EDITORIAL

AFRICA'S MUSHROOMS: A Neglected Bioresource whose Time has Come

Keto E. Mshigeni

ZERI Regional Office for Africa, UNDP/UNOPS Regional Project (RAF/99/021), University of Namibia, Private Bag 13301, Windhoek, Namibia, E-mail: kmshigeni@unam.na

Some of our readers, after assimilating the message contained in the Editorial of the last issue of our journal (D*iscovery and Innovation*, Vol. 15 Number 1/2, pp. 1-7), "*Surprises, scientific charm, socio-economic potential, and possibilities in the mushroom world*", wrote back, excited. One asked for more information on the Chinese mushroom farming experience with a view to exploring how Africa could also make it. Another wrote on the reticulately veiled mushroom collected from western Uganda, the edible *Dictyophora* mushroom, which had been mentioned in the previous Editorial. One who had read our other publications on Africa's mushroom resources, had exciting novel information to share about one of Africa's neglected wild mushrooms: *Ganoderma applanatum*.

In response to the positive feedback from our readers, and especially to the request for more information on the development of China's mushroom farming industry, we requested Prof. Shu-Ting Chang, Professor Emeritus at the Chinese University of Hong Kong, to contribute an invited article doing just that. Professor Chang's article appears in this volume.

There is no doubt that the wealth of information articulated in Prof. Chang's contribution, will be found to be extremely beneficial to Africa's scientists in our various universities, and in our Science and Technology (S & T) and Research and Development (R & D) centers. We believe that China's success story will also be of great interest to African leaders responsible for education and training, economic planning, sustainable resource development and management, rural development, women empowerment, and poverty reduction. It is our hope also, that the various agencies playing a significant role in Africa as our various Governments' development partners, will similarly take a keen interest towards assisting African nations to develop the continent's mushroom resources: a bioresource whose time has come.

In our previous Editorial, we had indicated that as we go to the field to learn more about Africa's mushroom resources, we always encounter pleasant surprises. Listen to this one, shared by Gareth Patterson, an author, a wildlife researcher and environmentalist, almost certainly known to many of our readers. The surprise came to me in the form of an e-mail letter. I am reproducing extracts from the letter, with permission. The letter read (and I quote):

> *"… Dear Professor Mshigeni:*
> *I was reading about aspects of your very interesting work in Namibia, and I thought I would contact you regarding my findings about Ganoderma applanatum and the rare Knysna elephants I have been studying in Southern Cape, South Africa…*
>
> *"…What I thought would be of interest to you is that I discovered that these elephants routinely eat Ganoderma applanatum. This came as a surprise to me, as well as to elephant experts I have been in contact with in various parts of the continent and in Asia. It seems it has never been known before for elephants to eat Ganoderma. I have been looking into whether this might be a case of self-medication/health maintenance...*
>
> *"…It is known that primates such as Bonobos, chimps, and gorillas also all relish these brackets, so much so that upon finding them this can cause inter-troop squabbles! But fungus eating is still a puzzle in primate research circles. No one has determined why they eat it. Again, I feel, but cannot prove, it may be eaten for medicinal or health maintenance reasons…*
>
> *"…What I have learnt here is that the Ganoderma is clearly important to these elephants, and is commonly eaten. I have found Ganoderma in more than 50% of all dung samples that I have analysed…"*

"…Interestingly, some of the people who live in the vicinity of the forests boil elephant dung in water (just like a tea, really) and drink the liquid for health maintenance purposes: much like how Ganoderma was/is taken as tea traditionally in China… I feel that the medicinal benefits people obtain from the dung is probably from Ganoderma…" (end of quote).

Gareth Patterson, the author of the e-mail extracts presented above, requested for information on whether the UNDP-funded Regional ZERI Project for Africa on Sustainable Development from Africa's Biodiversity, based in Namibia, is involved in research on Africa's *Ganoderma* species, and on their cultivation. The answer is in the affirmative. Thanks to UNDP Africa and to UNOPS facilitating the implementation of this vision.

Ganoderma is a woody, robust mushroom which needs strong physical support (Figure 1). It normally grows on the trunks of woody trees and shrubs, or on lignocellulosic residues below the ground. We have collected wild G*anoderma* plants growing on a wide range of tree species (both wild and cultivated), including coconut palm trunks, bamboo stems, montane forest trees, and wood buried in the soil in Namibia's Kalahari desert ecosystem.

To sustain Africa's wild *Ganoderma* populations, and to protect the various species against possible extinction, we must promote more afforestation and agroforestry, and we must conserve our various woodland ecosystems.

In many of the locations visited in Africa, *Ganoderma* mushrooms are ignored by the communities. However, among some communities such as the Wapare people of Tanzania's Kilimanjaro Region, the mushroom is used as a traditional remedy against some livestock diseases, including eradicating parasitic worms (Härkonen e*t al*., 1995). More research is needed here.

There is a growing body of scientific knowledge supporting the notion that G*anoderma's* natural products display a strong medicinal potency against many ailments. It is reported to be an antitumour, antiviral, antibacterial, and antiparasitic. It is also documented to be effective as an anti-inflammatory, as a kidney tonic, as a hepatoprotective, and as a blood pressure regulator. Additionally, it is reported to be effective in boosting the body's immunoresponse system (Chang and Mshigeni, 2001; Gao, *et al.*, 2003).

Thus Gareth Patterson's hypothesis that the routine consumption of *Ganoderma* mushrooms by the Knysna elephants might be a case of self-medication/maintenance seems plausible. Verification of that hypothesis calls for collaborative research amongst wildlife scientists, mushroom scientists, and medical practitioners.

In that regard, considering the reported immunoboosting attributes of *Ganoderma* mushroom natural products, the Namibia-based UNDP-funded Regional Project has initiated a collaborative regional R&D activity, under the scientific leadership of Africa's senior medical practitioners, in partnership with Africa's relevant government ministries and other collaborators, which involves clinical testing trials of *Ganoderma* mushroom nutriceuticals on HIV/AIDS victims. The clinical testing R&D activity will make use of a common, regionally developed standard testing protocol. The preliminary results reported so far, show good promise.

It is not inconceivable that the collaborative research initiative on the testing of *Ganoderma lucidum* nutriceuticals against HIV/AIDS may make a meaningful contribution towards finding a sustainable solution to the devastating pandemic, which is continuing to kill millions of people in Africa. The thinking along these lines is reinforced by the fact that HIV/AIDS involves the destruction of the body's immune system. Hence, if we could identify potent immune system boosters, like what G*anoderma* is claimed to be, whose biomass can be augmented through farming (farming by Africa's rural and peri-urban communities), then it would not be difficult for one to see the merits of the R & D activity.

The mushroom farming technologies developed over the years in China and other countries in East Asia, as elaborated in the contribution by Prof. S.T. Chang in this volume, can be adapted for use in Africa. Indeed, through several regional workshops hosted by the UNDP/UNOPS ZERI Regional Project, based in Namibia, with Prof. Chang as the key Resource Person, an increasing number of African scientists have now assimilated the basic technologies involved in mushroom farming. These pioneers will continue to perfect both the science and the art of mushroom farming through more training and mushroom production practice. Already some have begun to generate an impact in their respective countries. But definitely, many more mushroom scientists need to be trained, who, in turn, will train more farmers in rural communities.

Ganoderma and other mushrooms can be farmed using lignocellulosic biomass (e.g. sawdust), which, in Africa, is available in abundance. Artificial sawdust which is usable as a mushroom substrate, can be generated from a wide spectrum of agricultural crop residues and wastes, including chopped grass straw, chopped tree branches, and also from other categories of lignocellulosic residues from Africa's savannah grassland, woodland, and forest ecosystems. Figures 2 and 3 show healthy G*anoderma* and *Pleurotus*

(oyster) mushrooms supported nutritionally by sawdust placed inside plastic bags and plastic bottles, respectively, resting on wooden frames in a mushroom shed. Through stretching the of powers of imagination, a wide spectrum of other production methods, tailored to suit the dictates of the local environment, can be developed.

