dry matter after the stress is relieved. Kaurk *et al.* (2007) reported that water deficit during the reproductive stage in corn increases the interval from silking to pollen shed and reduce kernel number or weight while water deficit at seed set may result in a low number of seeds and after seed set may result in a high percentage of small seeds. In other cases severe water deficit can cause emergence of ready differentiated floral buds (Tenhunen *et al.*, 1985) and drought during developmental stage prior to kernel filling causes formation of wizened undeveloped seeds. Occurrence of early stage moisture stress leads to poor crop establishment and increased seed mortality in rice.

There are genotypic variations in the maintenance of leaf water potential and expression of osmotic adjustment among rice varieties with diverse backgrounds and environments of origin. The species adapted better to dry environments have higher relative

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water content at given water potential. The maintenance of leaf water potential is indicative of drought tolerance that minimises the impact of stress on grain yield mainly by reducing the effect of stress on spikelet sterility (Jongdee *et al*., 2002). Leaf water status is intimately related to several leaf physiological variables such as leaf turgor, growth, stomatal conductance, transpiration and photosynthesis (Penuelas *et al*., 1993).

The maintenance of leaf water potential is indicative of drought tolerance that minimises the impact of stress on grain yield mainly by reducing the effect of stress on spikelet sterility (Jongdee *et al*., 2002). Leaves normally present a large surface area to the surrounding air to facilitate CO_2 assimilation. Simultaneously evaporation of water from the moist cell walls is inevitable and thus transpiration must be replaced by water absorption from the soil. The availability of soil water to the roots of a plant and the efficiency of its absorption has a profound influence on the rate of transpiration. Absorption of water by the plant may lag behind the release of water via transpiration without noticeably affecting the plant for a short period, if the condition is prolonged, water deficit develops and the plant will wilt. Some plants avoid water deficit by water conservation and have a adaptations that limit the rate of water loss thus prevent the development of detrimental plant water deficits by conserving soil water for an extended period thus maintaining soil and plant water potential suitably high over a sufficient period for seed ripening (Jones, 1996). Plants can rapidly regulate their water loss through stomatal closure in order to maintain their water status despite decrease in water availability limiting transpiration to diffusion through the cuticle. Closure of the stomata improves water use efficiency under water deficit conditions. However, any structural feature which restricts water loss such as reduced leaf surface area inevitably decreases carbon assimilation due to reduction in physical transfer of CO_2 molecules. It also leads to increased leaf temperature, which reduces the rate of biochemical processes. Under water deficit conditions the leaf gas exchange of plants is reduced and this leads to a lower biomass accumulation and grain yield. It has been reported that over a wide range of crops, maize (Ray and Sinclair, 1997), soybean (Vadez and Sinclair, 2001) and rice (Serraj *et al*., 2008) show genotypic differences in how leaf gas exchange responds to water deficit, with certain genotypes being capable of sustaining plant transpiration until soil becomes dry whereas others react with a decline in transpiration when the soil is relatively wet. Higher stomatal conductance increases CO_2 diffusion into the leaf and favours higher photosynthetic rates which consequently favour higher yields. The effect of water deficit on photosynthesis depends on the plants adaptations to water deficit and the intensity and duration to which the plant is exposed to water deficit. According to Kaiser (1987), the intensity of this effect influences the capacity of different species to cope with the drought which also depends on the plant genetic background. Water deficit in plant tissue develops under drought conditions and the ability to maintain photosynthetic machinery functional under water deficit is a major importance for drought tolerance (Zlatev and Yordanov, 2004). According to Richards (2000), high photosynthetic rate (Pn) is considered to be one of the most important breeding strategies for crop improvement. At the whole plant level, limited soil water supply may have a strong effect on development, activity and duration of various sources and sink organs. The aim of this work was to study the response pattern of crop yield and gas exchange parameters of five NERICA (NERICA1, NERICA 2, NERICA 3, NERICA 4 and NERICA 5) varieties to water deficit occurring at vegetative stage or reproductive stage of their development which might provide basis for selecting the most tolerant variety to water deficit in order to increase rice yields and help in poverty alleviation.

II. Materials and Methods

The study was carried out at Maseno University Botanic Garden in the green house between January 2009 and August 2009. The green house was naturally illuminated and the light, CO_2 concentration and temperature conditions were not controlled. Conditions during the study were: day temperature ranged from 22 - 34^{0}C, relative humidity from 50 – 90% and photon flux density (PPFD) from 400 – 600 μmol photons $m^{-2}s^{-1}$. Seeds of five New Rice for Africa (NERICA) rainfed rice varieties namely NERICA 1, 2, 3, 4 and 5 coded as N-1, N-2, N-3, N-4 and N-5 were obtained from the NERICA adaptability trials in Maseno University Botanic garden. The soil was dug from the garden, solarized for one week then filled into 20 litre plastic pots up to ¾ full. The soils at Maseno are classified as acrisol being well drained, deep clay with pH ranging between 4.6 and 5.4 (Sikuku *et al*., 2010).The seeds were soaked in water at 30^{0}C for 72 hours prior to planting to facilitate germination. The pots were laid out in a Randomized Complete Block Design (RCBD). The seeds were sown at the rate of four seeds per hill and there were 4 hills per pot with a spacing of 15 x 25 cm and planting depth of 3cm. The treatment combinations consisted of three levels of water regimes, viz. T_1 - well watered throughout the life cycle in which the plants were watered with one litre of water after every two days throughout the growing period, T_2 - water deficit at vegetative stage in which water was withheld by irrigating the plants using one litre of water after every six days from 30-50 days after planting, T_3 - water deficit at reproductive stage in which water was withheld by irrigating the plants using one litre of water after every six days from 51-71 days after planting. One litre of water was used to irrigate all the pots after every two days for 28 days to maintain optimum moisture before initiating experimental treatments. Plants were irrigated after every six days from 30 to 50 days after planting to impose water deficit

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at vegetative stage and from 51 to 71 days after planting to impose water deficit at reproductive stage. After water deficit period, plants were irrigated after every two days. Three replications were performed for each treatment and each variety. The experiment was repeated twice.

a) Parameters measured

i. Relative leaf water content

Relative leaf water content was determined on the flag leaf of twelve plants per treatment for all replications at 28, 42, 56, 70 and 84 days after sowing. The leaves to be harvested were rinsed with distilled water to eliminate surface accumulation of salts two hours before harvesting. The sampled leaves were cut at the base of the lamina and one gram of each weighed immediately to get the fresh weight (W_f). The leaf disks were then placed in a test tube containing distilled water for 24 hours at room temperature to get the turgid weight (W_t). The disks were dried in an oven at 80°C until a constant weight was obtained to get the oven dry weight (W_d). The relative water content was calculated using the formula of Coombs *et al.* (1985) as follows: Relative water content $(R) = (W_f - W_d)/ (W_t - W_d) \times 100$ Gas Exchange.

Leaf transpiration, stomatal conductance and net photosynthesis were determined on day 28, 42, 56, 70 and 84 after sowing by use of a portable infrared gas analyser system connected to a plant leaf (CIRAS-1, PP Systems Ltd.,Herts, U.K.) on 0.7 cm^2 of leaf surface. The measurements were carried out between 0930 and 1300 hours on fully sun exposed top leaf of twelve plants per treatment for all replications. The photosynthetically active radiation ranged from 400 – 600 μmol photons $m^{-2}s^{-1}$, leaf temperature varied from 22°C to 30°C, relative humidity varied from 35% to 40% and vapour pressure deficit was between 1.6 -1.9 kPa.

ii. *Panicle lengths*

This was determined using a metre rule. Measurements were done from the panicle base to the tip of twelve plants per treatment and per replication.

iii. *Days to flowering*

This was determined every day after the plants had started heading. This was done by counting the flowering plants per pot and expressing them as a percentage of the total plants in the pot. The data was obtained by scoring for the percentage of flowering plants in each pot when the first inflorescences were observed and when half of all the plants in each pot had flowered.

iv. *Days to maturity*

This was done by counting the days taken by plants from planting to harvesting date. The rice were harvested when the panicles had turned down and were yellowish in colour according to Chatterjee and Maiti (1988).

v. *Yield at 14% moisture content*

This was determined by measuring the moisture content of the grains immediately after harvesting using a grain moisture tester (model number AF 34086, Japan) and then converting the yield of the grains to 14% moisture content.

vi. *Filled grain Ratio percentage*

Grains harvested from all the hills in the pots were put in different buckets of water and the poorly filled together with empty grains floated while the well filled grains settled at the bottom. Filled grains were then separated from empty and poorly filled grains. The grains were dried and later weighed but each was handled separately. The percentage of empty grains was obtained as follows;

Grain loss = (Weight of well filled grain –weight of empty grain) / Weight of well filled grains.

vii. *Grain yield*

The grain yield was determined at harvesting from an area of 0.038m^2 in the pots. The number of grains per 5g, and filled grains per panicle were determined. The yield was extrapolated in kilograms per hectare.

viii. *Statistical analysis of data*

Analysis of variance (ANOVA) was carried out on the data for the variables measured during the study period to test for differences between the treatments and the varieties using a statistical computer package (SAS). The treatment and variety means was separated using the least significant differences (LSD) test at 5% level.

III. Results

a) Leaf Relative water content

There was a highly significant difference ($P \leq 0.05$) among the varieties, treatments and DAS. Water deficit caused a significant reduction in leaf water content and the highest reduction among the varieties was at water deficit treatment during reproductive stage as compared to vegetative stage. NERICA 2 and 4 recorded higher leaf water content as compared to NERICA 1, 3 and 5 at water deficit treatments during vegetative (Fig.1a) and reproductive stage (Fig.1b).

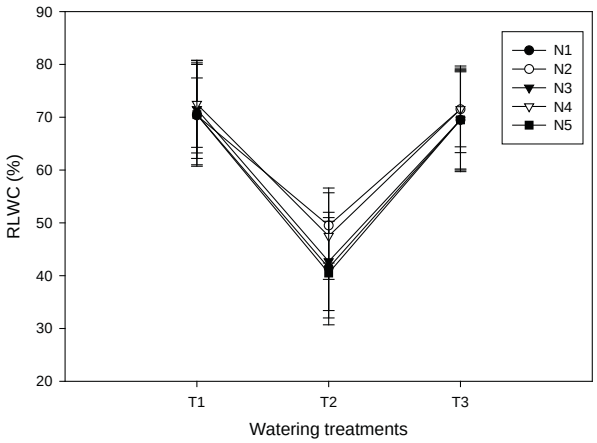

Fig.1a : Relative leaf water content (%) at DAS 42 (Vegetative stage) of five NERICA rice varieties grown at

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three levels of watering treatments (Means of three replicates ±SE). LSD (0.05) =0.4385 (T1- Well watered control, T2- water deficit at vegetative, T3- water deficit at reproductive).

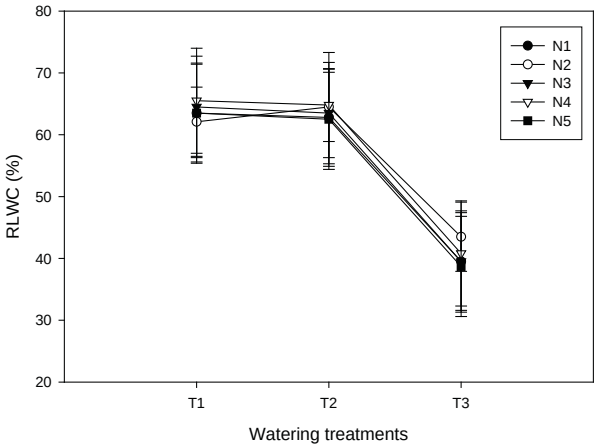

Fig.1b : Relative leaf water content (%) at DAS 70 (Reproductive stage) of five NERICA rice varieties grown at three levels of watering treatments (Means of three replicates ± SE). LSD (0.05) =0.4385 (T1- Well watered control, T2- water deficit at vegetative, T3- water deficit at reproductive).

b) Transpiration

There was a significant interaction between the varieties and the treatments ($P \leq 0.05$) in transpiration rate. Transpiration rate was significantly affected due to imposition of water deficit with the varieties recording slightly higher transpiration rates during water deficit at vegetative stage compared to water deficit at reproductive stage as shown in Figure 2a and b. The varietal effect was also significant ($P \leq 0.05$) with NERICA 1, 3 and 5 having higher transpiration rates compared to NERICA 2 and 4 at water deficit treatments.

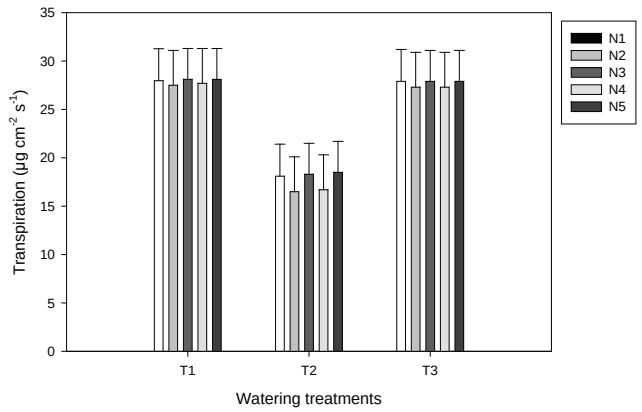

Fig. 2a : Transpiration rate at DAS 42 (Vegetative stage) of five NERICA rice varieties grown at three levels of watering treatments (Means of three replicates ± SE). LSD (0.05) = 0.2675 (T1- Well watered control, T2- water deficit at vegetative, T3- water deficit at reproductive).

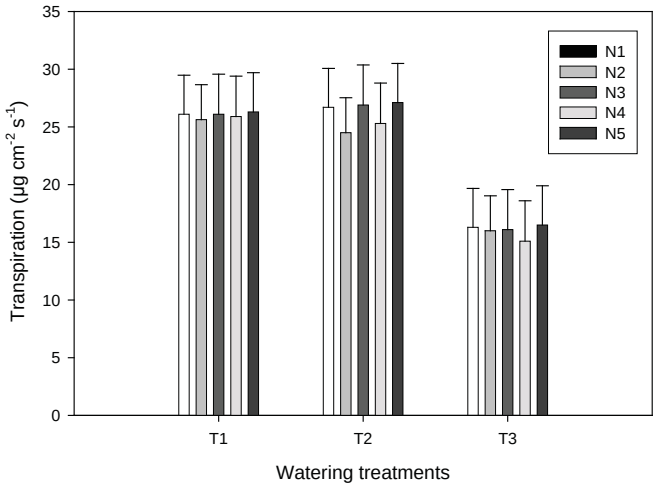

Fig. 2b : Transpiration rate at DAS 70 (Reproductive stage) of five NERICA rice varieties grown at three levels of watering treatments (Means of three replicates ± SE). LSD (0.05) = 0.2675 (T1- Well watered control, T2- water deficit at vegetative, T3- water deficit at reproductive).

c) Stomatal conductance

A reduction in stomatal conductance (gs) was observed in all NERICA varieties due to water deficit. There was a significant effect ($P \leq 0.05$) among the varieties. Water deficit treatment imposed during reproductive stage caused more reduction in stomatal conductance among the varieties compared to water deficit treatment at the vegetative stage as shown by Figure 3a and 3b. The varietal effect was also significant with N-2 demonstrating the most tolerance to water deficit at reproductive stage due to lower reduction (23%) from the control in stomatal conductance compared to N-4 (29%), N-5 (32%), N-3 (37%) and N-1(38%).

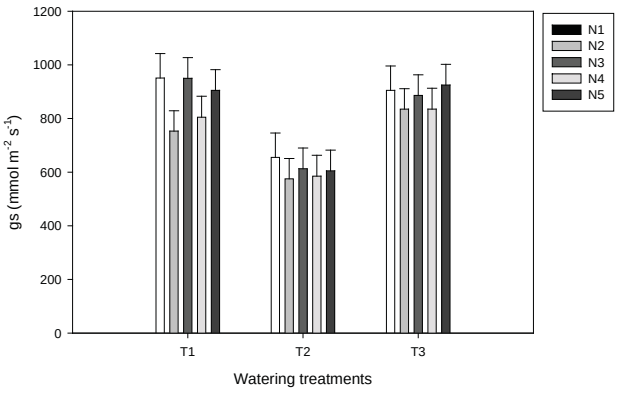

Fig. 3a : Stomatal conductance at DAS 42 (Vegetative stage) of five NERICA rice varieties grown at three levels of watering treatments (Means of three replicates ± SE). LSD (0.05) = 12.44 (T1- Well watered control, T2- water deficit at vegetative, T3- water deficit at reproductive).

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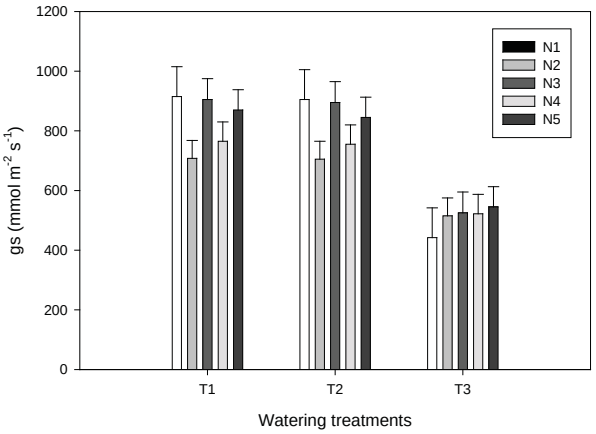

Fig. 3b : Stomatal conductance at DAS 70 (Reproductive stage) of five NERICA rice varieties grown at three levels of watering treatments (Means of three replicates ± SE). LSD (0.05) = 12.44 (T1- Well watered control, T2- water deficit at vegetative, T3- water deficit at reproductive).

d) Net photosynthesis

Results indicate that water deficit had a significant inhibitory effect on net photosynthesis of all the NERICA varieties. The highest reduction in photosynthesis was found at the reproductive stage as compared to vegetative stage in all varieties as shown by Figure 4a and 4b. There was a significant interaction ($P \leq 0.05$) between the varieties and the treatments and a highly significant interaction ($P \leq 0.05$) between treatments and DAS. N-4 had the highest photosynthetic rate at water deficit during vegetative stage while N-2 had highest at reproductive stage.

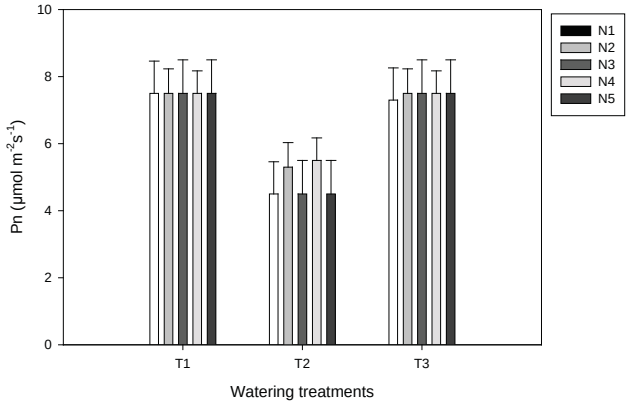

Fig. 4a : Net Photosynthesis (Pn) at DAS 42 (Vegetative stage) of five NERICA rice varieties grown at three levels of watering treatments (Means of three replicates ± SE). LSD (0.05) = 0.2215 (T1- Well watered control, T2- water deficit at vegetative, T3- water deficit at reproductive).