Figure 1: *Ganoderma* mushroom growing on dead bamboo stem

Photo: Keto E. Mshigeni

Figure 2: *Ganoderma lucidum* mushroom cultivated using sawdust placed in plastic bags

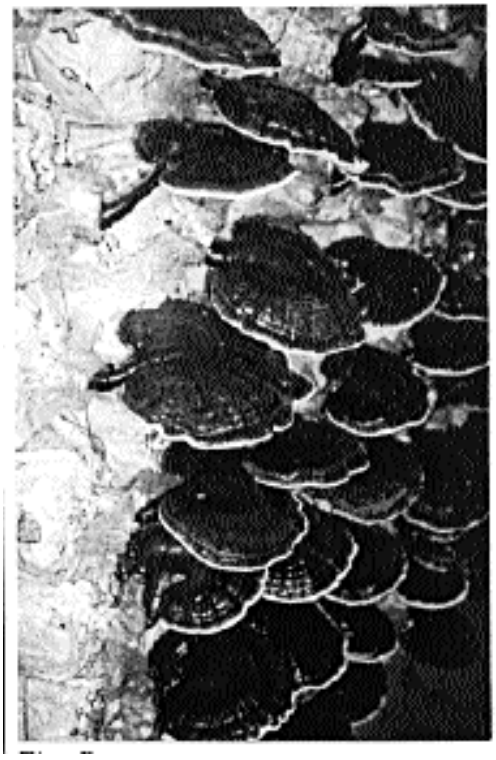

Photo: Keto E. Mshigeni

Figure 3: Healthy oyster mushroom *(Pleurotus sp.)* grown in lignocellulosic subtrate placed in plastic battles

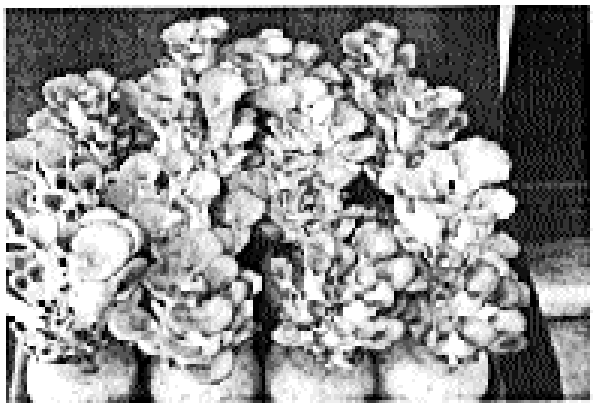

Photo: Keto E. Mshigeni

As we develop Africa's mushroom production industry, we need to establish good mushroom R&D laboratories, managed by a critical core of well trained scientists, who are organically linked to the mushroom growers through extension services. We need also to develop strategies on the popularization of mushroom farming and mushroom eating, especially considering their special tastes and unique flavours; their superior health benefits (e.g., some being medicinal, rich in protein, vitamins, and essential macro-and micronutrients); their fast growth rates; and also the fact that they can also be grown by the poor and the landless, if well trained as one does not need expensive stretches of land to farm them. If effective post-harvest crop handling and marketing strategies are developed simultaneously, we see Africa's mushrooms becoming a strong agent towards realizing our millennium goal of poverty reduction.

Coming back to the story shared by Gareth Patterson, I can see our R&D activities on Africa's mushrooms generating widespread multiplier effects. Do the ecologically conscious Namib desert elephants also crave for *Ganoderma* mushrooms? Can the same be said of the Serengeti ecosystem elephants in East Africa? I see more of our continent's scientists going to the field and confirming what Gareth Patterson has shared with us. I see our mushroom scientists also making a contribution towards helping nature.

At the right season, the scientists could inoculate many tree trunks in the elephant ecosystems with Ganod*erma* mushroom "spawn bullets", thus artificially "seeding" *Ganoderma* onto the trees. Holes of specific size would first be drilled into the tree trunks. Sawdust inoculated with *Ganoderma* spawn would then be pushed into the holes on the trees. The entrance would then be sealed with appropriate

material. The rest would then be left to the dictates of nature. Will it work? Nothing is impossible to a willing mind!

In summary, from Professor Chang's enriching contribution, and from the various inputs contained in this Editorial, I believe that there is sufficient ground for suggesting that time is ripe for the commencement of Africa's mushroom R&D revolution involving the teaching mushroom science differently, and at all levels of the school and university system. A revolution involving the establishment of National and Regional Mushroom Research Laboratories, or Mushroom Research Institutes. A revolution calling for the establishment of mushroom farming demonstration centers for both edible and medicinal mushrooms; and for mushroom processing and value-addition centers. And, a revolution towards promoting the habit of eating mushrooms and mushroom nutriceuticals regularly, in recognition of their health ameliorating benefits. We must take China's experience seriously.

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GUEST COMMENTARY

Development of the Mushroom Industry in China, with a Note on Possibilities for Africa

Shu-Ting Chang

Emeritus Professor of Biology and Director of Centre for International Services to Mushroom Biotechnology; The Chinese University of Hong Kong, Shatin, N. T. Hong Kong, China

Introduction

Witnessing the Development of the Mushroom Industry in China

In 1978, I was invited by Ministry of Light Industry to conduct the first Mushroom Training Workshop in China, which was held in Beijing for two weeks. At that time, the annual production of edible mushrooms in China was only 60,000 tonnes. However in 2002, China's mushroom production was over 8.6 million tonnes (Table 1). Table 1 also shows the growth rate of each interval period and the average annual percentage increase for China's mushroom production.

Now, China is a leading producer and consumer of both edible and medicinal mushrooms. In 1978, China's production of edible mushrooms accounted for only 5.7% of total world production. The percentage contribution of China's mushroom production to world mushroom production has increased steadily through the years, as indicated in Table 2. The production of mushrooms in China increased to 174,500 tonnes in 1983 (Chang, 1990), which accounted for 12.0% of the world output. In 1986, the total output of mushrooms in China increased to 568,000 tonnes, representing 27.0% of the total world production which had reached 2.18 million tonnes that year. The year 1990 can be considered the turning point in mushroom production in China. It was the year in which for the first time China produced more than one million tonnes of cultivated edible mushrooms, accounting for more than 28.0% of world mushroom production. Since then, the output of China has been growing steadily at a rate of 18.0 to 20.0% per annum.

The total production of cultivated edible mushrooms in 1994 was 2.6 million tonnes, which amounted to 54.0% of the world output. In 2002, the production of cultivated edible mushrooms in China was over 8.6 million tonnes which accounted for about 70.0% of the world total output. In addition, the number of species of edible mushrooms cultivated in China has been increasing over the years as well (Table 3). Whereas the dynamics of production have been maintained for quite a few years, the recent data indicate that the buoyant development is far from reaching its limits.

In 2002, over 80% of China's mushroom production was consumed domestically and less than 20% was exported. This is in sharp contrast with the situation in the 1980s when over 80% of mushroom productions in China was exported. However, it should be emphasized here that both mushroom crops (mushroom themselves) and mushroom products (mushroom derivatives) should be of good quality and free from potentially harmful substances. Reproducible quality, recognized grade and trustworthy products are of paramount importance in earning enduring public credibility, and in securing an expanding and stable market. However, as the market develops, and mushroom-based products assume more functional food and mushroom nutriceutical (dietary supplement) roles, regulatory controls will inevitably become more stringent. Three levels of control should be considered: (1) control of the raw materials, (2) control of the cultivation and manufacturing processes, and (3) control of the final products.

Table 1: Production of farmed mushrooms in China during the period 1978 to 2002

Year	Production (x 1000 MT)	Growth rate (%)	Av. annual increase (%)
1978	60.0	-	-
1986	586.0	876.7	109.6
1990	1,000.0	70.6	17.6
1994	2,600.0	160.0	40.0
1996	3,500.0	34.6	17.3
1997	3,918.3	12.0	12.0
2000	6,630.0	69.2	23.1
2001	7,818.0	17.9	17.9
2002	8,650.0	10.6	10.6

Sources: Chang, 1999; Huang, 2000, Lin, 2002.

Table 2: China's contribution to World mushroom production since 1978.

Year	World Production (x1000t)	China's Production (x1000t)	Contribution by China (%)
1978	1,060.0	60.0	5.7
1983	1,453.0	174.5	12.0
1986	2,176.0	585.0	26.8
1990	3,763.0	1,083.0	28.8
1994	4,909.3	2,640.0	53.8
1997	6,158.4	3,918.0	63.6
2002	12,250.0*	8,650.0	70.6

*Author's own estimation (estimated from previous historical records)
Source: Chang, 1991, 1992, 1999; Huang, 2000; Miles and Chang, 1986.

Table 3: Production of cultivated edible mushrooms in China in various years (x1000 tonnes).

Species	1986	1998	2000*	2001*
Agaricus bisporus	185	426	637	743
Lentinula edodes	120	1338	2205	2072
Pleurotus spp.	100	1020	1723	2594
Auricularia spp.	80	491	968	1124
Volvariella volvacea	*100*	32	112	116
Flammulina velutipes	10	189	299	389
Tremella spp.	50	100	103	114
Hericium erinaceus	50	28	6	9
Hypsizygus spp.	-	21	84	120
Pholiota nameko	0.8	31	48	51
Grifola frondosa	-	10	6	15
Others^	-	664	446	471

Source: Chang 1987; Chang & Miles 1993; Huang 2000.
* Estimated figures, courtesy of Chinese Mushroom Association (CMA).
^ There are several new species of mushrooms that have been cultivated recently in China on a small commercial scale but have great potential for further expansion, e.g. *Agaricus blazei, Lepista nuda,* Pleu*rotus eryngii, Agrocybe aegerita, Tricholoma giganteum, Auricularia fuscosuccinea, Tremella cinnabarina, Pleurotus cornucopiae, Pleurotus ferulae, Pleurotus ferulae var. nebrodensis, Oudemansiella radicata, Agrocybe chaxinggu, Coprinus comatus, Dictyophora spp.* etc.

During the past 25 years, I have been invited to conduct more than 80 mushroom training courses/workshops/seminars in 22 provinces in China. I have also been invited to tour rural villages in guiding and discussing the mushroom cultivation problems with mushroom farmers in over 140 counties all over China. The biggest and longest training course was held in Shijiazhuang, capital of Hebei province lasting over three weeks, from 3 July to 23 July 1983. 230 mushroom scientists, researchers and farmers from 25 provinces attended the course. The course consisted of lectures during the mornings and practical demonstrations/discussions in the afternoon sessions. The content of the training course has been published in a small booklet, in Chinese, entitled "The Genetics and Breeding of Edible Mushrooms".

The successful implementation of mushroom farming strategy has the possibility of engaging thousands, if not millions of farmers, in the industry. The production of mushrooms in China is highly decentralised. However, some 24 counties in seven provinces have each produced edible mushrooms in excess of 100 million Yuan (12 million USD) per annum. These 24 counties are spread across China, with Fujian, Henan and Zhejiang with six counties each, Shangdong with three, Hunan, Jiangshu and Sichuan with one each (as shown in Table 4).

Table 4: Twenty four most productive counties of cultivated mushrooms in China in 1996

County	Province	Value (million Yuan)	Value (million USD)
Shouning	Fujian	570	71.3
Biyang	Henan	520	65.0
Qingyuan	Zhejiang	370	46.3
Xixia	Henan	340	42.5
Lushan	Henan	320	40.0
Gutin	Fujian	280	35.0
Pan'an	Zhejiang	280	35.0
Jintang	Sichuan	270	33.8
Shinyau	Fujian	220	27.5
Zehenhe	Fujian	210	26.3
Liaocheng	Shangdong	200	25.0
Lushi	Henan	160	20.0
Xinxian	Shangdong	150	18.8
Sheyang	Jiangshu	150	18.8
Muping	Shangdong	150	18.8
Jingning	Zhejiang	149	18.6
Fugou	Henan	128	16.0
Jinyun	Zhejiang	125	15.6
Songyang	Zhejiang	120	15.0
Lining	Hunan	120	15.0
Pingnan	Fujian	110	13.8
Boshan	Henan	108	13.5
Yunhe	Zhejiang	100	12.5
Changting	Fujian	100	12.5

(exchange rate 8:1)

Source: Chang, 1999.

Magnitude of the Number of Mushroom Species

Out of the 1.5 million estimated fungi, Hawksworth (2001) has estimated that 140,000 species produce fruiting bodies of sufficient size and suitable structure to be considered as macrofungi. These can be named as mushrooms according to the definition of a mushroom as "a macrofungus with a distinctive fruiting body which can be either epigeous (above ground) or hypogenous (under ground) and large enough to be seen with the naked eye and to be picked by hand" given by Chang and Miles (1992). Hawksworth's (2001) above figure can be considered as a working estimate for the number of mushroom species actually present on earth. This implies that we currently know about 14,000 of all mushroom species, which account for 10% of the estimated 140,000 mushroom species. Of these, about 50% (7,000 species) are considered to possess varying degrees of edibility, and more than 3,000 species from 31 genera are regarded as prime edible mushrooms. But only 200 of them are experimentally grown, 100 economically cultivated, around 60 commercially cultivated, and more than 10 have reached an industrial scale of production in many countries. Furthermore, about 2,000 possess medicinal properties. The number of poisonous mushrooms is relatively small (approximately 1%). Of these some 30 species are considered to be lethal (Miles and Chang, 1997).

Mao (2003) has estimated that China has about 1500 to 2000 edible mushroom species and, at present, there are 981 known edible species (Table 5).

Table 5: Number of known edible domesticated, and commercially cultivated mushroom species in China from 1950 to 2002

	1950	1951-1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-2002
Edible Mushroom species	50	100	200-260	300-350	360-655	720-838	981
Domesticated species	5	7	10	16	50	86	92
Commercially cultivated species	5	5	7	9	16	26	50
Exported species, including wild mushrooms	4-5	5	6	6-7	8-18	33	35

Prior to 1983, the key mushroom industry in China was *Agaricus bisporus*. This mushroom was first introduced into Shanghai, China by French missionaries in 1930. However, the cultivation was disrupted during the Second World War. Following the trend of production, first in Taiwan in the 1950's, then South Korea in the 1960's, China resumed its cultivation of this mushroom in the 1970's. However, at that time, China's yield per unit was generally and comparatively low. Since the introduction of the Phase II composting technology into China in the Mushroom Training Workshop in Beijing in 1978, there has been a gradual increase in production capacity of *Agaricus bisporus* during the following four years. Afterwards, drastic improvements in production capacity were witnessed, due to familiarisation and improvements of the new composting technology, and also due to later introductions of selected high-yield and more adaptive strains.

In 1983, production of *Agaricus bisporus* in China was already gaining world prominence. The world production of *Agaricus* mushrooms in 1983 was one million tonnes and the production of the mushroom in China was 130,000 tonnes (Wang, 2000), which accounted for 13.0% of world mushroom production. The Production of the mushroom in Fujian had reached to 45,000 tonnes, which represented about 35% of the national production, and became the leading province of production of the mushroom in China from that year onwards. However, the national production of other species of mushrooms was still at infant stages. For example, the production of *Lentinula edodes* in 1983 was only 19,500 tonnes, which represented about 9.4% of the world total production of 206,700 tonnes (Royse, *et al.*, 1985). In that year, Japan produced 171,200 tonnes of this mushroom, which contributed to 82.8% of the world output. However, 14 years later, the production situation of *Lentinula* mushrooms has had a drastic change. In 1997, the share of China's *Lentinula* production (1,125,000 tonnes) had risen to 85.1%. On the other hand, the percentage of *Lentinula* contribution from Japan dropped from 82.8% in 1983 to 10.0% in 1997 (Table 6).

A comparison of the *Lentinula* production in 1985 and 1995 indicates that during the ten years, China increased her production by 1,060%, while Japan, Korea and Taiwan decreased their production by 46.5%, 23.2% and 82.2% respectively. Now China has become the world's largest producer, exporter and consumer of *Lentinula* mushrooms. The mushroom was usually regarded as a mushroom from Eastern Asia, but now its cultivation is rapidly spreading to other parts of the world. It is expected that production of this fastest growing species of mushroom, which can be used for both food and medicine, will continue expanding. The average biological efficiency of using synthetic sawdust is about 60-80 per cent over a period of six months. With an extended cropping period, 100 per cent yield is not unusual.

Table 6: World production of *Lentinula edodes* in different years in fresh weight metric tons x 1,000

Country	1983	1985	1991	1992	1993	1994	1995	1996	1997*
	Volume %	Volume %	Volume %	Volume %	Volume %	Volume %	Volume %	Volume %	Volume %
China	19.5 9.4	50.0 13.9	380.0 60.5	450.0 63.9	550.0 68.9	626.0 73.6	580.0 72.5	670.6 76.3	1,125.0 85.1
Japan	171.2 82.2	227.3 63.3	179.7 28.6	177.1 25.2	170.4 21.3	157.4 18.5	155.2 19.4	144.0 16.4	132.6 10.0
Taiwan	7.5 3.6	49.0 13.7	36.8 5.9	39.4 5.6	36.4 4.6	28.0 3.3	26.9 3.4	27.0 3.1	27.0 2.1
Korea	4.9 2.4	23.4 6.5	17.2 2.7	22.5 3.2	25.8 3.2	22.0 2.6	19.0 2.4	18.7 2.1	17.0 1.3
Others	3.6 1.8	9.4 2.6	14.5 2.3	15.0 2.1	16.0 2.0	17.0 2.0	18.0 2.3	19.0 2.1	20.0 1.5
Total	206.7 100	359.1 100	628.2 100	704.0 100	798.6 100	850.4 100	799.1 100	879.3 100	1321.6 100

Source: Royse, *et al.* 1985; Chang, 1996, 1999, 2002; Yao, 1998; Yamanaka, 1997.
*The national production of Lentinula mushrooms in China in 2001 was 2,072,000 tonnes.

The National Mushroom Conference held in San Ming Fungi Research Institute in 1983 had a long lasting influence on Chinese mushroom research and development. It provided a new vision and drive for the Chinese mushroom industry, as most of the leading Chinese mushroom scientists of that time were active participants. This was the beginning of focusing more attention upon the more exotic mushrooms, particularly *Lentinula edodes*. Since then, the mushroom industry in China has rapidly been developed in all aspects, not only in cultivation application technology but also in basic academic research, particularly into genetics and breeding of mushrooms. The number of commercially cultivated mushroom species steadily rose from 16 in the early 1980's to 50 in 2002 (Table 5). Nowadays, China has become a "Mushroom Kingdom" where more mushrooms are cultivated and more mushroom restaurants are operated than anywhere else in the world. More than 20 species are produced on industrial scales. Particularly, *Lentinula edodes* has become the leading mushroom in China, as well as in the World.

Case Studies

Here, I select three case studies on *Lentinula edodes* as special examples: Qingyuan, Biyang and Pan'an. I have visited Qingyuan four times since 1991, Biyang twice since 1998 and Pan'an once in 2003.