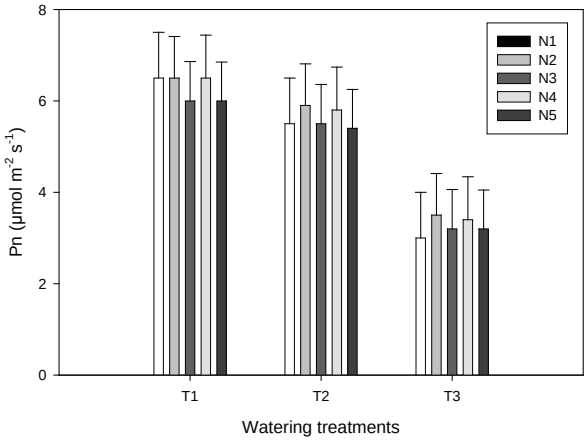

Fig. 4b : Net Photosynthesis (Pn) at DAS 70 (Reproductive stage) of five NERICA rice varieties grown at three levels of watering treatments (Means of three replicates ± SE). LSD (0.05) = 0.2215 (T1- Well watered control, T2- water deficit at vegetative, T3- water deficit at reproductive).

e) Days to 50% flowering

There was a significant effect ($P \leq 0.05$) in days to flowering among the treatments. There was also a significant varietal difference ($P \leq 0.05$) in days to 50% flowering. Water deficit caused a delay in flowering in all the varieties with the well watered plants flowering significantly early compared to plants exposed to water deficit. Plants that were exposed to water deficit at the reproductive stage flowered slightly earlier than plants stressed at vegetative stage. NERICA 2 and 4 took the least number of days to attain 50% flowering both at water deficit treatment and well watered treatments while NERICA 1, 3 and 5 flowered almost at the same time (Fig. 6a).

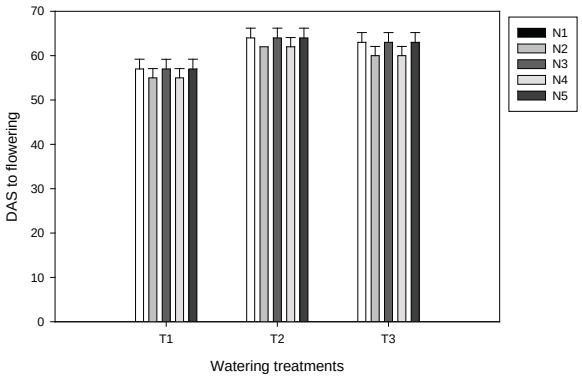

Fig. 5a : Effects of three levels of watering treatments on Days to flowering of five NERICA rice varieties. (Means of three replicates ± SE) LSD (0.05) = 1.2886 (T1- Well watered control, T2- water deficit at vegetative, T3- water deficit at reproductive).

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f) Days to harvesting

There was a significant difference ($P \leq 0.05$) among the treatments with the non water stressed plants maturing significantly early as compared to the plants exposed to water deficit. The plants exposed to water deficit at vegetative stage took slightly longer to mature compared to well watered plants. Plants exposed to water deficit at reproductive stage took the longest time to mature in all the varieties. The varietal difference was also significant ($P \leq 0.05$) with NERICA 2 and 4 maturing slightly early followed by N-3 while NERICA 1 and 5 took the longest time to mature as shown by Fig. 6b.

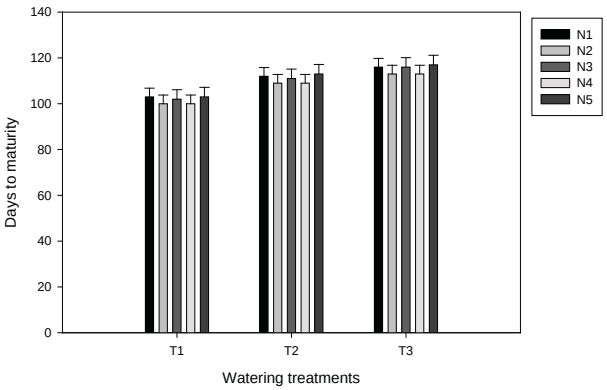

Fig.5b : Effects of three levels of watering treatments on Days to harvesting of five NERICA rice varieties. (Means of three replicates ± SE) LSD (0.05) = 1.272 (T1- Well watered control, T2- water deficit at vegetative, T3- water deficit at reproductive).

g) Panicle length

There was a significant effect ($P \leq 0.05$) in panicle length among the varieties and among the treatments. Water deficit at reproductive and vegetative stage caused a reduction in panicle length with the plants exposed to water deficit during reproductive stage being the most affected hence had the shortest panicle lengths (Fig. 5). The well watered plants had significantly higher panicle lengths compared to plants exposed to water deficit. N-2 had the highest panicle length both at the control and at water deficit treatments while N-3 had the lowest length at water deficit treatment during reproductive stage.

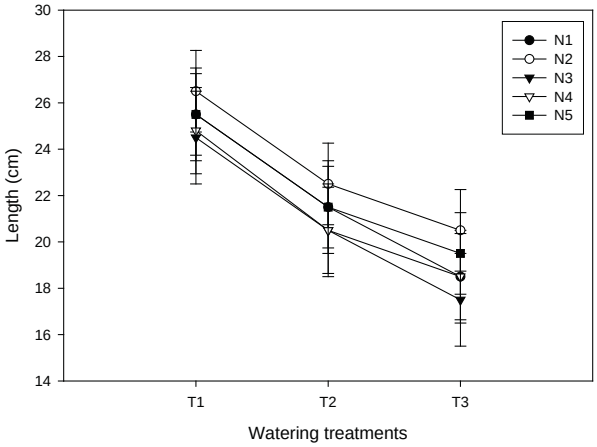

Fig. 6 : Panicle length of five NERICA rice varieties grown at three levels of watering treatments (Means of three replicates ± SE). LSD (0.05) = 0.5665 (T1- Well watered control, T2- water deficit at vegetative, T3- water deficit at reproductive).

h) Yield at 14% moisture content

The yield at 14% moisture content was significantly reduced by water deficit both at vegetative and reproductive stages of plants growth. There was a highly significant ($P \leq 0.05$) varietal effect in yield with N-2 having significantly higher yield at water deficit treatments followed by N-4 (Figure 7a). NERICA 3 and 5 were the most affected and recorded the highest percentage reduction in yield relative to the control at water deficit during vegetative and at reproductive stage. The treatments had a highly significant difference ($P \leq 0.05$) with the well watered plants producing higher yields followed by plants exposed to water deficit treatment at vegetative stage. However, the plants exposed to water deficit at reproductive stage were the most affected.

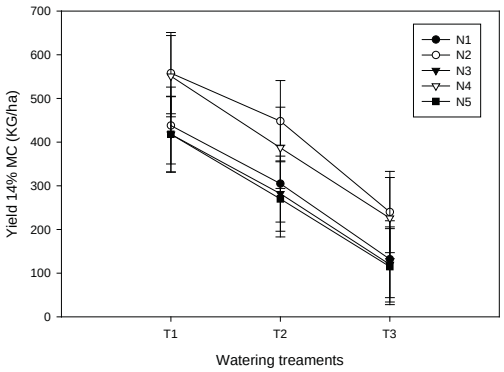

Fig. 7a : Yield at 14% moisture content of five NERICA rice varieties grown at three levels of watering treatments (Means of three replicates ± SE). LSD (0.05) = 14.088 (T1- Well watered control, T2- water deficit at vegetative, T3- water deficit at reproductive).

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i) Filled grain ratio (%)

There was a highly significant difference ($P \leq 0.05$) between the NERICAS and the treatments. Water deficit significantly reduced the filled grain ratio percentage with plants exposed to water deficit at the vegetative stage having a slight reduction from the control while those exposed to water deficit at reproductive stage had a significant reduction. The varietal difference was also highly significant ($P \leq 0.05$) with the varieties having almost the same filled grain ratio percentage at the well watered treatment, slight difference in treatment 2 and a marked difference in plants exposed to water deficit at reproductive stage with NERICA 2 and 4 registering the highest filled grain ratios while NERICA 3 and 5 had the lowest percentage ratios (Fig.7b).

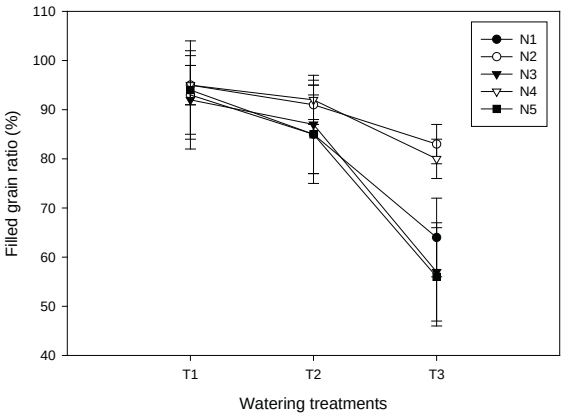

Fig. 7b : Filled grain ratio percentage of five NERICA rice varieties grown at three levels of watering treatments (Means of three replicates ± SE). LSD (0.05) = 1.4724 (T1- Well watered control, T2- water deficit at vegetative, T3- water deficit at reproductive).

j) Yield components

Significant reduction in yield was observed in all NERICA varieties due to water deficit. There was a highly significant difference ($P \leq 0.05$) among the treatments with the well watered having higher yield compared to plants exposed to water deficit treatments. The reproductive stage imposed water deficit had a significant effect on yield. Varieties also differed significantly ($P \leq 0.05$) with NERICA 2 and 4 recording higher yields both at well watered and at water deficit treatments and N-5 registering the lowest yield under water deficit treatment at reproductive stage (Fig. 7c). NERICA 2 had the least yield reduction relative to the control under water deficit both at vegetative and reproductive while N-3 and 5 had the highest percentage reduction when water deficit was imposed at the reproductive stage.

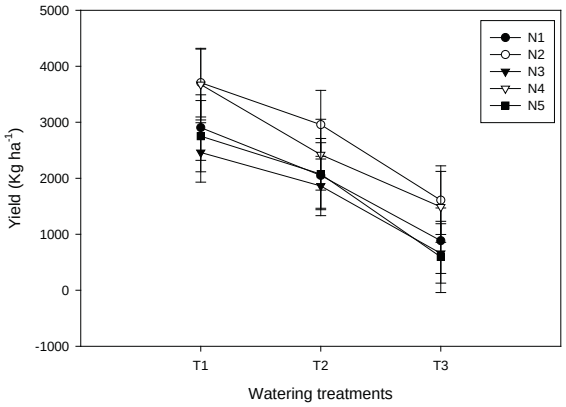

Fig. 7c : Yield of five NERICA rice varieties grown at three levels of watering treatments (Means of three replicates ± SE). LSD (0.05) = 140.87 (T1- Well watered control, T2- water deficit at vegetative, T3- water deficit at reproductive).

IV. Discussion

Relative water content decreased significantly at water deficit treatments (Fig. 1a and b). Similar observations were made by Cruz *et al.* (1986) in rice and Siddique *et al.* (2000) in wheat. Decrease in leaf water content may be attributed to water loss through evapotranspiration and decreased water absorption by the roots when the soil water was limiting. Relative water content is a key indicator of the degree of cell and tissue hydration which is crucial for optimum physiological functioning and growth processes. In the present study, low relative water content due to water deficit inhibited growth and plant function which were reflected in lower transpiration, decreased photosynthesis and lower yield. When the soil dries, water uptake by the roots becomes more difficult and uptake declines. The reduction in water uptake eventually resulted in the development of water deficit in the shoot hence the decrease in relative water content. According to Sah and Zamora (2005), relative water content is an integrated measure of plant water status. Higher relative water content is necessary for proper growth and function of plant. During drought stress the water balance of a plant is disrupted and as a result of which the relative water content decreases (Sikuku *et al.*, 2010). The varietal difference was significant but only at water deficit treatments. N-2 was able to maintain the highest water content at reproductive stage and it had the lowest percentage reduction from the control (25%) while N-5 had the highest reduction (39%). The higher relative water content recorded by NERICA 2 and 4 at water deficit treatments may be attributed to their ability to absorb more water from the soil and the ability to control water loss through stomata. According to Sinclair and Ludlow (1985), under water deficit conditions, the varieties that are tolerant to drought have more relative water content and relative water content can be used to select high yielding genotypes that maintain cell turgor under water

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deficit environments and give relative high yield. Transpiration rate decreased significantly in the plants under water deficit at reproductive and vegetative stage as compared to control. Similar results have been reported in wheat (El Hafid *et al.,* 1998) and soy bean (Sionit and Kramer, 1983). The severity of moisture deficit was most felt by plants at the reproductive stage as compared to vegetative stage hence plants had lower transpiration rates at water deficit treatment at reproductive as compared to vegetative stage. The lower rate of transpiration was possibly a result of moderate stomatal conductance. The varietal difference was significant but only at water deficit treatments. During vegetative stage, the plants recorded almost similar transpiration rates at well watered treatments but at water deficit treatment NERICA 2 and 4 had slightly lower transpiration rate as compared to NERICA 1, 3 and 5 (Fig 2a). At water deficit during reproductive stage, NERICA 2 and 4 had slightly lower transpiration rate compared to NERICA 1, 3 and 5 (Fig. 2b). This may suggest that NERICA 2 and 4 are fairly tolerant being able to minimize water loss in response to water deficit (Casadebaig *et al*., 2008). Previous studies by El Jaafari (2000) have shown that the ability of the plant to survive water deficits depends on its ability to restrict water loss through the leaf epidermis after the stomata have attained minimum aperture. While this physiological response to increasing water deficit can help prevent development of lethal water deficit it can also lead to lethal temperatures under warm sunny conditions as observed by Silva *et al*. (2007), hence tolerant genotypes like NERICA 2 and 4 maintain a more favourable leaf water status therefore more open stomata and sustained transpirational cooling. As a consequence CO_2 influx towards chloroplasts may be sustained longer thus allowing greater photosynthetic rates and ultimately crop yield (Silva *et al*., 2007). Stomatal conductance generally decreased with the imposition of water deficit (Fig. 3a and b). This tendency of reduction of stomatal conductance underwater deficit is consistent with observations made by Collinson *et al*. (1997) in bambara groundnuts. The reduction in the leaf water potential though not measured in this experiment may have led to the development of water deficit in the leaves causing guard cells to loose turgor hence reduced stomatal pores which apparently led to reduced CO_2 diffusion through the stomata (Flexas *et al*., 2004). In addition, the increased stomatal resistance may have led to reduced water transport in the leaves further causing a decrease in stomatal conductance (Silva *et al*., 2007). Reduction in stomatal conductance decreases transpiration and also limits photosynthesis (Sikuku *et al,* 2010). The varietal effect was significant and at water deficit during reproductive, N-2 (27%) recorded the lowest reduction from the control followed by N-4 (32%) while N-1 with 52% had the highest reduction. This shows that NERICA 2 and 4 were water deficit tolerant hence the lower deviation from the control at water deficit treatment during reproductive stage. It was also observed that stomatal conductance decreased with age of the leaves (Siddique *et al*., 2000). The results are in general agreement with those of Upretty and Bhatia (1989), who reported that stomatal resistance in the leaves of mungbean increased with water deficit. Plants exposed to water deficit during the vegetative and reproductive stage recovered their stomatal conductance after rewatering. Recovery of stomatal conductance may have resulted in increased CO_2 diffusion into the leaves to attain higher photosynthetic rates which favoured higher biomass (Siddique *et al*., 2000). Photosynthetic rate was inhibited by water deficit both at vegetative and reproductive stage. A reduction in photosynthesis was found at reproductive stage as compared to vegetative stage in all the varieties. The results are in agreement with observations of Siddique *et al*. (2000), and Bogale *et al*. (2011) on wheat. Decreased photosynthetic rate could have resulted from stomatal and non stomatal (biochemical) limitations. The apparent decrease in the photosynthetic rates in the varieties can be explained by the clear decline in the stomatal conductance and can also be related to the metabolic limitations (Lawlor, 2002) whereby Tezara *et al*. (1999) proposed that the decline in ATP synthesis was the main reason for the low photosynthesis rates under water deficit conditions. However, Cornic and Fresneau (2002) strongly supported the stomatal closing to be the main reason in reducing the photosynthesis rates as a result of water deficit. This is because the maximum value of photosynthesis can be recovered by supplying sufficient amount of CO_2 to the leaves. Thus the causes of low photosynthesis under water deficit depend not only on the stress and plant variety but also on the complex interaction between the age of the plant and the leaves, the light intensity (Flexas *et al.,* 2004). Significant varietal difference in net photosynthesis was observed both at vegetative and reproductive stage. At the vegetative stage NERICA 2 and 4 showed higher photosynthetic rate compared to NERICA 1, 3 and 5 (Fig. 4a). This shows that NERICA 2 and 4 are fairly more tolerant to moisture deficit than NERICA 1, 3 and 5 and can photosynthesize under certain levels of soil moisture deficit. Plants subjected to water deficit at the vegetative stage apparently recovered quickly to show a greater rate of photosynthesis at reproductive stage hence plants stressed at vegetative but not stressed subsequently gave similar photosynthesis rates at reproductive to the well watered control plants. This shows that the photosynthetic apparatus was not affected by water deficit. Water deficit had a significant effect on days to flowering and maturity of the five NERICA rice varieties (Fig.5a and b). Days to maturity among rice varieties ranged from 100 to 117. Plants exposed to water deficit took longer to reach flowering