(1) *Qingyuan in Zhejian Province*

Qingyuan is the birthplace of artificial cultivation of *Lentinula edodes,* dating back to about 1,000 years ago. The county of Qingyuan is located in a tropical monsoon climate which is considered ideal for the production of *L. edodes*. The production of the mushroom in Qingyuan has grown from a mere 2,765 tons fresh weight in 1986 to 48,202 tons in 1993 and to over 106,500 tons in 1997. By now, only 20% of the production comes from cultivation on wood logs with the remaining 80% obtained by using the synthetic sawdust log technique. The over-harvesting of wood has made the government to encourage farmers to abandon the traditional log technique. The imminent environmental damage of logging wood for mushroom cultivation has spurred new technological breakthroughs, including improving the average biological efficiency of approximately 100%. This efficient production of one county represents 10% of the world production and 20% of the Chinese output in 1993. This was one of the reason the County was officially named by the Chinese Government as "*Lentinula Mushroom Town of China*" in 1994.

It is interesting to note that the total population of the County is just less than 200,000 of which 120,000 were directly engaged in mushroom cultivation in 1994. This means that 60% of the population was engaged in mushroom production and management. In terms of job creation, the mushroom industry had 4,000 persons in the trading and marketing of mushroom, about 2,000 were engaged in the manufacturing of plastics for bagging substrates, sales, production and maintenance of machinery, printing of labels, packaging and related businesses over and above those directly engaged in mushroom produciton in 1997. The total value of mushroom production in 1997 was US$ 46.3 million. It is the main source of revenue of the local government and in recent years, the economic status of the population of Qingyuan is amongst the 100 richest counties out of the 3,000 counties in China. This improvement is solely due to the cultivation and marketing of L*entinula* mushrooms.

Prior to 1991, trading in *L. edodes* was conducted at numerous stores. But the regional government decided to invest in a trading floor which has been expanded since. Today, there are some 280 traders active each day, except during the Chinese New Year festival. Each trader employs up to eight persons (most of them women). The success of the trading is reflected by the fact that in 1999 there was a need for an expansion, with an additional 137 trading stalls. The market system and support services such as banking, hotel and restaurants, now employ 15,000 persons, of whom 3, 000 are paid directly by the traders. There are 60 traders who export as many as 50 tons of mushroom dry weight per annum.

The County is also producing medicinal extracts from *L. edodes* and *Grifola frondosa* for sales to the Chinese herbal communities worldwide. The spent substrate is now under study for its use as a medium for earthworm cultivation, which is a source of natural enzymes. In this way, the County expects to continue to increase its level of well-being.

(2) *Biyang in Henan Province*

Home of the Flower (Cracked) Mushroom. Biyang County is located about 400 km to the Southwest of Zhengzhou, the provincial capital of inland Henan. Zhengzhou is the cradle of Chinese civilization at the start of the Shang dynasty, nearly 4,000 years ago. These days, Zhengzhou is best known as an inland transport hub, a crossroad for train and highway. The county is surrounded by two mountain ranges which are rich in oak trees. About 50% of the County is covered by forests, and only 40% is farmland. The County has a population of 910,000 of which 800,000 are engaged in farming. There is no industry in the County, and therefore it enjoys the advantage of not being burdened by air or water pollution. In 1992, it was decided to proceed with the economic development of the county based on the creation of

"The *Lentinula* Mushroom Economy". Within five years (1997), the mushroom production value reached US$ 81 million which represents 32% of the total agricultural production value in the County.

Since the Small Rushy/Plastic Shed and Big Bag Method of Biyang was developed and adopted, the average income of the farmer increased 5.5 times between 1991 and 1997. In the mountain ranges of the county, the cultivation of *Lentinula* mushrooms along with other mushrooms has enabled the government to eliminate poverty in a few years only. Now the Biyang method has been introduced to 120 counties of 15 provinces. In 1997, 300 million mushroom bags had been planted for a total production value of US$ 375 million. Due to the influence of this new technique, many farmers can now produce high quality (flower/cracked) L*entinula* mushrooms using sawdust mixed with other lignocellulosic biomass materials, and thereby could be divorced from poverty, from which they suffered for years. I was very touched when a visit was arranged for me to see the *Lentinula* villages. I composed the following poem in order to express my emotions:

"If we begin to look at what they have in their life today, what they did not have for many years, we begin to see what they will have more due to the blessing of a small creature, a Lentinula mushroom, which may change their life forever".

(3) *Pan'an in Zhejiang Province*

Home of fresh *Lentinula* mushrooms. Pan'an is located in the middle of Zhejiang Province and is a mountainous county. It consists of twenty administrative villages and has a population of about 200,000 people. Mushroom cultivation has become a pillar of agro-economic development in the County. There are several special characteristics of mushroom cultivation and development in the county, such as: (a) L*entinula edodes* is the main mushroom species cultivated in this county. Traditionally, it is only harvested in autumn and winter. However, Pan'an has developed several new varieties of the mushroom which can be cultivated all year round. Therefore, Pan'an can supply this fresh mushroom to the markets all year round, amounting to a production of 40,000 tonnes annually. (b) Pan'an has become a county which not only sells its locally produced fresh mushrooms, but has also become a marketing hub for fresh *Lentinula* mushrooms of other counties. Many fresh *Lentinula* mushrooms exchange hands in Pan'an markets *en route* to other destinations, in China and overseas. These sales and exchanges are valued at approximately US$ 53 million. Additionally, some are exported, and the exports account for approximately US$ 27 million. This accounts for one third of the national export of fresh *Lentinula* mushrooms. In the County, there are 35 export companies that deal with fresh *Lentinula* mushrooms. Together, these companies have a total of 50 cold rooms especially for the storage of their fresh mushrooms. (c) Pan'an is now one of the leading producers of high-temperature mushroom strains in China, hence the *Lentinula* mushroom can be grown in summer. In 1992, this summer strain of *Lentinula* was valued at approximately US$ 6.25 million. (d) Since China is now a member of the World Trade Organisation (WTO), all products for export now face great challenge with respect to safety and quality control. Pan'an has also taken up this challenge in relation to its fresh *Lentinula* mushrooms for exports, by imposing high standard regulations regarding the safety and quality of the mushrooms. In 2003, Pan'an Government, published a document setting out various codes and rules to be observed by companies and farmers. (e) In recent years, Pan'an has evolved from a singular mushroom species producer, that is, *Lentinula edodes,* to producing multiple cultivated mushroom species, e.g., *Auricularia auricula*, *Grifola frondosa*, *Flammulina velutipes*, *Hericium erinaceus*, *Coprinus comatus*, *Pleurotus eryngii*, *Pleurotus ferulae var. nebrodensis*, *Pleurotus ostreatus*, *and Agrocybe aegerite*. However *Lentinula* mushrooms still account for 80% of the county's total mushroom production.

Summary on the Chinese experience

The year 1978 was also the first year of China's economic reform programme. Twenty five years of reform have transformed China from a centrally planned and closed system in agriculture and, particularly, in mushroom industry, to a predominantly market-driven and open-competition economy/business/industry. In particular, China has become a leading producer and consumer of both edible and medicinal mushrooms. In 2002, more than 200 million people in China were involved in mushroom-based agro-industrial businesses and mushroom production in China accounted for 70% of overall world mushroom production. Thus, China can be seen as the new powerhouse for the world mushroom industry.

This dramatic expansion in mushroom production in China in the last twelve years (1990-2002) from one to 8.6 million tonnes is mainly due to (1) the strong leadership and initiative of provincial and county governments in grasping cultivation techniques and promoting production. Under these governments, there is usually a special section called "Office of Mushroom Production", which bears responsibility for mushroom research and production and training. The Office frequently organizes mushroom farming training courses for farmers.

(2) The strong scientific support from the Academic institutions in China. The Edible Fungi Research at the Shanghai Academy of Agricultural Sciences; the Institute of Applied Mycological at the Huazhong Agricultural University in Wuhan, Province of Hubei; the Sanming Mycological Research Institute in Sanming, Province of Fujian; China National Research Institute of Food and Fermentation in Beijing; Guangdong Microbiology Research Institute in Guangzhou, Province of Guangdong; Fujian Light Industry Research Institute in Fuzhou, Province of Fujian;and Kunming Edible Fungi Research Institute in Kunming, Province of Yunnan,are the leading institutes in mushroom research and development on various aspects.

(3) The proliferation of mushroom scientists and scholars, with the China Agricultural University in Beijing, the Huazhong Agricultural University in Wuhan, the Nanjing Agricultural University in Nanjing and the Fujian Agricultural and Forestry University in Fuzhou, etc., offering MSc and Ph.D degree programmes.

(4) Many innovations of mushroom cultivation technology by talented mushroom farmers. For example, the technology of synthetic log method for cultivation of L*entinula edodes* was invented by a farmer, Mr. Pan Zhaowan in Gutian County in the Province of Fujian. This has raised the living standards of the farmers.

(5) The increase of the domestic market, which is also a key factor in the expanding cultivation of edible mushrooms in China as a result of the improvement of the national economy.

Therefore, the mushroom industry in China, like every science, has two aspects: theoretical (academic) and practical applications. It is like the two faces of a coin, inseparable and yet distinct. Knowledge of one is bound to enhance that of the other. The two are invariably complementary to each other, and only by combining the knowledge of academic research and farmer practical experience to achieve a common goal (continual improvements of the mushroom industry), will there be mutual benefits for researchers and farmers alike. Furthermore, it is the combination of the factors set out above which has led to improved cultivation technologies and the introduction of a broader variety of species at both the small-scale and industry-scale farming levels.

The mushroom industry in China has proved its production capacity to the world. However, it must now prove its quality control for the mushrooms as well. The basic condition for the production of good quality mushrooms is a pollution free cultivation environment. If the mushroom comes from regions which are characterized by clean air and clean water, and if the substrates are from a verifiable source, then time has come to promote the mushroom vigorously. Under these conditions, the good quality mushroom produced in China can start to confidently build a reliable and sustainable image, eventually obtaining a bigger and better share in the world mushroom industry pie. In addition, a further technology development strategy is needed, which concentrates on the market driven generation of value added goods. These include the improvement of the freshness of the harvested mushrooms, extending its present shelf life of one week to at least two weeks, and the introduction of pre-cut and pre-mixed mushroom and vegetable packages. This will then dramatically increase the value of the mushroom, and in turn generate more income for the farmers.

The complementary major challenge of mushroom industry in China is to enter the era of management, marketing and further promotion of research. Particularly, communication technology improvement is vital for modern business transactions. Increases in international contact should be stressed, for example encouraging participation in international mushroom conferences overseas. The improvement of the Chinese mushroom community's standing internationally should be encouraged as well, by hosting international conferences, producing and publishing more good quality scientific papers in international journals, and even establishing a home based International Journal of Mushroom Sciences.

China's success in the development of its mushroom industry during the past two and half decades should serve as an example on what is also possible for Africa. We should make a concerted effort to lobby the government and industrial organizations, reminding them that research and development of mushroom industry is not a luxury but a national necessity for human welfare. Activities in that direction have already begun, summarised in the following section.

Possibilities for Africa, with reference to the start made by the UNDP/UNOPS Regional ZERI Project (RAF/99/021)

The UNDP/UNOPS Regional ZERI Project for Africa was initiated in 2000. It was born following initial funding support from the United Nations University (UNU), within the broad framework of the UNU/UNESCO ZERI Chair for Africa, based in Namibia, at the University of Namibia. The project's key focus is to promote sustainable development from Africa's rich biodiversity using the principle

of zero emissions and zero waste (e.g. zero waste of the huge tonnage of lignocellulosic biomass, in the form of agricultural and forestry crop residues, which are generated by Africa's farmers in rural and peri-urban communities every year. Encompassing eight African countries during its pilot phase, the UNDP–funded ZERI Project has a strong component of mushroom farming. Since its commencement, I have been invited as a resource person, to conduct several mushroom farming training courses/ workshops/seminars, hosted in Malawi, Namibia, Swaziland and Tanzania.

The main objectives of the ZERI Project mushroom farming activity, can be summarized follows:

(1) Rural utilization of Africa's inedible crops, crop residues, and agro-industrial solid organic wastes as substrates for the cultivation of edible mushrooms as functional foods in protein-deficient communities. The current world market value of cultivated edible mushrooms is estimated at US$ 25-28 billion.

(2) Industrial development of potentially extractable mushroom products (e.g. nutriceuticals usable as dietary supplements) with health benefits, such as those generated by the mushroom, *Ganoderma lucidum*. This is with a view to enhance people's health and fitness, and also prevent and treat human disease conditions. Recent years have seen a surge of commercial interest in these products, the current value of which is estimated at US$ 8-9 billion.

(3) Research on, and development of edible ectomycorrhizal mushrooms. Mycorrhizae are symbiotic associations between fungi and plants, and also with insects. The complexities of mycorrhizal associations have proven to be a fertile ground for researchers. They are also of considerable interest to chefs since some species (e.g., some truffle mushrooms) are among the world's most expensive foods. Mycorrhizal mushrooms are estimated at a value of US$ 3-4 billion.

The strategies that could be followed towards developing mushroom production industries in the various African countries, are suggested to be as follows:

- At the beginning, the strategy is not to use highly mechanized technologies (as in the large farms in industrialized countries), but to promote cottage style enterprise for the rural poor, in thousands of small mushrooms sheds, constructed using locally available materials (like those used in China at the beginning of its mushroom industry).
- Then move towards gradual introduction and familiarization of the art of large scale commercial cultivation techniques. This was the path China had followed from its humble beginnings to its current status as the world's leading mushroom production powerhouse.
- Select appropriate target strains of different mushrooms grown on seasonal basis.
- Make use of existing lignocellulosic residues and waste, from agricultural activities and agro-industries.
- Create employment opportunities, particularly for women and the youth in rural areas, and control pollution.
- Emphasize quick-investment-return mushrooms, and select relatively fast growing species that can be harvested within three to four weeks after spawning, thus generating immediate benefits.
- Promote mushroom species demonstrated to generate potent nutriceuticals with superior immune-enhancing attributes: species whose natural products include unique bioactive compounds that can make people healthier and fitter.

The following ideas also need to be emphasized: Although science and farming practice have led to the development of some universal or general concepts concerning mushroom cultivation, the diverse biological nature of the process (in which large numbers of mushroom species and natural organic substrates are involved) also means that a wide spectrum of variations in farming methods must be employed. Thus the transfer of mushrooms from one region or country to another, cannot be treated in the same way as the transfer of non-biological industrial technology, such as that of a complete complex of factory equipment for textile or chemical fertilizer industries. Since the cultivation of mushrooms deals with living organisms, one should consider, not only the unique attributes of the mushroom itself, and of the various microorganisms growing with it (including both the harmful and beneficial ones), but also the biochemical nature of the substrates.

Then the specific methods must be tailored in accordance with the prevailing unique natural resources heritage, local climate, and socio-economic conditions of the farming community. All these considerations call for a critical mass of well trained mushroom scientists. Thus the training activities of

the UNDP/UNOPS Regional ZERI Project for Africa referred to earlier, need to be further supported. Governments of the various African countries and their development assistance partners, need to build upon the foundation already started during the pilot phase of the UND-funded ZERI Regional Project initiative.

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What's new about knowledge? - A View from Southern Africa

Aida Opoku-Mensah

Director, Panos Southern Africa

African countries have invested very little in their information infrastructures, and in some cases have failed to create an enabling environment for the private sector.

LUSAKA (PANOS) What's new with knowledge? After all, it has always been central to the development of all societies, including Africa's.

What's new is the fact that information today can be moved around very quickly. And this has presented all societies with challenges and opportunities. People's access to information and the level and quality of infrastructure available to them will define - to an extent - how well societies use and adapt the increased knowledge and information.

The success of Southern African countries in strengthening their national information infrastructures will be critical in determining how well people exploit knowledge. New communications technologies hold the promise of helping to increase agricultural production, deliver better health and education services, and provide more effective and participatory governance.

That's all well and good. But just how is Africa going to get there? Money is scarce for economies crippled by external debt and desperately trying to cut back social sector spending. Infrastructure equipment is scarce and, when available, expensive. Sometimes it is plain inappropriate.

On top of all this is the lackadaisical attitude of the region's political actors, most of whom do not yet have in place any of the policies or strategies needed to tackle the many communication challenges. With the exception perhaps of South Africa, countries have invested very little in their information infrastructures, and in some cases have even failed to create an enabling environment for the private sector.

Instead, it has been typically left to international organisations and local NGOs to initiate early efforts. These include connecting Africa to the Internet with financial assistance from external donors. Many countries are also hampered by the lack of transparency and accountability in their modernisation drive. The importance of telecommunications is nothing new to the World Bank either. It has been involved in the sector for many years, although loans made in the telecommunications sector only amount to 2-4 percent of all Bank lending in Africa.

All this is not to say nothing noteworthy has happened. The process of modernising basic telecommunications systems has begun and there remains plenty of room for adopting innovative technologies to suit the region's needs. Rural "telecentres" - kiosks that offer everything from computers to telephones and email services - in South Africa and Uganda are examples of innovative projects.

South African minister for posts and telecommunications Jay Naidoo recently remarked that, "African leadership must confront a major indictment against us. Two years from the next millennium there are 700 million people on the continent and only 12 million have access to a telephone, five million in South Africa alone.

"A key policy requirement is the achievement of a national communications infrastructure, essential for social and economic activity. This is important in a world where reliable and speedy communication is vital to the success of rapidly globalising trade, industry and services

When Knowledge Is Not Enough - Lessons From The AIDS Pandemic

We have the knowledge, we have the technology

The HIV / AIDS pandemic provides a classic example of a devastating development problem that should be containable through knowledge and information. Thanks to research carried out in the North, we have known for well over a decade that the HIV virus causes AIDS and that the main way that it is spread is through sexual intercourse. We have a cheap and, thanks to social marketing and other programmes, increasingly accessible technology - the condom - which can prevent the transmission of HIV. Huge efforts have been made to communicate this information to people at risk.

These efforts have been very successful - for many years, surveys have found in nearly all countries at greatest risk of AIDS that well over 90% of people know what causes AIDS and know that they can protect themselves by using a condom.