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and maturity. Similar results have been reported in rice (Fukai *et al*., 1999). The results may have been due to the fact that when plants are exposed to water deficit, their carbohydrates metabolism is affected, in turn the disorder slows down growth rate and delays development stages in stressed plants thus affecting maturity period (Atera *et al*., 2011). Plants that were exposed to water deficit at the vegetative stage took slightly longer to reach flowering as compared to plants stressed during reproductive stage. However, plants exposed to water deficit at reproductive stage took the most number of days to reach maturity. This may imply that the plants exposed to water deficit at vegetative stage had slow growth hence the delay in heading and flowering but recovered after rewatering to attain maturity earlier compared to plants exposed to water deficit during reproductive season. NERICA 2 and 4 took slightly fewer days to attain maturity compared to NERICA 1, 3 and 5. This shows that NERICA 2 and 4 may be able to evade moisture deficit that may develop late in the season. The variation for days to maturity was attributed to genetic constituent. The delay in flowering observed in NERICA 1 and 3 under water deficit is deleterious and indicates poor adaptation to water deficit. Plants exposed to water deficit at reproductive stage had lower panicle lengths as compared to plants stressed at vegetative stage (Fig.6). This may have been caused by the fact that under water deficit at the early reproductive stages, spikelet water potential as well as leaf water content decreased which inhibited cell growth or carbohydrate metabolism in the floral organ hence the reduction in panicle length (Boyer and Westgate, 2004). In addition, even a small decrease of photosynthates could be a cause for the insufficient development of young panicles because young panicles compete with vegetative organs for available photosynthates during meiosis stage. NERICA 2 and 5 had the highest panicle lengths while N-3 had the least. Water deficit at vegetative and reproductive stages of growth and development of NERICA rice significantly reduced 1000grain weight. The plants stressed during the vegetative stage had a reduced seed number per plant. This is because water deficit during this stage reduced plant growth therefore may have delayed and reduced appearance of nodes and so resulting in plants with fewer inflorescence and seed numbers per plant after rewatering (Vurayai *et al*., 2011). Yield at 14% moisture content was significantly reduced by water deficit. NERICA 2 and 4 had higher yields at 14% moisture content, higher filled grain ratio percentages (Fig.7b), higher 1000 grain weight and had the least yield reduction relative to the control as compared to NERICA 1, 3 and 5. Water deficit at vegetative and reproductive stage reduced yield by 26% and 67% respectively as compared to well watered plants. Similar results have been reported in maize (Sah and Zamora, 2005). The low yield might have been as a result of decreased filled grains per panicle caused by inhibition of sufficient translocation of assimilates to the grains as the plants competed for moisture. The lowest yield was recorded at water deficit during reproductive stage as compared to water deficit during vegetative stage (Fig.7c). This may be due to the fact that water deficit at reproductive stage accelerated the leaf senescence, inhibited photosynthesis, reduced the assimilate supply and thus decreased the rate and duration of grain filling (Sah and Zamora, 2005). Reproductive stage water deficit can cause asynchrony between pollen shedding and silk emergence and thus results failure of pollination. Lower water potential at early reproductive stage reduces the assimilate supply because of inhibition of photosynthesis which may cause low seed number (Westgate and Boyer, 1985). Among the NERICA varieties there was clear varietal diversity in the performance under water deficit and early maturing varieties performed better at water deficit treatments. Low growth rate of plants is one of the limiting factors of yield under water deficit conditions. Therefore varieties with greater growth rate under water deficit conditions provide the highest grain yield (Bogale *et al*., 2011). As observed by Gupta *et al.* (2001), favorable conditions during growth may permit an expansion of the last internodes as well as higher yield. Carbohydrates are also remobilized from the peduncle and flag leaf to the grain during grain filling period. NERICA 1, 3 and 5 were more sensitive to water deficit than NERICA 2 and 4 hence NERICA 2 and 4 had the highest yield and also the least reduction in yield relative to control at water deficit treatment during reproductive stage. Grain yield of rice may be limited by the supply of assimilates to the developing grain (source limitation) or by the capacity of the reproductive organ to accept assimilates (sink capacity).

V. Conclusion

In the present study, low relative water content due to water deficit inhibited growth and plant function which were reflected in lower transpiration, decreased photosynthesis and lower yield of the five NERICA rice varieties. The effect was more pronounced at water deficit during reproductive stage as compared to vegetative stage. The study shows appreciable differences among the NERICA rainfed rice varieties in respect to their response to vegetative or reproductive stage water deficit. It has shown that the production of yield by NERICA varieties under water deficit may be linked to maintenance of leaf water content and a relatively high photosynthetic rate during water deficit. It can also be linked to NERICAS' ability to recover in gas exchange parameters after rewatering. Water deficit at vegetative and reproductive stage has cumulative effect ultimately manifested by reduction in yield. The various amounts of NERICAS' yield (Kg ha^{-1}) obtained on different treatments showed that NERICA rice is capable of producing worthwhile yield even if it has been affected by water deficit at any stage of growth. The

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overall results indicate that there is genetic variability present in the NERICA varieties studied. NERICA 2 and 4 were tolerant to water deficit occurring at vegetative stage or reproductive stage as compared to NERICA 1, 3 and 5 because their gas exchange parameters and yield was less affected. The authors recommend that where possible adequate water should be available to NERICA varieties at all developmental stages in order to obtain an optimum yield.

VI. Acknowledgements

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Farmers' Groups Growth Trend in Delta State, Nigeria

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Abstract – This study investigated the growth trend of farmers' groups in Delta State, Nigeria. Primarily data were collected from 77 respondents randomly selected from 20 randomly selected farmers' groups, while secondary data were collected from 20 randomly selected farmer's groups records. The Data were measured with the use of frequency counts and percentages, contingent tables and inferential statistics was analyzed with the use of ANOVA. Most of the groups experienced dwindling membership strength and decreased payment of monthly subscription fees. The individual members rarely had access to credit and cheap inputs. There was significant difference in membership strength in the period (2002-2011) under study. Implication for sustainable agricultural production and extension service was emphasized. It was recommended that extension agents should organize leadership training, at regular intervals, for the group leaders; leaders of the various groups should endeavour to disseminate information on any meeting to members adequately and early enough and extension agents should fix their meetings with group members' participation.

Keywords : Farmers' groups, growth trend, extension services, cohesion, agricultural production, access to credit, input, self-help.

GJSFR-D Classification : FOR Code: 070106, 070108, 070107

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Farmers' Groups Growth Trend in Delta State, Nigeria

Ofuoku,A.U[α] & Chukwuji,C.O.[σ]

Abstract - This study investigated the growth trend of farmers' groups in Delta State, Nigeria. Primarily data were collected from 77 respondents randomly selected from 20 randomly selected farmers' groups, while secondary data were collected from 20 randomly selected farmer's groups records. The Data were measured with the use of frequency counts and percentages, contingent tables and inferential statistics was analyzed with the use of ANOVA. Most of the groups experienced dwindling membership strength and decreased payment of monthly subscription fees. The individual members rarely had access to credit and cheap inputs. There was significant difference in membership strength in the period (2002-2011) under study. Implication for sustainable agricultural production and extension service was emphasized. It was recommended that extension agents should organize leadership training, at regular intervals, for the group leaders; leaders of the various groups should endeavour to disseminate information on any meeting to members adequately and early enough and extension agents should fix their meetings with group members' participation.

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I. Introduction

Our society is made up of many groups and we function in groups. These groups include family, ethnic, religious, political clubs and national groups. Recent years have witnessed the formation of groups such as farmers groups like farmers' cooperatives, farmers association, farmers' unions, etc. These farmers' groups are regarded as self-help groups.

These farmers' groups may be regarded as socio-economic groups. They may be so regarded because they are developed to accomplish some common social and economic goals in relation to their farming activities. The achievement of their common social and economic goals translates into enhancement of their standard of living. Agriculture is a sure pathway towards reduction of poverty, improved income distribution, rapid industrialization and diversification of foreign exchange earning (Iwala *et al* (2006).

There are some functions that cannot be carried out alone individually, but can be carried out in groups. For instance, these groups form sources of credit facilities for the members. According to Ofuoku et al (2008), in such groups, members harness their financial resource for the benefit of members. These groups also constitute access to agricultural information. Ofuoku and Urang(2009) opined that as a result of the dearth of field extension agents, extension activities are now carried out in groups.

In their study, the most important reasons for subscribing to such farmers' groups is access to credit facilities and information. These factors are very much indispensable in the farming business of the group's members.

In spite of these ubiquitous farmers' groups, the level of production among farmers is still inadequate. For instance, Iwala et al. (2006) stated that there is decline in oil palm produce over the years. Nigeria, up till now is yet to achieve 5% total caloric intake of non-starchy crops recommended by Food and Agriculture Organization (FAO). Unless there are strong farmers' groups that create access to adequate amount of credits and relevant information for the farmers, agricultural production targets will not be met and efforts toward poverty alleviation among farmers will be inhibited.

This study was therefore set out to investigate the growth trend of farmers' groups in Delta State, Nigeria with the view of unveiling its implications for sustainable agricultural production and extension services. Specifically, the growth indicators – membership strength for the past ten years; trend in financial subscription; members perceptions on access to credit and inputs and frequency of extension service/information by the groups for the period were considered. It was thus hypothesized that ere are no significant differences in membership strength as one of the major growth indicators of the farmers' groups for the past ten years.

II. Methodology

This study was carried out in Delta State, Nigeria. Delta State, despite its petroleum wealth, is a predominantly agricultural economy. Farmers here cultivate both annual and perennial crops. Livestock and fish farming are important sub-sector of the agricultural sector of the state. These farming activities are supported by both the climatic and other environmental factors prevalent in the state.

Data for the study were collected from the records of 20 of the 63 farms' groups registered with the

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Delta State Agricultural Development Programme. The 20 groups were randomly selected with the application of the lottery method of selection. Primary data on frequency of extension contact and level of access to credit and cheap farm inputs were collected from randomly selected members of the groups that were selected on the basis of 20% of membership.

The data were analyzed with the use of contingency tables and percentages. The hypothesis was addressed with the use of analysis of variance (ANOVA). Code numbers FG_1 to FG_{20} were used to represent the farmers' groups to maintain the anonymity required by the secretaries of the groups who gave the authors access the required records in strict confidence.

The limitation encountered was that none of the groups released information on amount of credit given to farmers and the profit made.

III. Results and Discussion

a) Membership strength

Table 1 indicates that 85% of the farmers' groups experienced increasing trends in membership growth between 2002 and 2006, but between 2007 and 2011 they started experiencing a decreasing trend in membership enrolment.This is an indication that in the last five years, most of the groups experienced loss of members due either to death or dissatisfaction. Individuals have needs which they want to satisfy through group membership. Ofuoku *et al* (2008), Ofuoku and Urang (2009) discovered that farmers would like to remain in their various groups if their needs are satisfied by the group. Once the individual farmers' needs are satisfied the group remains cohesive. Cohesiveness is the extent to which members of a group want to continue as members of the group.

Members of these farmers' groups subscribe to them for the reason of accessing credit, cheap inputs and extension information. The reason for dissatisfaction and loss of membership of the various groups is attributed to weakness of the leadership. Ogionwo and Eke (1999) averred that democratic leadership which facilitates groups' performance and attainment of group and individual goals enhance group cohesiveness.

Table 1 : Membership Strength of Farmers' Group (2002 – 2011)

Farmers' Code	**Membership Strength**										
Code no.	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**% difference between 2002 & 11**
FG_1	33	33	31	31	35	34	32	32	30	30	-9.0
FG_2	15	18	21	21	29	25	21	20	19	17	13.3
FG_3	25	25	27	27	30	28	27	24	21	19	-24
FG_4	21	21	23	24	26	24	24	24	23	21	0
FG_5	35	34	35	36	39	36	34	28	26	26	-25.7
FG_6	18	23	25	26	26	24	22	22	20	17	-5.6
FG_7	26	27	27	28	29	28	24	21	20	19	28
FG_8	32	33	34	26	28	27	26	26	26	21	-34.4
FG_9	30	30	32	30	33	31	27	23	24	21	-30
FG_{10}	27	26	29	29	35	33	29	24	21	19	-29.6
FG_{11}	24	26	26	28	31	27	26	23	22	21	-12.5
FG_{12}	21	21	23	26	28	27	24	23	20	18	-14.3
FG_{13}	23	22	24	25	29	25	22	20	20	20	-13.0
FG_{14}	29	29	31	31	34	30	27	26	24	22	-24.1
FG_{15}	22	24	25	28	37	34	31	28	21	21	-4.5
FG_{16}	28	30	31	33	34	32	31	30	23	20	-28.6
FG_{17}	31	31	32	35	35	30	26	21	27	23	-25.8
FG_{18}	24	26	26	29	28	24	23	23	20	20	-16.7
FG_{19}	16	19	20	25	29	29	25	23	17	14	-12.5
FG_{20}	19	19	21	23	27	22	21	21	19	16	-15.8

Source : Various farmers' groups
FG = Farmers' Group

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b) Trend of financial subscription

It was observed that the rate of financial subscription in all the self-help farmers' groups was not fixed, but depended on the perceived capability of the individual subscriber. Each subscriber fixed his/her own subscription (Table 2). Follows the same trend as recorded in table 1. There were increasing trends between 2002 and 2006, while the groups experienced decreasing trends between 2007 and 2011. This is attributed to dissatisfaction of the members of the groups. They expressed their dissatisfaction by withdrawing; however, some did by reducing their subscriptions. The dissatisfaction was as a result of delay in receiving loans applied for and sometimes when received the desired amount is not released at a time. Some of the leaders also did not carry their members along in accessing cheap inputs through group purchase and extension services, especially with respect to cheap input supply. According to Ofuoku *et al* (2006), fish farmers subscribed to self-help groups in order to have access to cheap inputs and credit, among other reasons. The credit is to enable them expand and improve on their holdings. Ofuoku *et al* (2006) discovered significant difference between scale of production of fish farmers who subscribed to cooperative societies and those that were not members of cooperative societies. This difference was as a result of the access the subscribers had to cheap inputs and credit facilities. In situations where members of the groups do not have easy access to such credit and cheap input, the members are bound to express dissatisfaction by withdrawing their membership which translates into withdrawal or reduction of subscriptions.

Table 2 : Trend in financial subscription (2002-2012)

Farmers' group code	**Financial subscription (million naira) (US$1=Nig N150)**										
Code no.	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**% difference between 2002 & 11**
FG_1	2.30	2.30	2.10	2.10	2.40	2.35	2.20	2.20	2.0	2.0	-13.0
FG_2	1.10	1.26	1.40	1.40	2.03	1.70	1.40	1.30	1.20	1.19	8.2
FG_3	1.76	1.75	1.80	1.80	2.01	1.90	1.81	1.60	1.40	1.33	-24
FG_4	1.47	1.47	1.60	1.68	1.80	1.60	1.60	1.60	1.55	1.40	-4.8
FG_5	2.45	2.48	2.50	3.20	5.50	3.20	2.48	2.12	2.09	2.09	-14.7
FG_6	1.28	1.32	1.77	1.39	1.38	1.40	1.45	1.45	1.30	1.20	-6.3
FG_7	1.80	1.80	1.80	1.91	2.03	1.80	1.58	1.42	1.33	1.31	-27.2
FG_8	2.28	2.30	2.36	2.12	2.28	2.0	1.91	1.93	1.91	1.40	-38.6
FG_9	2.20	2.20	2.21	2.20	2.29	2.10	1.80	1.62	1.62	1.39	-81
FG_{10}	1.82	2.09	2.22	2.22	2.48	2.43	2.22	2.16	2.01	1.93	6.0
FG_{11}	1.65	1.93	1.95	2.10	2.15	1.92	1.94	1.60	1.43	1.40	-1.5
FG_{12}	1.45	1.46	1.80	2.13	2.18	2.10	1.93	1.65	1.58	1.45	0
FG_{13}	1.66	1.64	1.67	1.69	1.74	2.65	1.63	1.35	1.33	1.33	-19.9
FG_{14}	2.33	2.36	2.38	2.38	2.42	2.37	1.83	1.69	1.58	1.41	-39.5
FG_{15}	1.45	1.53	1.57	1.61	2.11	1.99	1.96	1.63	1.40	1.40	-8
FG_{16}	1.95	2.10	2.11	2.14	2.15	2.13	2.11	2.10	1.81	1.69	-13.3
FG_{17}	2.16	2.16	2.18	2.21	2.21	2.14	1.95	1.44	1.51	1.42	-34.3
FG_{18}	1.63	1.68	1.68	1.72	1.70	1.64	1.61	1.61	1.58	1.58	-3.1
FG_{19}	1.20	2.22	1.25	1.34	1.46	1.48	1.33	1.29	1.26	1.24	3.3
FG_{20}	1.33	1.33	1.46	1.47	1.51	1.48	1.44	1.46	1.32	1.25	6.0

Source : Various farmers' groups

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c) Members' perception on access to credit and cheap inputs

Most (54.5%) of the respondents were of the opinion that they rarely have access to credit (Table 3). The same trend was discovered with access to cheap farm inputs as 58.4% of them reported that cheap farm inputs were rarely accessible. These are attributed to weakness on the part of the leadership. The implication is that the members were not satisfied as their needs were not being well met. This trend is counter productive and will lead to low cohesiveness of the groups. The higher the degree to which a group fulfills the needs of its members, the more cohesive the group will be (Ogionwo and Eke, 1999). This finding is at variance with that of Ofuoku and Urange (2009) who discovered that members of farmers' cooperative societies in Delta State were highly satisfied with release of credit to the members. This finding is also at variance with an earlier finding by Ofuoku et al (2008) who observed that members of fish farmers' group in Southern Nigeria were highly satisfied.

Table 3 : Members' perception on access to loan and cheap inputs (n=77)

Facilities	Highly accessible	Accessible	Rarely Accessible	Not Accessible
Credit	6(7.8)	21(27.3)	42(54.5)	8(10.4)
			45(58.4)	11(14.3)

Figures in parenthesis are percentages.

d) Frequency of extension contact

Most (76.6%) of the groups met with extension agents once monthly (Table 4).This falls short of 2 time's monthly standard established by the Delta State Agricultural Development Programme (DTADP). The extension service could lead to the willingness of members to disengage from such groups and this will mean that the groups would no longer be cohesive. This confirms the findings of Ofuoku *et al* (2008) who discovered that most farmers had contact with extension agents once monthly.

Table 4 : Frequency of extension/farmers' contact (n=77)

Number of times (monthly)	Frequency	Percentage (%)
None	0	0
1 time	59	76.6
2 times	12	15.6
3 times	6	7.8
4 times	0	0

e) Group related constraints of members of farmers' groups

Most of the respondents indicated (table 5) that their group related constraints included inadequate information on extension/farmers' group meetings (79.2%), leadership incompetence and inadequate access to credit and cheap inputs (72.7%). Another constraint pointed was time of group meetings. These confirm an earlier attribution to the falling trend observed with membership strength and subscription fees. These findings are congruent with Ofuoku *et al* (2008) who discovered some of these constraints among members of fish farmers' groups in Southern Nigeria.