Despite this knowledge, the pandemic has continued to escalate: Millions of people who have known that they are at risk of infection, who have known how to protect themselves, who have had access to the means to protect themselves, have not done so. Knowledge is not enough. The virus continues to spread because people, for a variety of complex reasons, can't or don't take action to protect themselves. Women whose husbands are unfaithful sometimes prefer the risk of HIV infection to the certainty of being beaten if they insist on using a condom. Sex workers are often too poor to insist their clients use condoms. Unemployed men have no choice but to migrate away from their families in search of work and place themselves at risk. Health services are often so under-resourced that they cannot cure the sexually transmitted diseases that vastly increase the risk of contracting HIV.

Changing sexual behaviour involves not just knowing and communicating what is good for people. It involves changing social attitudes and it involves tackling root causes of poverty. This requires, among other things, debate and argument within societies and between societies. There are no simple ways to achieve such changes, but knowledge alone is not enough.

A Vaccine for Who?

A cheap, effective vaccine against AIDS would represent an ideal technical solution to the pandemic. There is no cure, and treatments that can extend life are both too expensive and too complex to administer to be affordable for poor people in poor countries. A vaccine which could be administered once for lifelong protection could reverse a still escalating epidemic.

When testing for a promising experimental vaccine against AIDS was planned in Uganda in 1996, street demonstrations broke out, fanned by a suspicious and hostile media convinced that their countrymen were being used as guinea pigs. The anger was understandable: there had been little public consultation over the trials; the vaccine was designed for use against a strain of HIV not common in Uganda; and the organisers of the vaccine trials could give no guarantees that, if the trials were successful, the vaccine would be made widely available in Uganda.

Following the protests, UNAIDS and other organisers of the trials organised a public meeting bringing together more than 200 people - representatives of the medical and religious communities, legal experts, counsellors, NGOs, policy makers and the media. The high ethical standards being used by the trial organisers, the strong involvement of the Ugandan government and other Ugandan institutions, combined with a commitment to establish a national review committee to oversee all future medical research in the country helped to allay public fears.

The introduction of knowledge into a society cannot occur in a vacuum. Public debate not only makes its introduction more credible and legitimate, it leads to better policy as well.

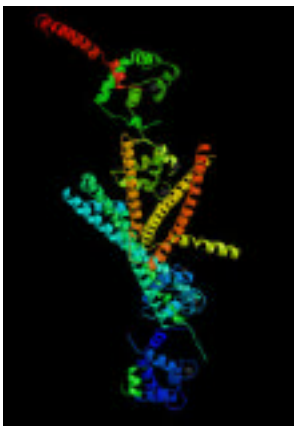
New Standard to Help Diagnose Heart Attacks

Diagnosing heart attacks will become a more precise science thanks to the first of a new series of clinical standards just issued by the National Institute of Standards and Technology (NIST). Standard Reference Material (SRM) 2921 (human cardiac troponin complex) will help manufacturers develop and calibrate assays that measure specific protein concentrations in patient blood samples to determine whether a heart attack has occurred.

The SRM is a solution containing certified concentrations of three related proteins, including cardiac troponin I, purified from human heart tissue from cadavers. Users can calibrate their assays by analyzing the SRM and comparing the results to the NIST-certified value for troponin I. The standard is expected to help reduce variations in clinical test results from as much as 50-fold on the same sample to just twofold. "It's a big first step toward getting the system under control," says Michael Welch, leader of the NIST development team.

NIST already produces more than 60 SRMs for the clinical diagnostics community, but this is the first one designed to help measure concentrations of large, protein-based health status markers. Troponin I is difficult to measure because it can exist in low concentrations and in different chemical forms, sometimes attached to other related proteins. NIST is developing additional standards and methods for measuring other health status indicators of this type, including hormones used to assess thyroid function, and other markers for heart attack risk such as homocysteine and C-reactive protein.

SRM 2921 is intended to help U.S. makers of in vitro diagnostic (IVD) medical devices sell their products in Europe. A European Union directive requires that such devices be calibrated with standards that are traceable to internationally recognized certified reference materials or procedures. SRM 2921 has been nominated for inclusion on the international list of higher order reference materials. The list currently contains approximately 150 entries for 96 health status markers; NIST SRMs provide traceability for 72 of these.



Computer model of the complex crystal structure of the human protein cardiac troponin.
Graphic Courtesy Protein Data Bank

Media Contact:
Laura Ost, (301) 975-4034

Superconducting R&D Wire Achieves Major Milestone

Using improved processing equipment developed with support from the National Institute of Standards and Technology's Advanced Technology Program, American Superconductor Corporation (AMSC) has produced lengths of record-breaking high-temperature superconductor (HTS) wire.

The company recently announced that it achieved electric current carrying capacity in multiple 10-meter lengths of second-generation (2G) HTS wire equal to or better than 250 Amperes per centimeter of width, an industrial world record that approaches performance levels required for commercial applications. The company's 2G results were achieved through a reel-to-reel liquid deposition production process that has been designed to be scalable to high-volume, low-cost manufacturing.

Large-scale use of 2G HTS wire carrying high amperage electrical current with virtually no resistance promises dramatic gains in energy efficiency. Today about 10 percent of transmitted electricity is wasted, largely due to resistance. The new technology also can increase the efficiency of large electric motors by as much as 50 percent and enable smaller, more powerful magnetic resonance imaging machines for medicine.

The 2G wires will cost less than first-generation HTS wire. AMSC received ATP support to develop a large-scale continuous-process reaction furnace for producing 100-meter lengths of 2G HTS ribbon, a key element for practical commercial production of the wire.

More information on the AMSC 2G HTS wire project and a white paper on the technology may be found on the company's Web site: *www.amsuper.com.*

Media Contact:
Michael Baum, (301) 975-2763

Effect of Some Physical Properties of Cocoa Beans and Post-Harvest Delay on its Compressive and Impact Rupture Load

A. Isaac Bamgboye

Department of Agricultural Engineering, University of Ibadan

Abstract

Samples of F_3 Amazon (Hybrid) whole cocoa pods were used in this study. The physical properties of the cocoa pod considered are husk thickness, pod diameter and pod length. The effects of these properties on weight, mass density, and rupture loads were investigated. The effect of post-harvest delay on impact and compressive failure loads was also investigated. Compressive and impact tests were carried out on the samples for a period of six days. 40% of the changes in compression loads in the longitudinal axis can be predicted from changes in husk thickness of a pod. 79% of the changes in husk thickness can be predicted to affect the weight; however, less than 10% of changes in mass density can be predicted from changes in husk thickness.

The result of the effect of pod diameter and length of the pod on the rupture loads indicates that neither the impact nor the compressive rupture loads depends on the length or diameter of a pod alone for rupture to take place. It was found that cocoa pod exhibits linear resistance to breakage for both impact and compression tests in the lateral axis than in the longitudinal axis. Most of the force required to crack the pod was dissipated in rupturing the pod husk after which the undamaged beans are easily removed.

The impact and compressive rupture loads were found to increase with time after harvest for the first three days after which it begins to drop. Therefore, it is much better to break cocoa pods within 24hours after harvest to prevent excessive increase in rupture loads or at worst within 72 hours to prevent bean deterioration.

Key words: cocoa pods, cocoa husk, cocoa bean, compression loads, impact of rupture loads, resistance, physical proprieties, post harvest processing

Résumé

Des échantillons de noix entières de l'hybride F3 du cacao Amazone ont été utilisés au cours de cette étude. Les propriétés physiques examinées étaient l'épaisseur, le diamètre et la longueur de la cosse de la noix. Les effets de ces propriétés sur le poids, la densité de la chair et sur les forces de résistance à la cassure ont été étudiés. L'impact du retard dans le décorticage après la récolte du cacao et les forces de résistance à la cassure ont été également étudiés. Des essais portant sur les forces de résistance à la cassure et l'impact de celles-ci sur la fève ont été effectués sur les échantillons pendant une période de six jours. Cette étude révèle que 40% des changements des forces de résistance à la cassure sur l'axe longitudinal peuvent être prédits à partir de la variation de l'épaisseur de la coque de la noix. De même, 79% des variations de l'épaisseur de la noix peuvent être prédits pour leur effet d'affecter le poids de la noix; tandis que moins de 10% de variations de la densité de la masse peuvent être prédits par les changements de l'épaisseur de la cosse. Les résultats de l'effet du diamètre et de la longueur de la noix sur les forces de cassure indiquent que l'impact et les forces de résistance à la cassure ne sont pas les seuls à déclencher la cassure des noix. Lors des essais d'évaluation de l'impact des forces de résistance à la cassure, on a constaté qu'il existe une résistance linéaire à la cassure de la noix de cacao plutôt dans son axe latéral que dans l'axe longitudinal. La majeure partie de la force requise pour faire éclater la noix est dépensée pour la rupture de la coque, après quoi les fèves intactes peuvent être facilement détachées. Les forces de résistance à la cassure et l'impact de la cassure de la coque sur la fève ont semblé augmenter avec le temps au cours des trois jours qui suivent la récolte du cacao, après quoi, elles commencent à chuter. Par conséquent, il est préférable de casser les noix de cacao dans les 24 heures qui suivent leur récolte afin d'éviter l'augmentation excessive des forces de résistance à la cassure ou au plus, endéans 72 heures pour parer à la détérioration de la fève.

Mots clés: noix de cacao, coque de noix, fève de cacao, forces de résistance à la cassure, impact de la force de cassure, résistance, propriétés physiques, transformation post-récolte.

Introduction

Cocoa *(Theobroma cacao L)* is a strictly tropical tree crop which today is cultivated in the tropical forests of West Africa, Latin America and South East Asia (Opeke, 1987). Over 20 species of *Theobroma* are recognised worldwide, but all cocoa cultivated for international market belongs to the single specie *Theobroma cacao*, which is a small tree of 4-7m high with a rounded canopy of 6-8m diameter if grown in isolation (Opeke, 1987).

Cocoa is one of Nigeria's most important cash crops that serve as source of foreign earnings. This is common in the western part of the country, accounting for about 90-95 per cent of her total production. The economic importance of cocoa cannot be over emphasized. These ranges from its use in the manufacturing of beverages to wines, floor tiles, ceiling board and slide polish among many others.

With advancement in technology, and increase in the global population, there is need to boost the production of cocoa to meet the global demand. One area of interest is processing of the cocoa pods. The primary processing of whole cocoa pods involves breaking of pods, extraction of the bean, fermentation, and drying of the fermented beans. In spite of the overwhelming importance of cocoa, almost all the operations involved in the primary processing of whole cocoa pods are still manually carried out. The experience of cocoa farmers in processing the pods suggest that pod breaking and separation of cocoa beans from the husks are difficult tasks because the breaking of pods by manual labour is slow, time consuming and labour intensive.

A limited work has been done on the mechanization of cocoa processing. Breaking of the pods has been found to be tedious and energy intensive. Several methods of breaking the cocoa pods have been adopted, ranging from cracking pods together or against blunt object or by using a cutlass and other sharp object to cut through the pod husk before twisting to force the husk pieces apart to release the beans (Are & Gwynne-Jones, 1974). The structure and nature of the pod are believed to be important in relation to the pods breaking behaviour (Maduako & Faborode, 1990). It is necessary to carry out the pod behaviour under load to obtain its force-deformation characteristics for a systematic design and development of a pod processing machine (ASAE, 1990). Agricultural materials are usually reduced to sizeable particles for effective utilization. This is by applying commensurate force to the materials for size reduction. This has been identified as impact force, compressive force, shearing force and cutting force (Brennan *et al.*, 1969).

The compression behavior of most agricultural products is affected by the physical nature of the products, moisture content, rate of loading, and temperature (Recee and Lott, 1976; Chuma *et al.*, 1978, Mohsenin, 1980).

The morphology of a whole cocoa pod is such that the pod can be considered as a composite material with three distinct sections, namely: the pod wall (husk); the wet beans (seeds); and the placenta (the central mucilaginous pulp). Mohsenin (1980) reported that shape, size, volume, density and porosity are some of the physical characteristics of importance in determining the behavior of a material during handling operation.

Materials and Methods

Cocoa pods harvested from Cocoa Research Institute of Nigeria (CRIN), Idi-Ayunre, Ibadan were used for the experiments. The thickness of the pod husks was measured at the ridges and furrows using a vernier calipers. The length and diameter of twenty whole cocoa pods were measured directly using a vernier calipers with an accuracy of 0.01mm.

The pods were later subjected to compressive and impact test, noting the rupture load. The impact test was carried out by dropping the cocoa pod at different heights in both lateral and longitudinal axes on a flat metal galvanized surface. The compression test was carried out on the cocoa pod in both lateral and longitudinal axes using a Tensometer. The procedure was replicated eight times. Fifteen whole cocoa pods were used for moisture content determination. At 24 hours after harvest, pods were subjected to impact drop tests and uni-axial tests. This was repeated at 48, 72, 96 and 120 hours respectively. The moisture content of the cocoa bean was determined at each interval of 24, 48, 72 96, 120 hours respectively using the oven dried method.

Results and Disscussion

The results of the effect of husk thickness on pod weight and mass density of whole cocoa pod are as shown in table1. From the table, the husk thickness varies as the weight varies, showing an increase in the weight with husk thickness. This is expected since the husk thickness is expected to form part of the weight of the cocoa pod. The statistical analysis shows the coefficient of determination, r^2 to be 0.79; indicating that about 79% of the changes in husk thickness can be predicted to affect the weight. However, the mass density is poorly correlated with husk thickness, r^2 = 0.075, which indicates that less than ten percent (10%) of changes in mass density can be predicted from changes in husk thickness. This indicates that the husk thickness does not affect the mass density of the cocoa pod.

Table 1: Effect of Husk Thickness on Pod Weight and Mass Density of F_3 Amazon Whole Cocoa Pods

Pod Number	Weight of Pod (kg)	Volume of Pod (ml)	Mass density of Pod (kg/m^3)	Average husk thickness (mm)
1	0.396	495	800.0	10.9
2	0.495	650	761.5	11.4
3	0.230	310	741.9	8.8
4	0.364	480	758.3	10.3
5	0.337	425	792.9	12.0
6	0.536	710	754.9	14.5
7	0.657	840	782.1	14.1
8	0.307	405	758.0	9.9
9	0.321	400	802.5	9.2
10	0.283	400	707.5	9.1

Table 2: Effect of Husk Thickness on Impact Rupture Load of F_3 Amazon Whole Cocoa Pods

	Lateral Axis		Longitudinal Axis	
Pod Number	Impact rupture load (KN)	Husk thickness (mm)	Impact rupture load (KN)	Husk thickness (mm)
1	2.47	10.1	2.63	7.4
2	2.28	9.3	3.57	11.0
3	2.10	8.7	2.61	7.3
4	2.60	7.9	1.72	5.3
5	2.50	10.0	2.22	7.0
6	2.33	7.7	2.94	7.6
7	2.42	8.7	1.94	6.5
8	1.90	5.8	1.74	6.4

Table 3: Effect of Husk Thickness on Compressive Rupture Load of F_3 Amazon Whole Cocoa Pods

	Lateral Axis		Longitudinal Axis	
Pod Number	Compressive rupture load (KN)	Husk thickness (mm)	Compressive rupture load (KN)	Husk thickness (mm)
1	1.942	14.5	2.060	11.4
2	1.263	10.3	1.560	8.8
3	1.315	9.2	2.070	9.1
4	1.216	9.9	2.158	14.1
5	1.197	10.9	1.933	12.0

The effect of husk thickness on both the impact and compressive rupture load of whole cocoa pods is as shown in tables 2 and 3. The statistical analysis of the results also indicate that the compression and impact rupture loads are well correlated with husk thickness with the exception of compression in the longitudinal axis where the coefficient of determination is not reliable ($r^2 = 0.40$). This indicates that only about forty percent (40%) of changes in compression loads in the longitudinal axis can be predicted from changes in husk thickness of a pod. The implication of this is that the husk thickness alone does not determine a pod's resistant failure.

The effect of pod diameter and length on the impact and compressive rupture loads of F_3 Amazon whole cocoa pods is as shown in tables 4 and 5.

Table 4: Effect of Pod Diameter and Length on the Impact Rupture Load of F_3 Amazon Whole Cocoa Pods

	Lateral Axis		Longitudinal Axis	
Pod Number	Diameter of pod (mm)	Impact rupture load (KN)	Length of pod (mm)	Impact rupture load (KN)
1	70.3	2.47	142.2	2.63
2	80.4	2.28	152.9	3.57
3	72.2	2.10	152.1	2.61
4	82.1	2.96	127.4	1.72
5	81.4	2.54	141.4	2.22
6	71.8	2.33	160.2	2.94
7	72.5	2.42	123.9	1.94
8	69.5	1.90	127.4	1.73

Table 5: Effect of Pod Diameter and Pod Length on Compressive Rupture Load of F_3 Amazon Whole Cocoa Pods

	Lateral Axis		Longitudinal Axis	
Pod Number	Diameter of pod (mm)	Compressive rupture load (KN)	Length of pod (mm)	Compressive rupture load (KN)
1	91.2	1.942	131.9	1.933
2	38.4	1.263	157.8	2.060
3	76.3	1.315	126.2	1.560
4	71.3	1.216	137.9	2.070
5	80.3	1.197	1186.0	2.158

Statistical analysis of the results show a coefficient of determination, r^2 of 0.43. This shows a reliable correlation coefficient, but only 43% of the changes in diameter of pod can be predicted. This is not reliable in predicting the effect of pod diameter on rupture load. However, in the longitudinal axis, the coefficient of determination is reliable (r^2=0.75). In the compressive lateral load, the coefficient of determination is found to be unreliable in both (r^2=0.27) for the pod diameter. For the pod length, coefficient of determination is reliable (r^2=0.52). These results indicate that neither the impact nor the compressive rupture loads depends on the length or diameter of a pod alone for rupture to take place. In order to ensure that every pod will be properly broken during mechanical breaking or processing of cocoa pods, the upper limits of the range of values of husk thickness at the ridge should be used for estimating the rupture loads.

The result of the effect of post-harvest delay on the rupture load and the moisture content of F_3 Amazon cocoa pods is illustrated in table 6 and Figures 1-2.