Table 5 : Group related constraints of members (n = 77)

Constraints	Frequency	Percentage (%)
Inadequate access to credit and inputs	56	72.7
Inadequate information on extension/farmers' group meetings	61	79.2
Time of group meetings	36	46.8
Leadership incompetence	57	74.0

f) Multiple responses were observed

The implication is that extension/farmers meetings could not be attended regularly by members of the various farmers' groups because of incomplete and belated information on such meetings, some of the reason farmers subscribe to farmers' self-help groups is access to information and extension services. In this situation where extension contact is inadequate, information access is also inadequate. Since access to extension services and information are members do not find such times fixed as being conducive, considering the time they retire home from farm daily and the time they devote to domestic affairs at home and cultural activities and local market days. This is in consonance with Ekong (2003) who opined

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incompetence is attributed to the way leaders steered the affairs of the groups. This is with respect to organization of the groups' activities and their responses to issues bordering on members' problems and decisions (Ofuoku *et al* (2008). According to Deckor and Nnodim (2005), one of the most important characteristics of leadership is empathy. This is the ability to share the feelings of others in your community or group. If this is lacking, the leadership is considered as being incompetent. These challenges have the implication of low level of cohesion of the various farmers' groups. Cohesiveness can only be achieved if the needs of the members of the groups are satisfied.

g) Test of hypothesis

The test of hypothesis indicates that there is significant difference at α 0.05 in membership strengths in the various farmers' groups in the years under study (Table 6).The null hypothesis is therefore, rejected. This is congruent with *a priori* expectation.

This trend is attributed to dissatisfaction among members of the various groups. This implies that the various groups are tilting towards low cohesiveness. The dissatisfaction among members is related to groups' leaders' behaviour. Lott and Lott (1995) discovered close relationship between the behaviour of group's leader and group cohesiveness. Group leaders who do not put up selfless service to their groups by not carrying the members along in every activity and who are undemocratic cannot nurture a cohesive group.

Table 6 : Difference in membership strength and paid subscriptions

Membership trends	Sum of Squares	df	Mean	F	Significance
Between Groups	2352.400	19	123.811	10.758*	0.000
Within Groups	2071.600	180	11.509		
Total	4424.000	199			

** Significant at 5% level of significance*

IV. Conclusion and Recommendations

Considering the results of this study, the membership strengths of the various farmers' groups are dwindling. This has also translated into deceased or decreasing amount paid as regular subscription fees. Extension/farmers' groups contact falls short of the required/desired frequency and most of the members rarely have access to cheap inputs and credit. These developments are related to leadership incompetence. It is concluded that the various farmers' groups are not growing, but experiencing retrogression.

Bearing the above in mind it is therefore recommended that:

i. The extension agents in charge of the various farmers' groups are required to sensitize, persuasively the leaders of the groups on the need to disseminate information on meetings adequately to their members and early enough too.

ii. The extension agents as the facilitators should help the groups to fix particular times for them to meet for extension service and should make it an important point of duty to meet with the groups as required by the extension agency (DTADP).

iii. Extension agents need to organize leadership training for the various leaders at regular intervals.

iv. Leaders of the groups should endeavour to disseminate notice of meetings of any kind to members early enough through various media that are convenient for the groups.

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Impacts of Variation in Agroclimatological Indices and Crop Combination on Growth and Yield Response of Okra in Mixtures with Two Sorghum Cultivars and Maize in a Forest - Savanna Transition Zone of Nigeria

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Abstract – Impacts of variation in agroclimatological indices and crop combination on growth and yield response of okra in mixtures with two sorghum cultivars and maize in a forestsavanna transition zone of Nigeria was investigated at the Experimental Research Farmland of the National Horticultural Research Institutes (NIHORT), Ibadan during the 2009 and 2010 cropping seasons. Plants phenological stages formed the basic unit of time for the investigation. During these phenological stages, agroclimatological thermal and moisture indices were measured daily and processed into ten-day (decadal) averages likewise selected agronomic growth and yield parameters of the components crops were taken fortnightly. The results showed that the 2010 season crops had relatively longer growth duration, received more rainfall than 2009 season (692mm vs 487.2mm) while 2009 experienced warmer temperature during establishment and early vegetative stage than 2010 season (33.2°C vs 32°C), and (28.5°C vs 27 °C) during the reproductive phase for 2009 and 2010 season respectively.

Keywords : *Phenological stages, agroclimatological indices, okra, sorghum, maize.*

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IMPACTS OF VARIATION IN AGROCLIMATOLOGICAL INDICES AND CROP COMBINATION ON GROWTH AND YIELD RESPONSE OF OKRA IN MIXTURES WITHTWO SORGHUM CULTIVARS AND MAIZE IN A FOREST –SAVANNA TRANSITION ZONE OF NIGERIA

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Impacts of Variation in Agroclimatological Indices and Crop Combination on Growth and Yield Response of Okra in Mixtures with Two Sorghum Cultivars and Maize in a Forest-Savanna Transition Zone of Nigeria.

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Abstract - Impacts of variation in agroclimatological indices and crop combination on growth and yield response of okra in mixtures with two sorghum cultivars and maize in a forest-savanna transition zone of Nigeria was investigated at the Experimental Research Farmland of the National Horticultural Research Institutes (NIHORT), Ibadan during the 2009 and 2010 cropping seasons. Plants phenological stages formed the basic unit of time for the investigation. During these phenological stages, agroclimatological thermal and moisture indices were measured daily and processed into ten-day (decadal) averages likewise selected agronomic growth and yield parameters of the components crops were taken fortnightly. The results showed that the 2010 season crops had relatively longer growth duration, received more rainfall than 2009 season (692mm *vs* 487.2mm) while 2009 experienced warmer temperature during establishment and early vegetative stage than 2010 season (33.2°C *vs* 32°C), and (28.5°C *vs* 27 °C) during the reproductive phase for 2009 and 2010 season respectively. The mean pod yields of okra in both seasons were dependent on crop combination since pod yield in sorghum cultivars mixtures (Farin Dawa and Janare) (97.33 *and* 93.67 pods) was significantly higher than in maize mixtures (58.33 *and* 49.65 pods) in 2009 season likewise in 2010 season when okra pods in sorghum mixtures (Farin Dawa and Janare) had (309.67 *and* 232.33 pods) against (162.67 *and* 67 pods) in maize mixtures for the two sorghum cultivars. The lower pod yield in 2009 season can be attributed to a higher frequency of a 5-day dry spell during flowering stage which led to a condition of moisture deficient, reduced pollination or cause spikes to dry out and heavy flower abortion. Also, it took okra pods longer to reach marketable size in the 2009 season than 2010 season (i.e. 5-9 v. 2-6 days).

Keywords : Phenological stages, agroclimatological indices, okra, sorghum, maize

I. Introduction

In crop production, climate has direct effect on the rate and duration of growth of individual plant, which ultimately determines the final yield (Egli 2004). The extent of weather influence on crop yield depends not only on the magnitude of weather variables but also on the distribution pattern of weather over the crop season which as such calls for the necessity of dividing the whole crop season into fine intervals. Controlled environment studies have shown that lower night temperature and higher day temperature can substantially decrease yields (Allen and Boote 2000).

Intercropping ensures efficient utilization of light by component plants and other environmental resources and helps to maintain greater stability in crop yields. It also guarantees greater land occupancy and higher net returns. Although some researchers, Ikeorgu et al. (1983) and Olasantan (2005) have evaluated the effects of intercropping on common vegetable crops, there is still paucity of information on this. In particular, information on okra-sorghum-maize mixtures is not available from forest-savanna transition zone of Nigeria despite wide cultivation of okra in this zone. Kurt (1984) explained that specific intercropping systems have developed over the centuries in the different regions and they are closely adapted to the prevailing ecological and weather conditions. An investigation was therefore, carried out to determine if variation in agroclimatological indices and crop combination might be associated with differences in growth and yield of okra(*Abelmoschus esculentus* (L. Moench) in mixtures with two sorghum cultivars and maize in a forest-savanna transition zone of Nigeria.

II. Materials and Methods

a) Experimental site

The experiment was carried out at Experimental, Teaching and Research Farmland of the National Horticultural Research Institutes (NIHORT), Ibadan (7° 22'N, 3° 50'E) during the 2009 and 2010 cropping seasons (Figure 1). The study area is characterized by a tropical climate with distinct wet and dry seasons. The wet season is associated relatively with the prevalence of the moist maritime southerly monsoon from Atlantic Ocean and the dry season by the continental North Easterly harmattan winds from the Sahara desert. The

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area is also characterized by bimodal rainfall pattern (April to July being the wettest months, followed by August to October). The annual rainfall ranges between 1400 and 1500mm in Ibadan and its environs. Isolated and scanty rains usually start in mid-March and steadily increase to reach the peak values in July followed by a short break in August and another peak in September. The dry season is normally from October to March and often characterized by hot days. The region is characterised by relatively high temperature with mean annual air temperature of about 30°C. The greatest variation in temperature is experienced between July (25.7°C) and February (30.2°C). The humidity is lowest (37-54%) at the peak of dry season in February and highest (78-85%) at the peak of the rainy season in June to September.

b) Planting and crop management

Two Sorghum cultivars; (*Farin Dawa* and *Janare*) , one maize(*suwan 1*) and okra(*NHAe 47-4*) cultivars were used in two field trails during 2009 and 2010 planting seasons. About three and four seeds of sorghum, maize and okra were planted at a depth of 2.5cm. Sorghum was planted three weeks after planting okra and maize to enable the okra and maize gain establishment. Sorghum spacing was 90 x 60cm (2 seedlings/stand), maize spacing was 90 x 30 cm (1 seedling/stand) and okra spacing was 90 x 30 cm (1seedling/stand). Each plot size was 6m by 3m; making a total plot size of 100 m x 20 m. The plots were hoe weeded at 3 and 6 weeks after planting. The experimental plots were arranged in a randomize complete block design (RCBD) fitted into split-plot design with three replicates. Three sets of data were collected based on critical phenological stages. These data sets were: agroclimatological indices, growth Parameters and yield parameters .

i. *Agroclimatological data*

This includes moisture base, thermal base and aerodynamic indices of the plant micro-environment easured daily from meteorological enclosure 200m from the experimental site and were later processed into decadal values. Moisture base indices include rainfall (P, mm) relative humidity (%) and open water evaporation (mm). Thermal base indices include maximum and minimum temperature (T, °C), and sun shine hour while aerodynamic indices measured is wind speed (Ws at a height of 2m (ms^{-1})).

ii. *Growth parameters*

The data were collected on the desired growth parameters of the components crops as per treatment by using standard procedures. Major growth parameters considered include: Plant height (cm), Leaf area (cm^2), Number of leaves and Stem diameter (mm) for each of the component plants.

The leaf area was determined by non destructive method. Ten leaves were measured for each treatment plot and the mean leaf area determined.
Okra leaf area was estimated, using a non-destructive method, from the equation;

$$Y = 115X - 1050$$

Where Y = leaf area (cm^2) and X = the length of mid rid (cm) (Asif, 1977).

The area of each individual sorghum and maize leaf blade (Y, in square centimetres) was computed as; length x maximum width x 0.75. The value of 0.75 was considered an acceptable average of reported values: 0.75 (Montgomery, 1911), 0.73 (Mckee, 1964; Dwyer and Stewart, 1986), 0.72 (Keating and Wafula, 1992), 0.79 (Birch *et al.,* 1998) and 0.74 (Stewart and Dwyer, 1999).

Y= (L x W) 0.75 (leaf area factor)
(Stewart and Dwyer, 1999)
Where L=length (cm) and W= maximum width (cm)

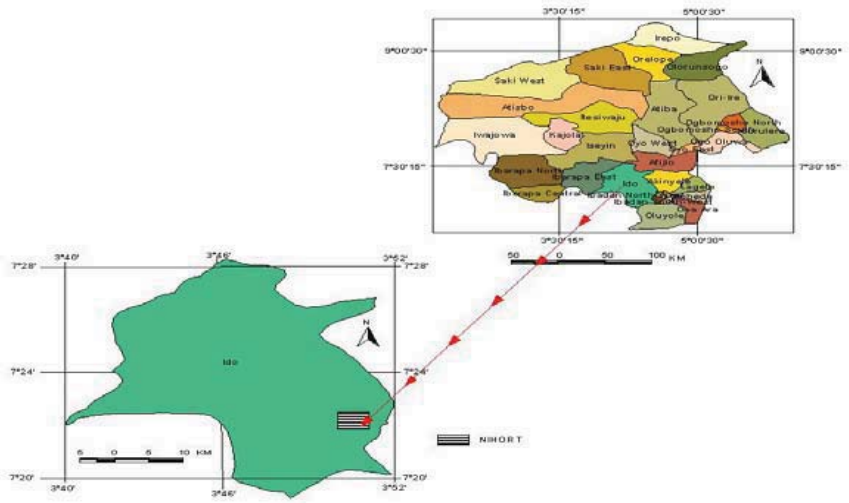

Figure 1 : Location of NIHORT within Ido local government area in Oyo state

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iii. *Yield parameters*

Yield parameters considered include grain yield (sorghum and maize), panicle length (sorghum), cob weight (maize), weight of 100 grains (maize), pods number/plant and pods weight, length and diameter of okra yield.

c) Statistical analysis

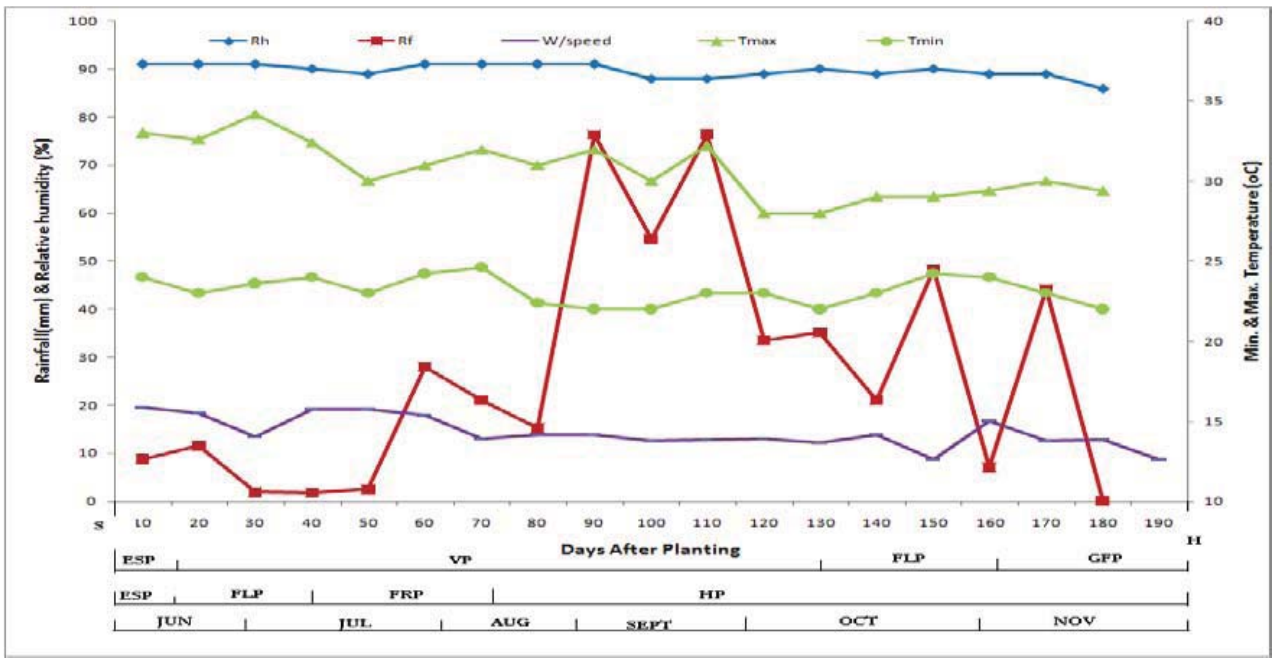
Analyses of variance were carried out by established methods (Steel *et al*. 1997) using the PROC GLM procedure of the SAS Statistics package (SAS Institute Inc. 2000). The cropping pattern and cultivars were considered as random effects, while the planting seasons were fixed effects. Cultivars and cropping patterns mean differences within each planting season were separated using Fishers' protected least significant difference (l.s.d.) test at $P \leq 0.05$.

III. Results and Discussion

a) Distribution of Agroclimatological indices

Agroclimatological indices for the growing seasons differed considerably at various stages of the crop growth. The 10-days values for rainfall, maximum and minimum temperature, relative humidity and wind speed for 2009 and 2010 seasons at National Horticultural Research Institute (NIHORT), Ibadan were related to the main phases of vegetative growth and reproductive development of sorghum in Fig. 2 & Fig. 3. Rainfall during stages of growth was much higher in 2010 cropping season than 2009 cropping season (i.e 692 *vs.* 487.2 mm). Consequently, rainfall during the vegetative growth stages was lower in the 2009 season than 2010 season crops (i.e 331.5 *vs* 537.5mm*).* The same scenario was observed during the reproductive phase in 2009 season with 366.6mm against 560.2mm in 2010 season.

Temperature also varied during the the two seasons (Fig. 2 & Fig.3) and was similar in its distribution to that found elsewhere in the savanna region (7° 49'N, 6° 03'E) of Nigeria (Olaniran and Babatolu, 1987). Minimum temperature varied between 22 and 24 °C in 2009 season while it ranged between 21.2 and 23.4 °C in 2010 season. Maximum temperature ranged between 28 and 33°C in 2009 season while it range between 27 and 32 °C in 2010 season. Temperatures were warmer during planting, establishment and early vegetative stages than during reproductive stage in 2009 season (24 v 22 and 33 v 28 °C) and similar trend was observed in 2010 season (23 v 22 and 31v 27 °C).



ESP: Establishment; VP: Vegetative period; FLP: Flowering period; GFP: Grain filling period; H: Harvesting
FRP: Fruiting period; HP: Harvesting period; S: Sown.

Figure 2 : Distribution of Agroclimatological indices during different phenological stages of experimental crops in 2009 season (June-November) at NIHORT, Ibadan

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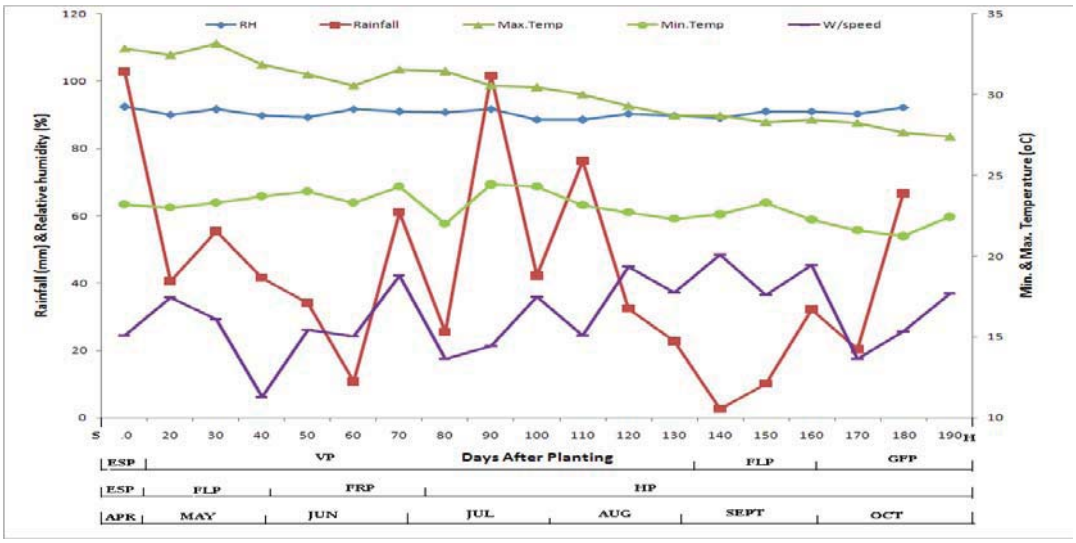

Figure 3 : Distribution of Agroclimatological indices during different phenological stages of experimental crops in 2010 season (April-October) at NIHORT, Ibadan

The pattern of thermal trends (maximum and minimum air temperature) for both the 2009 and 2010 seasons at NIHORT, Ibadan is as shown in figure 4. The mean minimum temperature during the early growing season was 24°C during 2009 season at establishment stage (ESP) but dropped to 23°C at flowering period (FLP) while the least minimum temperature of 22°C was observed at grain filling period (GFP). The growing season of 2010 experienced a much lower minimum temperature with ESP, FLP and GFP having 23.2, 22.57 and 21.6°C, respectively. Displayed in figure 5 is the trend of maximum temperature for both the 2009 and 2010 seasons at NIHORT, Ibadan. The results revealed that 2009 season maximum temperature trend dropped from 33°C at ESP to 29.3°C at FLP while 30°C was recorded at GFP. In 2010 season maximum temperature values were 32.7, 28.71 and 28.24°C at ESP, FLP and GFP, respectively.

Presented in figure 5 is the aerodynamic trend (wind speed (m/sec)) for both the 2009 and 2010 seasons at NIHORT, Ibadan. The prevailing wind situation from 10 – 60 days after planting (DAP) was higher during 2009 season (19.56 – 13.4 m/sec) than 2010 season (15.07- 11.3 m/sec). However, the prevailing wind situation during 2010 season (20.08 – 133.62 m/sec) from 70- 180 DAP was higher than during 2009 season that ranged from 16.74 to 8.73 m/sec. Days with higher wind speed experienced a relatively windy situation though not enough to cause physical damage as plant had fully established and nearing maturity or at maturity while those days with lower wind speed experienced a calm weather condition when plant can stand in proper position to receive sun light for maximum photosynthesis.

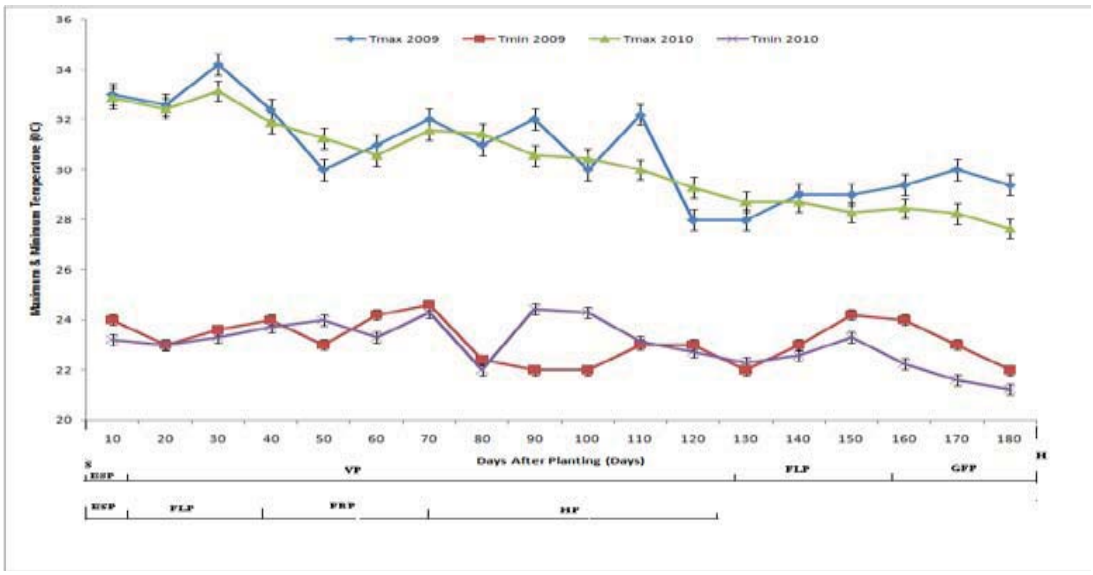

Figure 4 : Comparison of thermal trends for 2009 and 2010 seasons at NIHORT, Ibadan.

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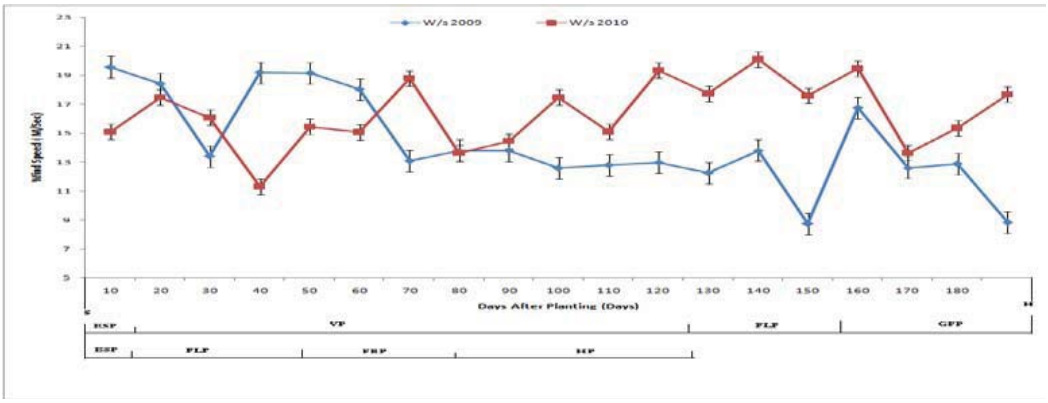

Figure 5 : Aerodynamic trends during 2009 and 2010 seasons at NIHORT, Ibadan

b) Okra growth characteristics

i. *Plant height*

a. 2009 season

Figure 6 showed the difference in plant height of okra in monoculture and mixtures of maize/okra (MO), okra/white sorghum (S1O), okra/ red sorghum (S2O) and the combination of maize/okra/white sorghum (MOS1) and maize/okra/red sorghum (MOS2) at 4,6,8,10 and 12 weeks after planting (WAP). The result showed that there was generally no statistical difference in okra plant height in both monoculture and mixtures. Okra plant height in okra/red sorghum mixtures (S2O) increased from 15.48cm at 4WAP to 70.51cm at 12WAP while okra height in okra/white sorghum mixtures (S1O) increased from 16.44cm to 69.15cm at 4 and 12WAP respectively. In maize/okra/sorghum intercrop, okra height in maize/okra/white sorghum (MOS1) increased from 15.45cm to 55.86cm against okra height in maize/okra/red sorghum (MOS2) combination that increased from 14.73cm to 67.87cm at 4 and 12 WAP respectively.

Plant height in maize/okra mixture (MO) ranged from 16.06 to 68.03cm while okra plant height in okra/white sorghum (S1O) mixtures ranged from 16.44 to 69.15cm and okra/red sorghum mixtures ranged from 15.48 to 70.51cm. Though no significant difference was observed in the treatments means, the okra plants perform better in red sorghum (S2) than white sorghum (S1).

b. 2010 season

Okra height in okra/red sorghum mixtures (S2O) increased from 17.77cm at 4WAP to 73.00cm at 12WAP while okra height in okra/white sorghum mixtures (S1O) increased from 17.78cm to 82.78cm at 4 and 12WAP respectively. In maize/okra/sorghum intercrop, okra height in maize/okra/white sorghum (MOS1) increased from 17.25cm to 60.00cm against okra height in maize/okra/red sorghum (MOS2) combination that increased from 15.02cm to 69.22cm at 4 and 12 WAP respectively. Okra plant height in maize/okra mixture (MO) ranged from 17.46 to 68.89cm while okra plant height in okra/white sorghum (S1O) mixtures ranged from 17.78 to 82.78cm and okra/red sorghum mixtures ranged from 17.77 to 73.00cm.

ii. *Number of leaves*

a. 2009 season

Mean difference in number of leaves per plant of okra in monoculture and mixtures of maize/okra (MO), okra/white sorghum (S1O), okra/red sorghum (S2O) and the combination of maize/okra/white sorghum (MOS1) and maize/okra/red sorghum (MOS2) at 4,6,8,10 and 12 weeks after planting (WAP) is presented in figure 7 in 2009 and 2010 seasons. The figure revealed that the difference in number of leaves per plant of okra in both monoculture and mixtures was significant at all sampling occasions for treatments containing white sorghum (S1) cultivar while difference in treatment containing red sorghum (S2) was significant at 6,8,10 and 12 WAP. Leaves per plant in okra/red sorghum mixtures (S2O) increased from 6.93 at 4WAP to 22.74 at 12WAP while leaves per plant of okra in okra/white sorghum mixtures (S1O) increased from 7.33 to 20.00 at 4 and 12WAP respectively. In maize/okra/sorghum intercrop, leaves per plant of okra in maize/okra/white sorghum (MOS1) increased from 6.48 to 12.78 as against the values in maize/okra/red sorghum (MOS2) combination that increased from 7.62 to 17.23 per maize plant at 4 and 10 WAP respectively.

b. 2010 season

In 2010 season, significant difference existed in number of leaves per plant of okra in both monoculture and mixtures at 8, 10 and 12WAP for treatments containing white sorghum (S1) cultivar while the difference was significant in treatment containing red sorghum (S2) at 10 and 12 WAP (Figure 7). Leaves per plant of okra in okra/red sorghum mixtures (S2O) increased from 7.44 at 4WAP to 19.11 at 10WAP while in okra/white sorghum mixtures (S1O) it increased from 7.78 to 23.67 at 4 and 10WAP respectively. In maize/okra/sorghum intercrop, leaf per plant of in maize/okra/white sorghum (MOS1) increased from 6.89 to 10.45 against the corresponding values of 7.22 to 13.33 in maize/okra/red sorghum (MOS2) combination at 4 and 10 WAP respectively.

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iii. *Leaf area (cm^2)*

a. 2009 season

Presented in figure 8 is the leaf area of okra in monoculture and mixtures of maize/okra (MO), okra/white sorghum (S1O), okra/ red sorghum (S2O) and the combination of maize/okra/white sorghum (MOS1) and maize/okra/red sorghum (MOS2) at 4,6,8,10 and 12 weeks after planting (WAP). The figure showed that leaf area of okra in both monoculture and mixtures was not statistically difference except at 12WAP for treatments containing white sorghum (S1) cultivar while the difference was significant ($p<0.05$) in treatment containing red sorghum (S2) at 6,10 and 12WAP. Leaf area of okra in okra/white sorghum mixtures (S1O) increased from 1288.9 cm^2 at 4WAP to 3839.3cm^2 at 12WAP while in okra/red sorghum mixtures (S2O) it increased from 829.1 to 4237.3 cm^2 at 4 and 8WAP respectively. In maize/okra/sorghum intercrop, okra leaf area in maize/okra/white sorghum (MOS1) increased from 904.5 to 3046.7cm^2 at 4 to 12WAP while the values in maize/okra/red sorghum (MOS2) combination increased from 766.2 to 3650.4 cm^2 at 4 and 8 WAP respectively.

b. 2010 season

During the 2010 season leaf area of okra was not different significantly except at 12WAP for treatments containing white sorghum (S1) cultivar and similar trend was observed for treatments containing red sorghum (S2) except at 10WAP. Leaf area of okra in okra/white sorghum mixtures (S1O) increased from1301.4 cm^2 at 4WAP to 3811.8cm^2 at 10WAP while in okra/red sorghum mixtures (S2O) it increased from 941.8 to 3630.9 cm^2 at 4 and 8WAP respectively. In maize/okra/sorghum intercrop, okra leaf area in maize/okra/white sorghum (MOS1) increased from 986.7 to 2962.4cm^2 at 4 to 10WAP while the values in maize/okra/red sorghum (MOS2) combination increased from 815.7 to 2988.4 cm^2 at 4 and 8 WAP respectively.

iv. *Days to 50% flowering and first harvest of Okra plant*

a. 2009 season

The data on average number of days to 50% flowering and days to first harvest as influenced by two sorghum cultivars and maize intercrop on okra phenology are presented in Table 1. It is evident from the table that the two sorghum genotypes and maize intercrop had significant effects on the days taken to reach 50% flowering and days to first harvest. During 2009 season the two sorghum genotypes hastened the 50% flowering and days to first harvest of okra than maize intercrop. Days to 50% flowering of okra treatment containing white sorghum (S1), sole okra (O) and okra/white sorghum mixtures (S1O) took 49 days while both maize/okra (MO) and maize/okra/white sorghum (MOS1) mixtures took longer days of 52 days. The values in red sorghum combination ranged from 50 days for both sole okra (O) and red sorghum/okra mixture (S2O) followed by okra/maize/red sorghum mixtures (MOS2) of 53 days while it took maize/okra (MO) mixture 54 days.

Days to first harvest of okra for treatment containing white sorghum (S1), sole okra (O) and okra/white sorghum mixtures (S1O) took 53 days while both maize/okra (MO) and maize/okra/white sorghum (MOS1) mixtures took longer days of 57 days. Days to first harvest in red sorghum combination ranged from 54 days for red sorghum/okra mixture (S2O) followed by both sole okra (O) that took 55 days then maize/okra (MO) and okra/maize/red sorghum mixtures (MOS2) that took longer days of 59.

b. 2010 season

During 2010 season, the two sorghum genotypes hastened the time to 50% flowering and days to first harvest of okra than maize intercrop. Days to 50% flowering of okra treatment containing white sorghum (S1), sole okra (O) took 49 days followed by okra/white sorghum mixtures (S1O) of 50.67 days while both maize/okra (MO) took 51.00 days and maize/okra/white sorghum (MOS1) mixtures took longer days of 53 days. Days to 50% flowering in red sorghum combination ranged from 51 days for both sole okra (O) followed by red sorghum/okra mixture (S2O) that took 52 days then okra/maize/red sorghum mixtures (MOS2) of 53 days while maize/okra (MO) mixture took 55 days.

Days to first harvest of okra for treatment containing white sorghum (S1), sole okra (O) took 55 days followed by okra/white sorghum mixtures (S1O) and maize/okra (MO) that took 56 days while maize/okra/white sorghum (MOS1) mixtures took longer days of 57 days. Days to first harvest in red sorghum (S2) combination ranged where not significantly different as all treatments have pods ready for harvest at 58 days after planting.

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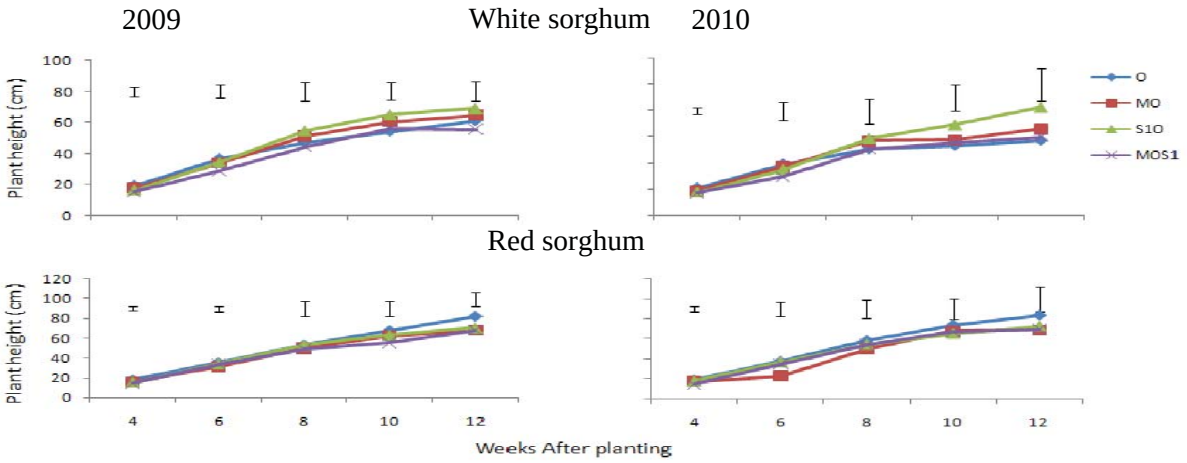

Figure 6 : Effects of intercropping two sorghum cultivars and maize on plant height (cm) of okra in 2009 and 2010 seasons at NIHORT, Ibadan, Nigeria.

MOS1: Maize/okra/White Sorghum Intercrop; MO: Maize/Okra Intercrop; MOS2: Maize/Okra/Red Sorghum Intercrop; O: Okra (NHAe 47-4); S1O: White sorghum/okra intercrop; S2O: Red sorghum/okra intercrop.

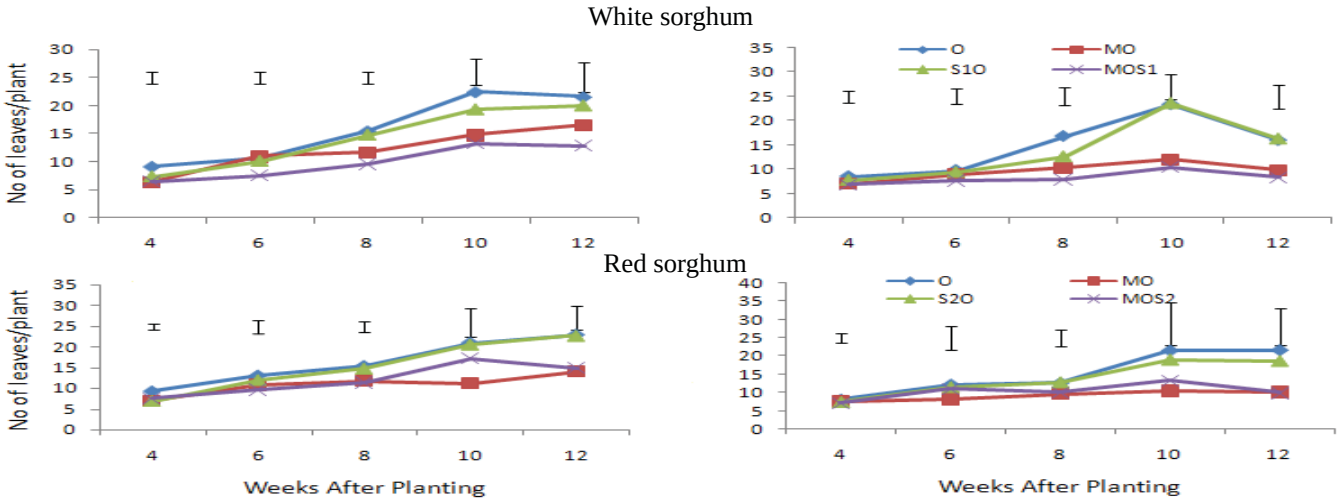

Figure 7 : Effects of intercropping two sorghum cultivars and maize on the number of leaves per plant of okra in 2009 and 2010 seasons at NIHORT, Ibadan, Nigeria.

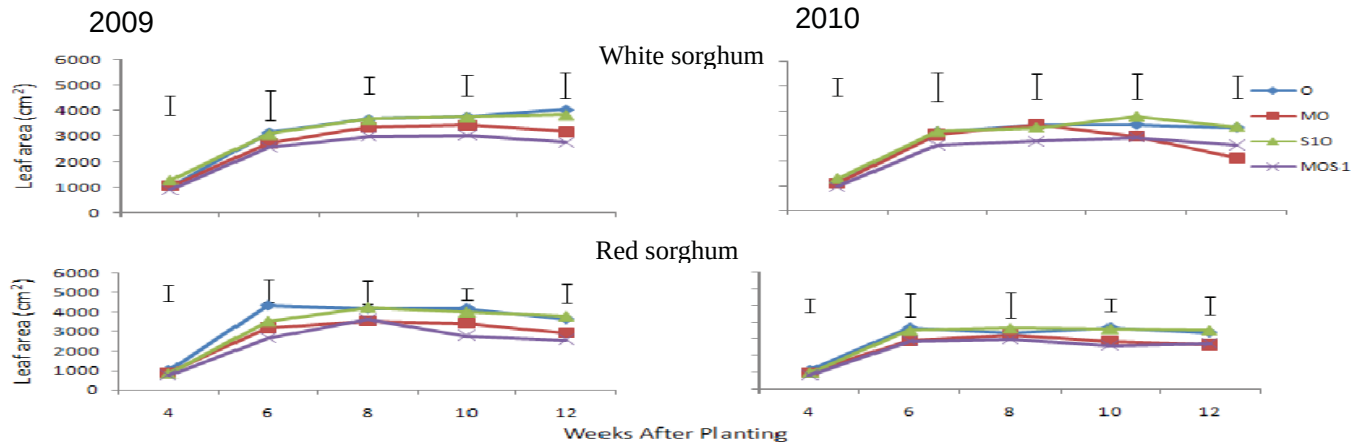

Figure 8 : Effects of intercropping two sorghum cultivars and maize on the leaf area (cm^2) of okra in 2009 and 2010 seasons at NIHORT, Ibadan, Nigeria.

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MOS1: Maize/okra/White Sorghum Intercrop; MO: Maize/Okra Intercrop; MOS2: Maize/Okra/Red Sorghum Intercrop; O: Okra (NHAe 47 - 4); S1O: White sorghum/okra intercrop; S2O: Red sorghum/okra intercrop.

Table 1 : Effects of intercropping two sorghum cultivars and maize with okra on the phenology of Okra in 2009 and 2010 seasons at NIHORT, Ibadan, Nigeria.

	2009		2010	
Treatments	Days to 50% flowering	Days to first harvest	Days to 50% flowering	Days to first harvest
White sorghum				
O	49	53	49	55
MO	52	57	51	56
S1O	49	53	51	56
MOS1	52	57	53	57
Red sorghum				
O	50	55	51	59
MO	54	59	55	59
S2O	50	54	52	59
MOS2	53	59	53	59
LSD(0.05)	1.62	1.08	1.32	1.83
White sorghum (mean)	50	55	51	56
Red sorghum (mean)	52	57	53	59
LSD(0.05)	1.84	1.50	1.35	1.74
Sole okra (mean)	49	54	50	57
Okra/sorghum (mean)	50	54	51	57
Okra/maize (mean)	53	58	53	57
Okra/Sorghum/ maize (mean)	53	58	53	58
LSD(0.05)	2.06	1.91	1.38	1.65

MOS1 : Maize / okra / White Sorghum Intercrop ; MO : Maize / Okra Intercrop ; MOS2 : Maize / Okra / Red Sorghum Intercrop ; O : Okra (NHAe47-4) ; S1O : White sorghum/okra intercrop ; S2O: Red sorghum/okra intercrops.

c) Okra yield and Pod components

i. *Yield frequency*

a. 2009 season

Shown in Figure 9 is the frequency of okra pod harvest during 2009 and 2010 seasons in both monoculture and mixtures of okra/maize (MO), okra/white sorghum (S1O) and maize/okra/white sorghum (MOS1). In 2009, fresh pod yield of okra intercropped with white sorghum (S1O) were significantly higher than okra yield in maize/okra (MO) mixtures. Number of fresh pod harvested from Sole okra (O) increased from 12pods at 8WAP through 26 pods at 10WAP and reach peak value of 26.33pods at 12WAP while the least harvest of 8.67pods was observed at 16WAP. Number of fresh pods harvested from maize/okra mixtures (MO) ranged from 5.67 pods at 8WAP through 12.67pods at 10WAP and reach peak harvest of 21pods at 12WAP while the lowest yield of 5.33pods was also observed at 16WAP. The pod yield in white sorghum/okra (S1O) mixtures was 8.33, 20.33, 39 and 8pods at 8, 10, 12 and 16WAP respectively. Also, the pod yield in maize/okra/white sorghum (MOS1) mixtures was 7, 14.67,27 and 5pods at 8, 10, 12 and 16WAP respectively.

In treatments containing red sorghum, fresh pod yield of okra intercropped with red sorghum (S2O) were significantly higher than okra yield in maize/okra (MO) mixtures. Number of fresh pod harvested from Sole okra (O) increased from 9pods at 8WAP through 35 pods at 10WAP and reach peak value of 43pods at 12WAP while the least harvest of 8pods was observed at 16WAP. Number of fresh pods harvested from maize/okra mixtures (MO) ranged from 3.33 pods at 8WAP through 13.33pods at 10WAP and reach peak harvest of 16.66pods at 12WAP while the lowest yield of 4pods was also observed at 16WAP. The pods yield in red sorghum/okra (S2O) mixtures was 4.67, 27.67, 30 and 6pods at 8, 10, 12 and 16WAP respectively. Also, the pod yield in maize/okra/red sorghum (MOS2) mixtures was 2.33, 15.67,18 and 4pods at 8, 10, 12 and 16WAP respectively.

b. 2010 season

In 2010 season, pod yield of okra intercropped with white sorghum (OS1) were significantly higher than okra yield in maize/okra (MO) mixtures. Number of fresh pod harvested from Sole okra (O) increased from 7pods at 8WAP through 13 pods at 10WAP and reach peak value of 42pods at 14WAP while 11pods was harvested at 20WAP. Number of fresh pods harvested from

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maize/okra mixtures (MO) ranged from 7.67pods at 8WAP through 19.33pods at 10WAP and reach peak harvest of 39.67pods at 18WAP while 6pods was harvested at 20WAP. The yield in white sorghum/okra (S1O) mixtures was 17.33, 25.67, 89 and 10pods at 8, 10, 14 and 20WAP respectively. Also, the yield in maize/okra/white sorghum (MOS1) mixtures was 6.33, 22, 40 and 5.67pods at 8, 10, 18 and 20WAP respectively.

In red sorghum treatment combinations, fresh pod yield of okra intercropped with red sorghum (S2O) were significantly higher than okra yield in maize/okra (MO) mixtures. Number of fresh pod harvested from Sole okra (O) increased from 6.67pods at 8WAP through 28.67 pods at 10WAP and reach peak value of 95pods at 18WAP while 13pods was harvested at 20WAP. Number of fresh pods harvested from maize/okra mixtures (MO) ranged from 2pods at 8WAP through 3.33pods at 10WAP and reach peak harvest of 21.67pods at 18WAP while 6pods was harvested at 20WAP. The yield in red sorghum/okra (S2O) mixtures was 4.33, 25.67, 61 and 11.33pods at 8, 10, 14 and 20WAP respectively. Also, the yield in maize/okra/ red sorghum (MOS2) mixtures was 2.33, 10.66, 38.67 and 5pods at 8, 10, 18 and 20WAP respectively.

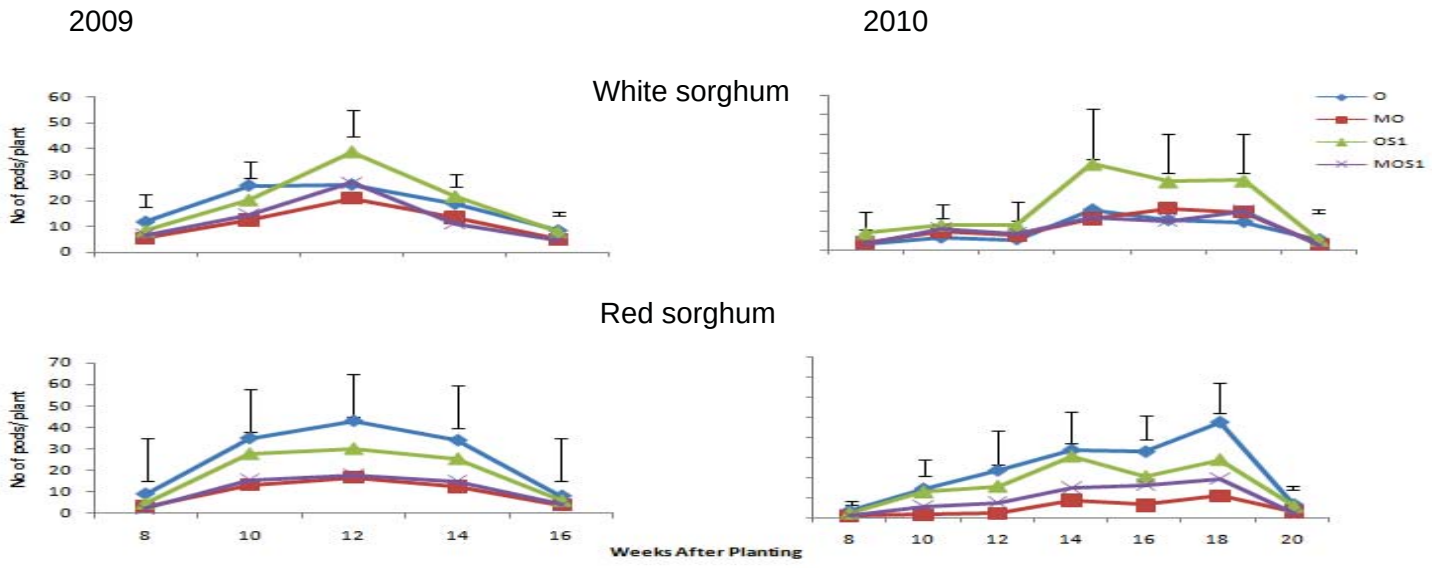

Figure 9 : Effects of intercropping okra with sorghum cultivars and maize on the yield frequency of fresh okra pods during 2009 and 2010 seasons at NIHORT, Ibadan, Nigeria.

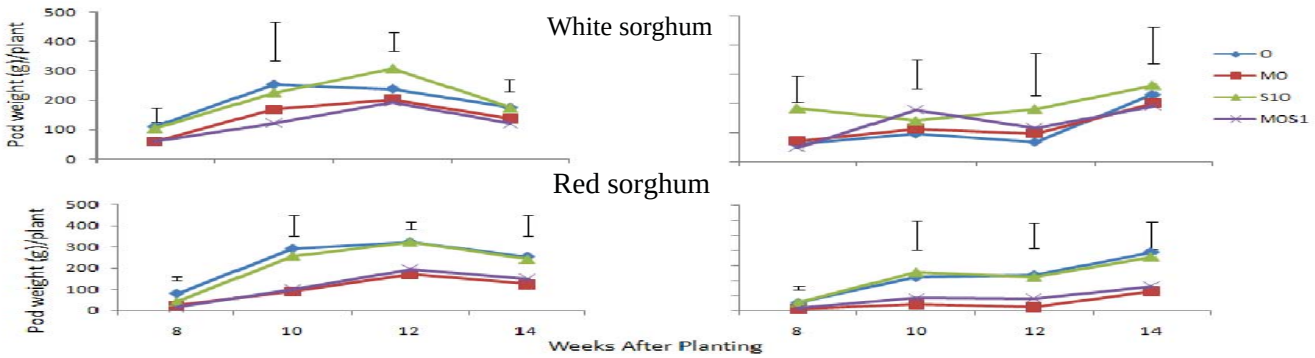

Figure 10 : Effects of Intercropping two sorghum cultivars and maize on the weight (g) of fresh okra pods per plant in 2009 and 2010 seasons at NIHORT, Ibadan, Nigeria.

ii. *Okra Pod weight*

a. 2009 season

The weight of fresh okra pods in monoculture and mixtures of okra/white sorghum (S1O), okra/ red sorghum (S2O), okra/maize (MO) and the combination of maize/okra/white sorghum (MOS1) and maize/okra/red sorghum (MOS2) at 8,10,12 and 14 weeks after planting (WAP) is presented in figure 10. The figure showed that the pods weight in both monoculture and mixtures was statistically difference at all sampled occasions except at 8WAP. Similarly pod weight of okra in red sorghum (S2) treatment showed significant

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difference ($p<0.05$) at all sampled occasions. Pod weight of sole okra (O) in white sorghum (S1) treatments ranged from 111.18 to 253.18g whereas pod weight of sole okra (O) in red sorghum (S2) treatment ranged from 80.67 to 324.00g. Pod weight of Okra (O) in okra/white sorghum mixtures (S1O) increased from 106.07 to 307.27g while the value in red sorghum (S2) treatment for okra/red sorghum mixtures (S2O) increased from 42.82 to 325.50g. In the mixtures of maize/okra (MO) in white sorghum treatment, the values ranged from 59.64 to 201.77g compared with that in red sorghum treatment that ranged from 25.20 to 170.50g. In maize/okra/sorghum mixtures, pod weight in white sorghum treatment for maize/okra/white sorghum (MOS1) increased from 60.65 to 192.94g while the values in red sorghum treatments for maize/okra/red sorghum (MOS2) combination increased from 15.53 to 194.81g.

b. 2010 season

Pod weight was significantly different at all sampled occasions except at 8 weeks after planting for treatments containing white sorghum (S1) cultivar. Similarly, the difference in pod weight was significant for treatments containing red sorghum (S2) at all sampled occasions. Pod weight of okra in white sorghum treatment for sole okra (O) ranged from 59.40 to 230.50g whereas the values in sole red sorghum treatments ranged from 52.08 to 387.20g. Pod weight in okra/white sorghum mixtures (S1O) ranged from 140.00 to 561.60g while the corresponding values in red sorghum treatment for okra/red sorghum mixtures (S2O) ranged from 52.47 to 356.02g. In the mixtures of maize/okra (MO), pod weight ranged from 71.45 to 200.00g compared to the values in maize/okra (MO) that ranged from 10.00 to 129.08g. In maize/okra/sorghum mixtures, pod weight in maize/okra/white sorghum (MOS1) ranged from 48.62 to 191.30g while the corresponding values in maize/okra/red sorghum (MOS2) combination from 15.28 to 162.00g. Generally, pod weight of okra in both sorghum cultivars was higher than the pod weight in sorghum/maize intercrop during 2009 and 2010 season.

iii. *Pods components*

Number of pods, pod weight, pod length, pod diameter and pod yield of okra in 2009 and 2010 seasons in both monoculture and mixed stands are presented in Table 2. These characters varied significantly among the treatments in both 2009 and 2010 seasons. Yield characters in 2010 season were generally higher than their corresponding values in 2009 season. Pods attributes in okra/sorghum mixtures regardless of the sorghum cultivars were significantly higher than pods attributes obtained in okra/maize mixtures in both 2009 and 2010 seasons.

a. Number of pods/plant

Number of pods per plant in white sorghum mixtures was generally higher than in red sorghum mixtures in both 2009 and 2010 season. In 2009 season, for white sorghum mixtures, the highest number of pods/plant was from S1O mixtures (10 pods/plant) followed by Sole okra (O) with 9 pods/plant then MOS1 mixtures with 7 pods/plant while the least values came from MO mixtures with 6 pods/plant. In case of red sorghum mixtures, numbers of pods were in the following order sole okra (12 pods/plant), followed by S2O mixtures with 9 pods/plant then MOS2 mixtures with 6 pods per plant while MO mixtures had lowest number of pods per plant (5 pods/plant).

The trend of number of pods/plant in 2010 season revealed that in white sorghum mixtures, the highest pods/plant was from S1O mixtures with 22 pods/plant followed by MO mixtures with 12 pods/plant then MOS1 with 11 pods/plant while sole okra (O) produced the least with 10 pods/plant. On the other hand, in red sorghum mixtures, sole okra (O) had highest pods/plant with 23 pods followed by S2O mixtures with 16 pods/plant then MOS2 mixtures which had 10 pods/plant while the lowest was from MO mixtures with 5 pods/plant.

b. Pod length/plant (cm)

Table 2 also shows the length of fresh okra pods/plant in monoculture and mixtures of okra/white sorghum (S1O), okra/ red sorghum (S2O), okra/maize (MO) and the combination of maize/okra/white sorghum (MOS1) and maize/okra/red sorghum (MOS2) in 2009 and 2010 seasons at NIHORT, Ibadan. Pods length in both monoculture and mixtures was statistically difference among the treatment means with pods length in sorghum cultivars mixtures having higher values than in maize mixtures in both 2009 and 2010 seasons. Generally, pod length/plant in white sorghum was slightly higher than corresponding values from red sorghum. In 2009 season, for white sorghum mixtures, S1O mixtures had longest pods of 4.3 cm followed by sole okra (O) with 4.2 cm then MO mixtures with 3.5cm while the shortest pod was obtained in MOS1 mixtures with 3.4 cm. Whereas, in the mixtures containing red sorghum cultivar the values were in the following order, sole okra (O) (4.6 cm) followed by S2O mixtures with 4.5 cm then MOS2 which had 3.2 cm while MO mixtures produced shortest pod of 2.9 cm.

In white sorghum mixtures during 2010 season, pods length of okra in S1O mixtures had longest pod of 5.0 cm followed by MOS1 mixtures with 4.8cm then MO mixtures with 4.4cm while the shortest pod (3.2cm) was found in sole okra (O). In contrast, for red sorghum mixtures, longest pod of 4.9 cm was obtained in sole okra (O) followed by 4.6 cm from S2O mixtures then 3.5 cm from MOS2 mixtures while shortest pod of 2.9 cm was from MO mixtures.

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c. Pod diameter/ plant (mm)

Trend of pod diameter in 2009 season, for white sorghum mixtures, as shown in Table 2 revealed that the highest pod diameter was from S1O mixtures (21.5mm) followed by Sole okra (O) with18.6mm then MOS1 mixtures with 17.4mm while the least values came from MO mixtures with 17.2 mm. In case of red sorghum mixtures, pods diameter were in the following order sole okra (23.4mm), followed by S2O mixtures with 20.6mm then MOS2 mixtures with 16.4 mm while MO mixtures had lowest pod diameter of 13.9 mm.

In 2010 season for white sorghum mixtures, the highest pods diameter was from S1O mixtures with 24.8 mm followed by MOS1 mixtures with 23.9 mm then MO with 21.8 mm while sole okra (O) had the least with 19.9 mm. On the other hand, in red sorghum mixtures, sole okra (O) had highest pods diameter with 24.2 mm followed by S2O mixtures with 21.5 mm then MOS2 mixtures which had 21.0 mm while the lowest was from MO mixtures which had 15.1 mm.

d) Okra yield (tha^{-1})

In 2009 season, in white sorghum mixtures, the highest pod yield was obtained in okra/white sorghum mixtures (S10) (3.1tha^{-1}), followed by sole okra (O) (2.8 tha^{-1}), then okra/maize mixtures (MO) (2.0 tha^{-1}) while the least pod yield is from maize/okra/white sorghum mixtures (MOSI) (1.9 tha^{-1}). The result showed that for red sorghum treatment combinations, the highest pod yield is obtained in sole okra (O) (4.2 tha^{-1}), followed by okra/red sorghum mixtures (S2O) (3.4 tha^{-1}), then maize/okra/red sorghum mixtures (MOS2) (2.1 tha^{-1}) while the least pod yield was obtained in maize/okra mixtures (MO) (1.8 tha^{-1}) the mean yields were statistically different.

Similarly during 2010 season, in white sorghum combinations, the highest pod yield was recorded in okra/ white sorghum mixtures (S1O) (9.9 tha^{-1}), followed by sole okra (O) (5.5 tha^{-1}) then maize/okra/white sorghum mixtures (MOS1) (4.4 tha^{-1}) while the least yield was obtained in maize/okra (MO) (4.3 tha^{-1}). Whereas in red sorghum combinations, the yield were in the following order, sole okra (O) (9.5 tha 1) followed by red sorghum/okra mixtures (S2O) (7.1tha^{-1}), then maize/okra/red sorghum mixtures (MOS2) (3.6 tha^{-1}) while the least yield in maize/okra (MO)(2.1tha^{-1}).

IV. Conclusion

The study proved that growing okra between sorghum rows rather than okra/maize mixtures is more valuable cropping option to diversify food production and improve economic returns for farmers and starch-based diets of the people in forest-savanna transition zone of Nigeria. This study also indicates that intercropping okra with sorghum varieties resulted in vegetative and yield comparable to the sole okra. Okra in monoculture or mixed stand showed great potential for environmental modification. Study confirmed that minimal rainfall availability prolong harvesting period of okra as witnessed in the experiment and the optimum planting date for okra production must be the one which will make the period of harvest coincide with the period when minimal rainfall is steady and not the peak rainfall. Again, in order to reduce the risk of total crop loss to peasant farmers due to unpredictable weather conditions, okra/sorghum intercropped is highly recommended as their combinations maximize the use of available environmental resources at all season and therefore reduce the potential negative impact of climate change on component crops.

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Table 2 : Effects of intercropping sorghum cultivars and maize on the yield characters of okra in 2009 and 2010 seasons at NIHORT, Ibadan, Nigeria.

Treatment	2009					2010				
	No of pods/plant	Pod weight (g)	Pod length (cm)	Pod diameter (mm)	Pod yield (t/ha)	No of pods/plant	Pod weight (g)	Pod length (mm)	Pod diameter (mm)	Pod yield (t/ha)
White Sorghum										
O	9	38.9	4.2	18.6	2.8	10	22.7	3.2	19.9	5.5
MO	6	28.3	3.5	17.2	2.0	12	24.0	4.4	21.8	4.3
S1O	10	40.7	4.3	21.5	3.1	22	38.2	5.0	24.8	9.9
MOS1	7	24.9	3.4	17.4	1.9	11	26.8	4.8	23.9	4.4
Red Sorghum										
O	12	47.6	4.6	23.4	4.2	23	44.9	4.9	24.2	9.5
MO	5	20.6	2.9	13.9	1.8	5	10.2	2.9	15.1	2.1
S2O	9	43.5	4.5	20.6	3.4	16	44.3	4.6	21.5	7.1
MOS2	6	23.1	3.2	16.4	2.1	10	17.1	3.5	21.0	3.6
LSD (0.05)	5.63	15.35	1.19	3.85	0.82	9.26	18.21	2.27	7.02	4.67
White sorghum (mean)	9	33.2	3.9	18.7	2.5	14	27.9	4.4	22.6	6.0
Red sorghum (mean)	8	33.7	3.8	18.6	2.9	14	29.1	4.0	20.4	5.6
LSD (0.05)	2.05	7.65	1.2	4.40	0.75	3.80	9.82	2.1	7.40	0.51
Sole okra (mean)	11	43.2	4.4	21.0	3.5	17	33.8	4.0	22.0	7.5
Okra/sorghum (mean)	10	42.1	4.4	21.1	3.3	19	41.3	4.8	23.1	8.5
Okra/maize (mean)	5	24.4	3.2	15.5	1.9	8	17.1	3.6	18.4	3.2
Okra/maize/sorghum (mean)	6	24.0	3.3	16.9	2.0	10	22.0	4.1	22.4	4.0
LSD (0.05)	3.24	10.34	1.12	4.96	1.32	10.35	12.65	1.93	7.77	3.6

MOS1 : Maize / okra / White Sorghum Intercrop ; MO : Maize / Okra Intercrop ; MOS2 : Maize / Okra / Red Sorghum Intercrop ; O : Okra (NHAe47-4) ; S1O : White sorghum / okra intercrop ; S2O : Red sorghum/okra intercrops.

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Experimental Evaluation of Solar Dryer for Kokam Fruit

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Abstract – Rotary solar dryer developed and evaluated for Kokam drying. Kokam fruits were selected as drying material. Time required reducing the moisture content upto 10 % as a safe storage for solar dryer was observed for ripen and unripe kokam fruits. Evaluation parameters were collection efficiency, system drying efficiency, pick-up efficiency, moisture ratio and drying rate. Maximum temperature inside the foldable solar dryer was 570C whereas maximum ambient temperature observed was 35.30C and solar irradiation was 600 W/m2.Humidity varies from 32.2% to 22.3% inside the solar dryer whereas outside humidity varies from 43.02% to 29.35%. Overall collection efficiency was found as 70.97 %. Maximum drying efficiency for salted ripen kokum was 9.88 per cent and unsalted salted ripen kokum was 7.66 percent.

Keywords : Collection efficiency, System drying efficiency, Pick-up efficiency, Moisture ratio, Drying rate.

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Experimental Evaluation of Solar Dryer for Kokam Fruit

S. H. Sengar [α], A. G. Mohod [σ], & Y. P. Khandetod [ρ]

Abstract - Rotary solar dryer developed and evaluated for Kokam drying. Kokam fruits were selected as drying material. Time required reducing the moisture content upto 10 % as a safe storage for solar dryer was observed for ripen and unripe kokam fruits. Evaluation parameters were collection efficiency, system drying efficiency, pick-up efficiency, moisture ratio and drying rate. Maximum temperature inside the foldable solar dryer was 57^{0}C whereas maximum ambient temperature observed was 35.3^{0}C and solar irradiation was 600 W/m2.Humidity varies from 32.2% to 22.3% inside the solar dryer whereas outside humidity varies from 43.02% to 29.35%. Overall collection efficiency was found as 70.97 %. Maximum drying efficiency for salted ripen kokum was 9.88 per cent and unsalted salted ripen kokum was 7.66 percent.

Keywods : Collection efficiency, System drying efficiency, Pick-up efficiency, Moisture ratio, Drying rate

I. Introduction

The kokum is famous in Goa and Maharashtra for its cooling and anti-cholesterol properties (Mumtaz Khalid Ismail (2009)). The present area under kokum is 5000 hectares. It is proposed to increase this area up to 100000 hectares by the year 2025. It is further proposed to increase the productivity of these crops from the present level of 10 t/ha. to 15 t/ha. The pulp of the fruit is a very popular culinary ingredient in Maharashtra and in particular Konkan. (Lele, 2008) The fruits are beaten with sticks to separate the rind from seeds. The rind is repeatedly sun dried after soaking in the pulp juice. The dried purplish rinds, known as Kokum, are used for imparting flavour and taste to curries (Konkani cuisine (2009), much in the same way as tamarind fruit pulp is used in South India. The fruit is anthelmintic and cardiotonic and useful in piles, dysentery, fumours, pains and heart complaints. Kokam butter as sold in markets consists of eff shaped lumps or cakes, having a greasy feel and a bland oily taste. It is used mainly as edible fat. It is also used as an adulterant ghee. Kokum butter is considered nutritive, demulcent, astringent, suppositories and other pharmaceutical preparations.

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Solar energy in Konkan region was available for 8 to 9 months in a year with average sunshine hours ranged from 6.5 to 8 hours per day. The average solar energy ranged between 450-500 cal/cm2-day. The average lowest temperature for Konkan region was 15 ^{0}C and average highest temperature was 35^{0}C. At present these fruits are used for drying due to their availability and good market value at local level. It is a fruit dried and used as sour agent in cookery. Since anthocyanin is present, it is also used in making sherbet. The only alternative available is drying (Senadeera et al.,2003), which is most important techniques of food preservation (Menon and Muzumdar, 1987). To reduce the processing losses during the drying and to retain the quality of dried product, it is necessary to dry such fruit in the close chamber(Lambert, 1980) with preventing product from dust, insect, larva, birds and animal (Ong, 1999). By keeping importance of kokum drying in region, low cost rotary solar dryer was developed to carry out solar drying study.

II. Materials and Methods

a) Construction of low cost dryer

The low cost solar rotary dryer was design to dry commodities under hot and humid conditions prevailing in Konkan region of Maharashtra where most of the agricultural products need drying (Potdukhe and Thombre, 2002). This dryer can be rotated from all sides for easy to loading and unloading the material.

Dryer (Figure 1a & b) having a size 92cm x 75 cm was made by locally available bamboo, which consist of three main parts, collector, drying chamber and inlet and outlet openings (Koyuncu,2006). Drying chamber designed in such way that it consist 16 trays of 70cm x 50 cm size. Mosquito net was used for trays as it betters performance in humid region. Capacity of each tray is 0.6 kg. UV stabilized 200 micron plastic film was used for collection of solar energy (Best et.al., 1996). This film surrounded around the drying chamber and fixed by Velcro strip. Bottom and topside of the dryer was provided with openings for air circulation. Total cost of this dryer was Rs. 1700/-.

b) Measurements

The developed dryer was evaluated with standard procedure against the moisture removal and thermal analysis (Leon et.al, 2002). Total solar irradiation measured by using micro control based, liquid crystal

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solarimeter. The temperature and humidity at different location inside the drying chamber and outside environment was measured with thermocouple via a 8 channel dataloger (DataLog ver.v 81). In order to measure reading at a different point of air column through top and bottom of drying bed, temperature sensor were set at inlet and outlet as well as mid position of drying chamber. Airflow rate along the drying chamber was calculated by measuring the velocity of exist air at top opening through an anemometer.

c) Moisture Content

The percentage moisture content was determined by using following formula, (A.O.A.C. 1980)

$$\text{M.C.(w.b.)\%} = \frac{(W_1 - W_2)}{W_1} \times 100$$

$$\text{M.C.(d.b.)\%} = \frac{(W_1 - W_2)}{W_2} \times 100$$

Where, W_1= weight of sample before drying, gram

W_2= weight of bone dried sample, gram

d) Drying Rate

The drying rate (g/h/100g of bone dry weight) of kokum sample during drying period was determined as follows,

$$\text{Drying rate (D.R.)} = \frac{\Delta W}{\Delta T}$$

Where, ΔW = weight loss in one hour interval (g/100g of bone dry wt)

ΔT= difference in time reading (h)

The drying was carried out by loading the weighted kokum fruits in dryer from morning 8:00 am to 17:00 pm. The kokam fruits were dried up to the final moisture content of (Malviya and Gupta 1985) 10 % (w.b.) (Siaka and Nkembo, 2004). The drying time required for drying the ripen and unripe kokum fruits from IMC to 10 % (wb) in solar dryer condition was critically observed.

e) Moisture Ratio

The Moisture ratio of prawns was computed by using the initial moisture content (IMC) and equilibrium moisture content (EMC)

$$MoistureRatio = \frac{(M - M_e)}{(M_o - M_e)}$$

where,

M = Moisture content (d.b.), %

M_e = EMC, (d.b), %

M_0 = IMC, (d.b), %

The EMC for kokum fruits was considered as 10 % (w.b.) Drying tests of kokum fruits sample under solar dryer conditions was carried out.

f) Weight measurement

Moisture removal rate was calculated by taking 1000 g samples among the commodities. These samples were measured using weight balance with accuracy up to ten milligram.

g) No load test and load test

Dryer was tested with no load test for the thermal profile, which could be suitable for drying of kokum fruits. As per the thermal ingredients, collection efficiency of dryer was calculated. The purpose of load test to calculate the time required drying the commodities as well as to find out the system drying efficiency and pick up efficiency of dryer.

III. Results and Discussion

a) No load test

i. *Analysis of Temperature profile inside the dryer*

Under no load condition of solar drying, radiation and temperature inside the collector were measured with time of day in the interval of 10 minute were plotted in Figure 2. Maximum temperature observed at tray no 4 at 13 pm was 57^{0}C while 38.7^{0}C at 10:54 am, 41.6^{0}C at 12:24 pm, 46.3^{0}C at 15:04 pm, and 55.1^{0}C at 11.14 am for tray number 1, 2, 3, and 5 respectively whereas maximum ambient temperature observed was 35.3^{0}C at 12:54 pm and solar irradiation was 600 W/m2 at 11:14 am. Minimum temperature was observed at the end of the day at 17:00 pm for all bottom trays. It implies in total five slots of trays inside the drying chamber, increasing profile temperature was observed from bottom tray to upper tray. Humidity inside dryer was minimum as compare to outside condition. Humidity varies from 32.2% to 22.3% inside the solar dryer whereas outside humidity varies from 43.02% to 29.35% shown in Fig.3.

In no load test temperature inside the dryer increases from bottom tray to upper tray due to decreasing air density as it passes through hottest zone. Lower tray of dryer contain minimum temperature because of just below the lower tray there is opening for fresh air entrance in dryer where the density of air is higher as compare to trays above lower trays. Top-most tray inside the dryer is not achieved maximum temperature as it just above upper tray, opening is provided to pass the hot air and hence maximum temperature was observed at tray number 4 which was hottest zone (T4) below the upper tray (T5). As the temperature increases humidity decreases, as per this phenomenon, humidity's inside the dryer was minimum as compare to outside condition of dryer. Optimum Collection efficiency was found inside rotary solar the dryer due to it exposes three sides of dryer to sun as well as it was perfectly airlock so as it gives better hot air draft.

ii. *Collection Efficiency*

Collection efficiency is defined as the ratio of heat received by the drying air to the insolation upon the absorber surface and is calculated from equation (i).

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$$n_c = v \times \rho \times C_p x \times \Delta t \times C_p \div A_C \times I_C \quad \text{(i)}$$

Where,

V= Volumetric flow rate of air (m^3S^{-1}), ρ = Air density (kgm^{-3}), ΔT= Air temperature elevation (K), Cp = Air specific heat ($Jkg^{-1}K^{-1}$), Ac= Collector area (m^2), Ic= Insolation on collector surface (Wm^{-2}).

Since η_c is a assessing of the performance of collector, it was calculated using the reading for no load tests shown in Figure 4 and overall collection efficiency was found as 70.97 % (Tiris, et.al., 1995).

b) Load test

i. *Moisture content, drying rate and moisture ratio variation*

Kokum fruits were selected for load test under rotary dryer. Initial moisture content was found to be 85-93 per cent in laboratory test for ripen and unripe kokum. These kokum fruits were dried upto 10 per cent moisture content inside the solar dryer. Time required to each condition for kokum drying was calculated. Salted ripen kokam inside the dryer required 15 hours to dry upto 9.62 per cent while unsalted ripen Kokum required 21 hours to reach moisture content upto 9.62 per cent. Unsalted unripe Kokum inside the dryer took 27 hours time to reach upto moisture content 9.67 per cent whereas salted kokam required 32 hours to dry upto 10.12 per cent shown in Figure 5. Trend observed during the kokum drying inside solar dryer for drying rate and moisture ratio was depicted in Figure 6.

In load test of dryer, kokum required more time in open condition due to minimum temperature and maximum humidity's and vice versa in solar drying conditions. Use of salt treatment to kokum before drying helpful to remove moisture rapidly as compare to unsalted kokum and it also gives better colour than dried unsalted kokum (Dubey and Pryor,1996). Drying efficiency and collection efficiency depends on the removal of moisture from kokum and hence maximum drying efficiency and collection efficiency was found in salt treatment method.

ii. *Drying Efficiency (ηd)*

Amount of heat required to evaporate the moisture inside the product is called as drying efficiency. Total heat in case of solar dryer is the availability of solar radiation on collector surface of the dryer. This drying efficiency was calculated by equation no. (ii)

$$n_d = w \times \Delta H_L / A_C \times I_C \quad \text{(ii)}$$

Where,

W= moisture evaporated (kg)

ΔH= Latent heat of vaporization of water, 2320 (kJkg-1)

Id= Total hourly insolation upon collector, (Wm-2)

Ac= Area of collector (m2)

Maximum drying efficiency for salted ripen kokam was 9.88 per cent and unsalted salted ripen kokum was 7.66 per cent. For salted and unsalted unripe kokum, maximum efficiency was found as 4.72 per cent and 4.20 per cent respectively depicted in Fig. 7. Where as pickup efficiency (Balladin, et.al., 1997) for salted and unsalted kokam was found as 3 per cent cent respectively shown in Figure 8.

IV. Conclusions

1. Rotary solar dryer generate higher air temperature and consequential lower relative humilities, which are both conductive to improved drying rates and lower moisture content of the drying kokum fruit.
2. Solar rotary dryer is suitable for domestic drying of kokum fruit upto10 kg capacity.
3. Best results were found in salted ripen kokum compare to unsalted unripen kokum inside the dryer.
4. The dried kokum had good colour and appearance.
5. Comparative cost of solar dryer is low.

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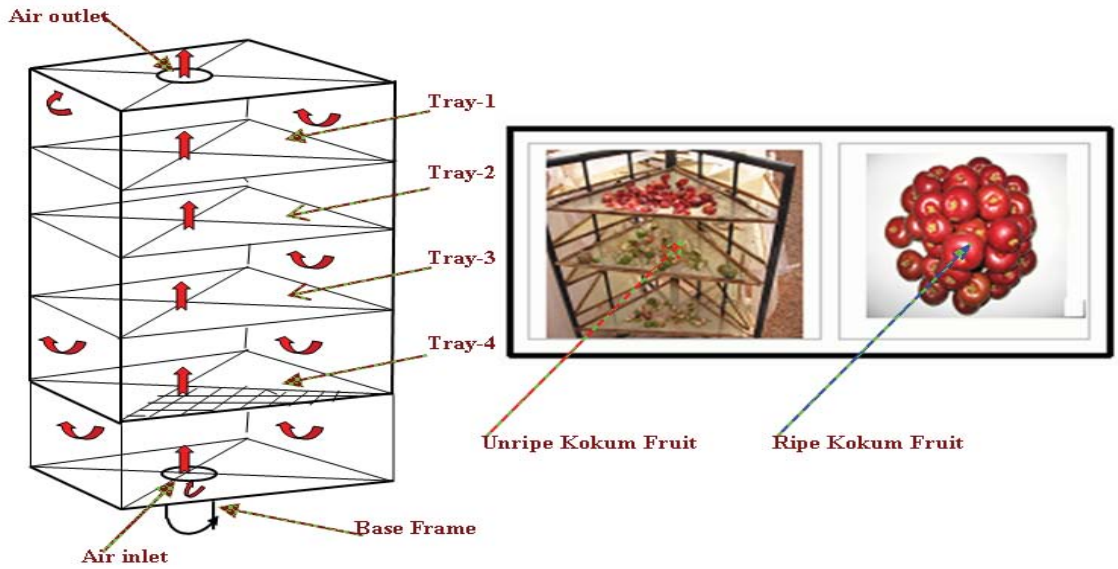

Fig.1 : Inside View of Rotary Solar Dryer.

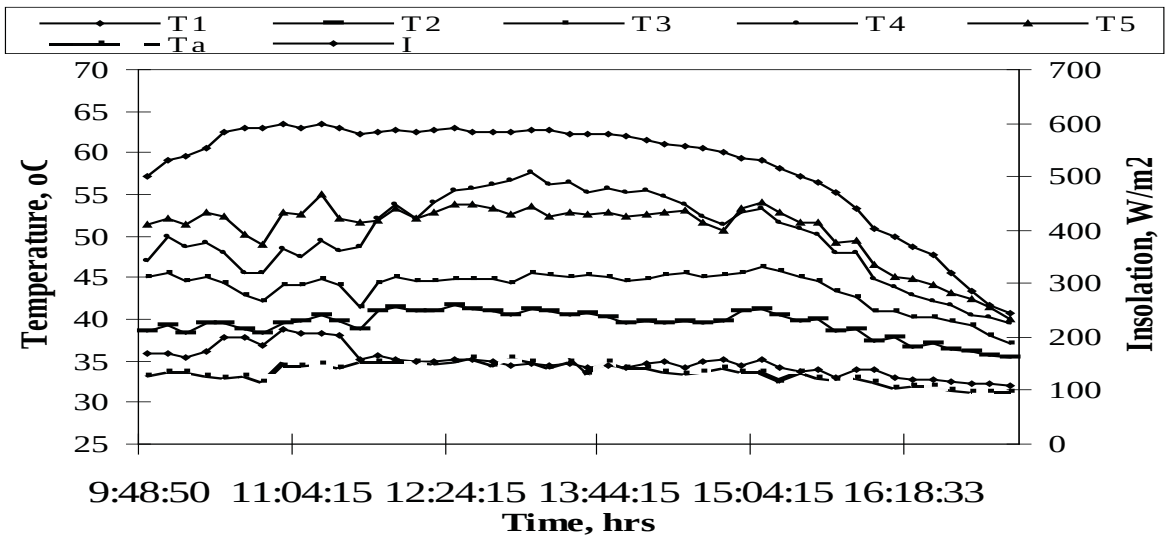

Figure 2 : Thermal profile inside the solar dryer.

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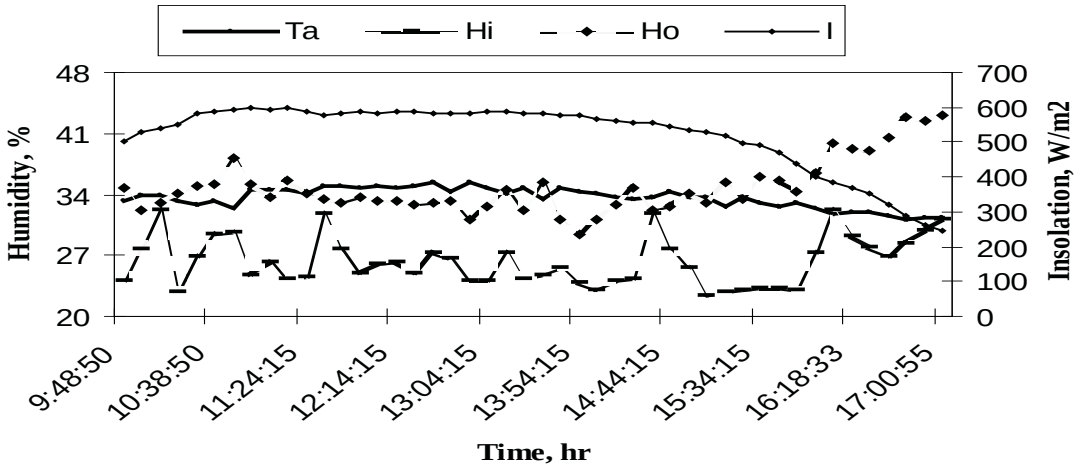

Figure 3 : Variation of humidity inside the solar dryer.

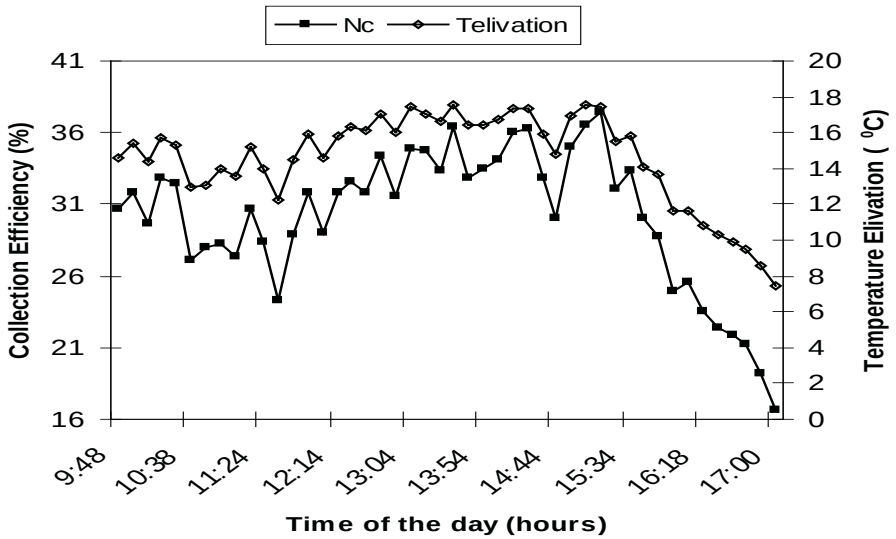

Fig. 4 : Variation of collection efficiency with time.

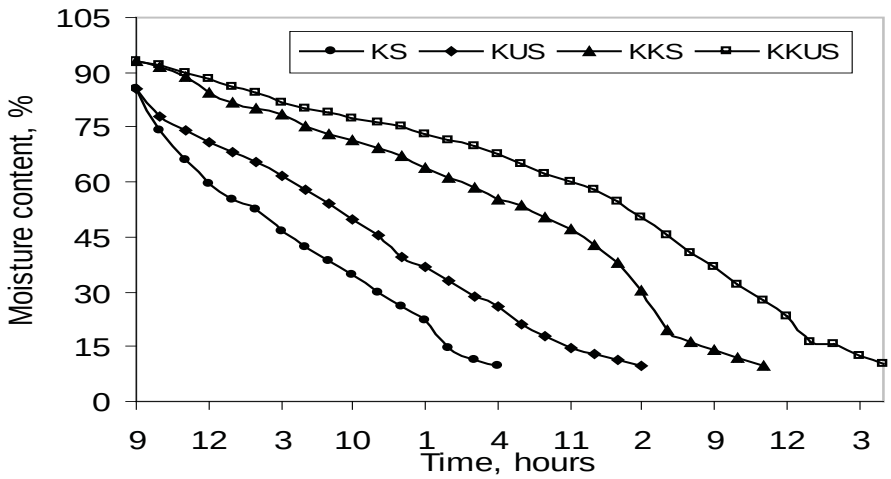

Fig. 5 : Variation of moisture content with time.

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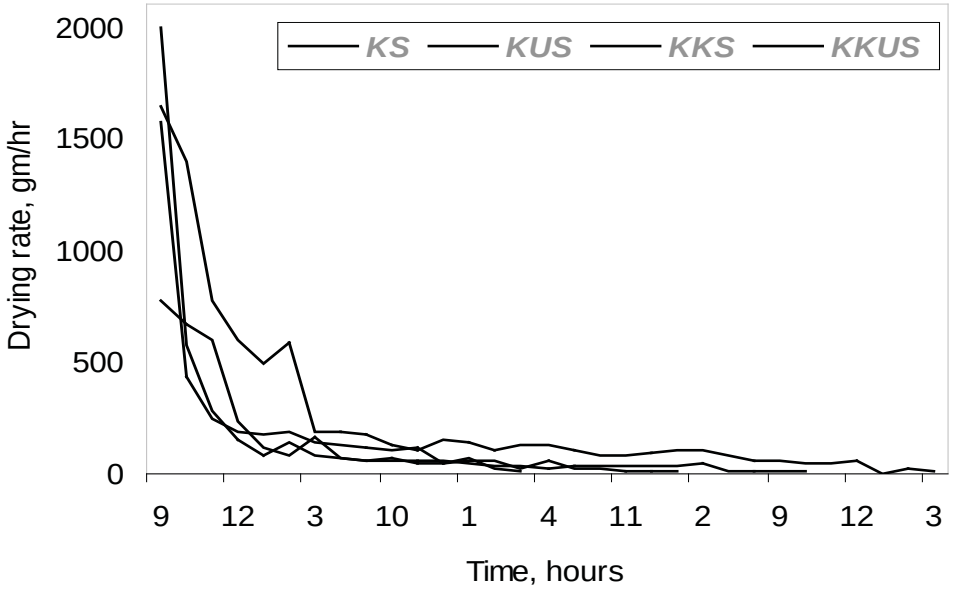
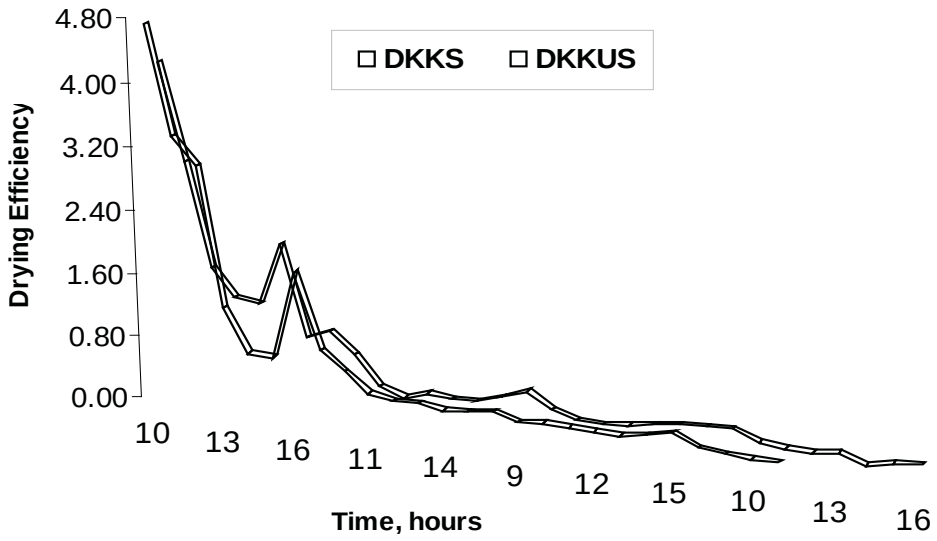
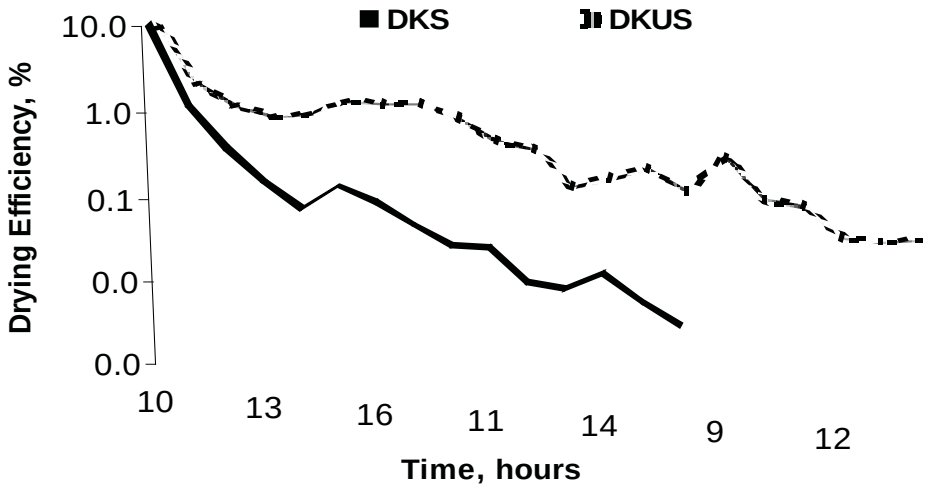


Fig. 6 : Variation of drying rate with time.



(a)



(b)

Figure 7 : Variation of drying efficiency with time

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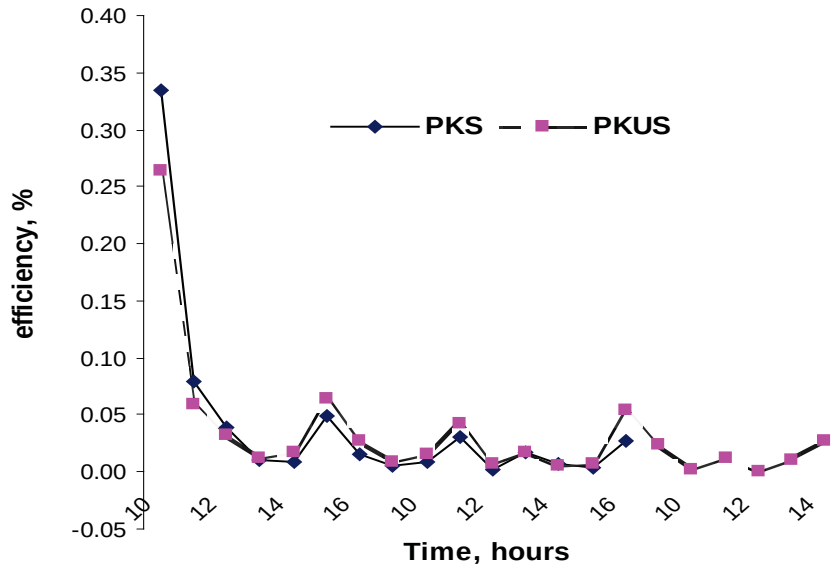

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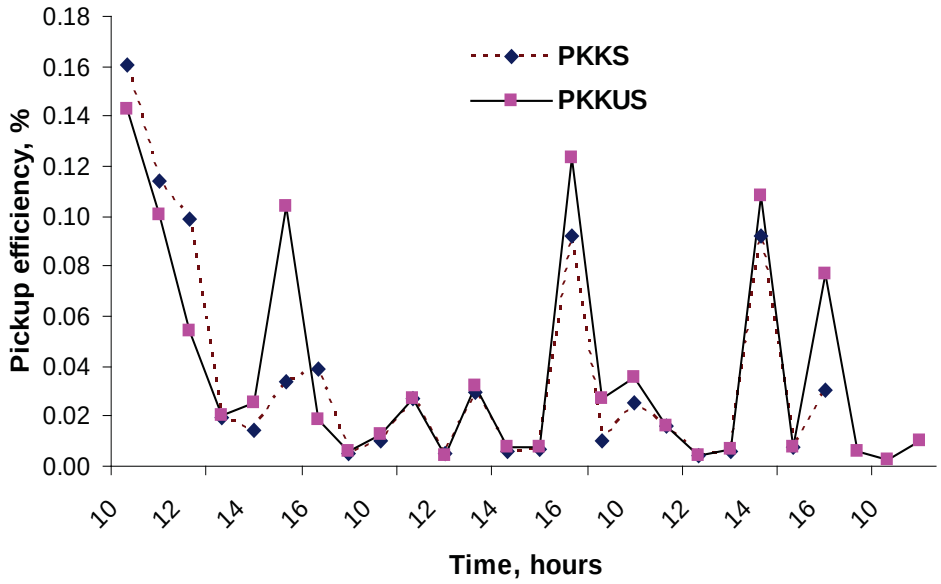

Fig. 8 : Variation of pickup efficiency with time.

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Choice of key words is first tool of tips to write research paper. Research paper writing is an art.A few tips for deciding as strategically as possible about keyword search:

- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

Acknowledgements: Please make these as concise as possible.

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

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Tables: Tables should be few in number, cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g. Table 4, a self-explanatory caption and be on a separate sheet. Vertical lines should not be used.

Figures: Figures are supposed to be submitted as separate files. Always take in a citation in the text for each figure using Arabic numbers, e.g. Fig. 4. Artwork must be submitted online in electronic form by e-mailing them.

Preparation of Electronic Figures for Publication

Even though low quality images are sufficient for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit (or e-mail) EPS (line art) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings) in relation to the imitation size. Please give the data for figures in black and white or submit a Color Work Agreement Form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution (at final image size) ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs) : >350 dpi; figures containing both halftone and line images: >650 dpi.

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the search? Will I be able to find all information in this field area? If the answer of these types of questions will be "Yes" then you can choose that topic. In most of the cases, you may have to conduct the surveys and have to visit several places because this field is related to Computer Science and Information Technology. Also, you may have to do a lot of work to find all rise and falls regarding the various data of that subject. Sometimes, detailed information plays a vital role, instead of short information.

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11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

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19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

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21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. **Think technically:** Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be

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32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

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Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

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- Insertion a title at the foot of a page with the subsequent text on the next page

- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

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· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

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The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

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shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

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The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

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- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
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- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

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- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

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The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
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- Present a background, such as by describing the question that was addressed by creation an exacting study.
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- Do not present the similar data more than once.
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- Never confuse figures with tables - there is a difference.

Approach

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- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

INDEX

N

P

R

S

T

V

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