Table 6: Effect of Post-harvest Delay on the Moisture Content of F_3 Amazon Whole Cocoa Pods

Time of pod breaking after harvest (Hours)	Replications of moisture content (%w/w)			Average moisture content (%w/w)
3	75.52	81.63	76.71	77.93
24	75.47	79.53	75.58	76.86
48	72.95	74.38	75.47	74.27
72	69.26	69.28	68.26	68.93
96	68.10	67.07	67.47	67.55
120	66.80	67.02	66.55	66.79

Figure 1: Effect of post-harvest delay of cocoa pod on impact load in lateral and longitudinal axes

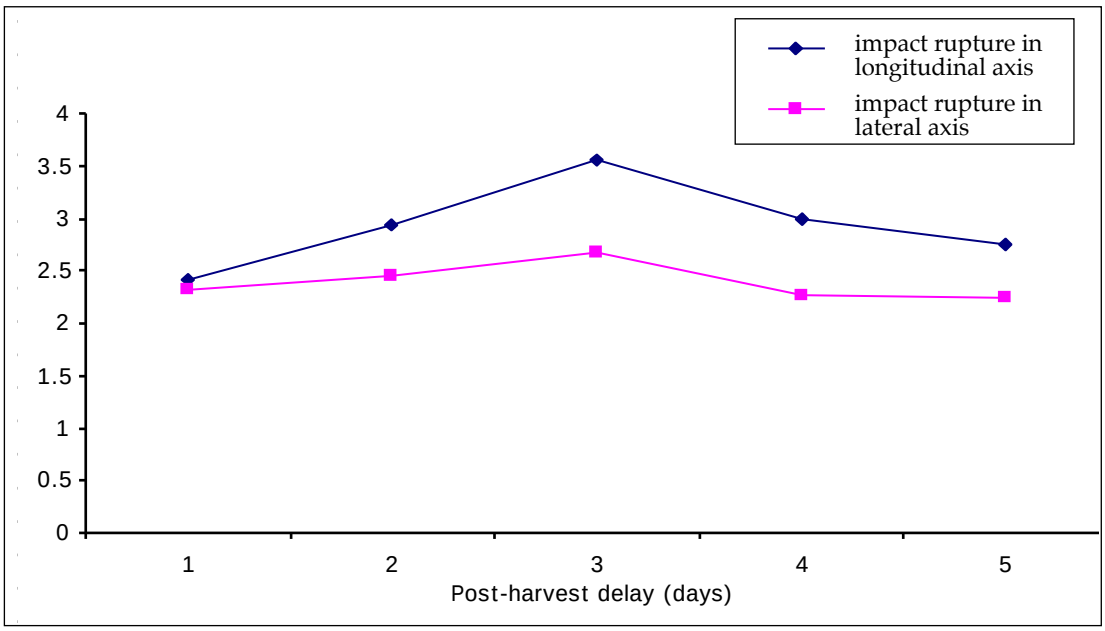
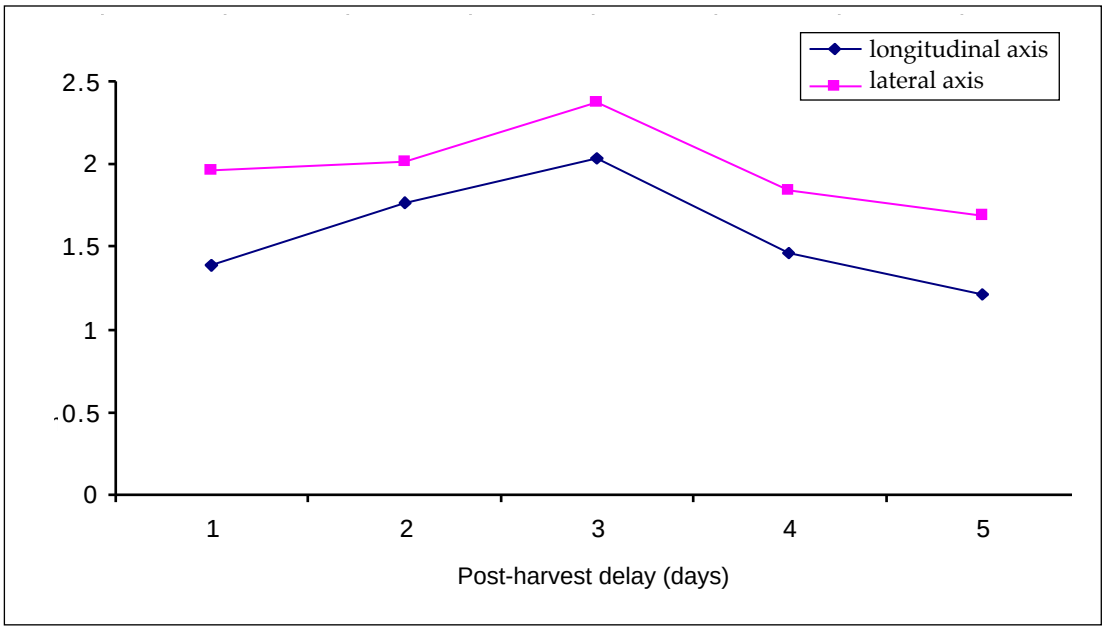


Figure 2: Effect of post-harvest delay of cocoa pod on compressive rupture load in lateral and longitudinal axes



The moisture content was found to decrease with delay period, while the impact and compressive load increases at both axes for a while. This continues till the third day, after which a decrease in both the impact and compressive loads is observed with decrease in moisture content. The initial increase in the impact and compressive loads with a decrease in moisture content could be due to the fibre generation due to loss of moisture content. However, on the fourth day, physiological action commences, leading to a reduction in the strength of the cocoa pods. The delay in breaking or processing the pods was observed to lead to a continuous drop in moisture content of the pod. The drop in the moisture content

of the pod will likely increase the relative percentage of fibre in the pod with respect to the weight of the pod.

The impact and compressive loads in the longitudinal axis of the cocoa pods subjected to the same treatment was more than in the lateral axis. This may be connected to the length of the cocoa pod being longer in the longitudinal axis than the diameter. From Figure 1, an initial increase in the impact rupture load in both lateral and longitudinal direction was observed with delay period. The increase was observed till about 72 hours before a gradual decrease in the impact rupture load. The initial increase in the impact load observed could be due to the increase in the relative percentage of fibre in the pod with respect to the weight; but after 75 days, deterioration of the fibre was observed, leading to a reduction in the rupture impact load. The same trend was observed in compressive rupture load as shown in Figure 2.

From 24 hours to about 72 hours after harvest of the whole pods, the impact rupture load increased by about 16% in the lateral axis and 46.7% in the longitudinal axis, while the compressive rupture loads increased by about 46% and 20.9% in both axes respectively. Beyond 72 hours after harvest, the rupture loads was noticed to decrease for both impact and compressive testing. The decrease can be attributed to the commencement of internal physiological and microbial degradation of the ripe pods as the cocoa beans begin to develop moulds and starts to germinate inside the pods (Are and Gwynne-Jones 1974). Externally, the husk colour begins to change from yellow to brown from the fifth day after harvest. Furthermore, beyond 72 hours, the impact and compressive loads dropped by about 16.4% and 40.4% in the lateral axis, and about 22.8% and 29.0% in the longitudinal axis. Therefore, it would appear safer to break ripe cocoa pods as soon as they are harvested, preferably within 24 hours after harvest to avoid any appreciable increase in the rupture loads. Nevertheless, for large cocoa farms where it may not be feasible to break all pods within 24 hours after harvest, efforts should be made to break them within three days after harvest.

Conclusions

The pod husk contributes almost 100% resistance to the rupture of F_3 Amazon whole cocoa pod. Indeed, the impact and compressive rupture loads are well correlated with husk thickness. It is seen that neither the impact nor the compressive rupture loads depends on the length or diameter of a pod alone for rupture to take place. The moisture content of cocoa pod decreases with time and has a significant effect on both the impact and compressive load of the cocoa pod. It is concluded that it is better to break cocoa pods within 24hours after harvest to prevent excessive increase in rupture loads or at worst within 72 hours to prevent bean deterioration.

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REVIEWS

Extension Management in Peasant Agriculture: Finance, Personnel and Training in Nigeria

A. J. Udoh

Department of Agricultural Economics & Extension, University of Uyo, Uyo, Akwa Ibom State - Nigeria

Abstract

A number of approaches for instance, Farm Settlement Scheme (FSS), Integrated Rural Development (IRD), Agricultural Extension Research Liaison Services (AERLS), National Accelerated Food Production Project (NAFPP), Operation Feed the Nation (OFN) and the River Basin Development Authority (RBDA) had been adopted by the Nigerian Government at various periods to develop agriculture and improve on food production. The various approaches had their respective shortcomings and were folded up except the River Basin Development Authority whose objective had been modified. The most recent and last of the approaches is the Agricultural Development Projects (ADPs) which is a nationwide project but was instituted in Akwa Ibom State in 1988. The study was undertaken between March and September in the year 2000 in Akwa Ibom Agricultural Development Programme (AKADEP) in Nigeria to assess the organization on how it has performed in the first 10 years in personnel recruitment, manpower development and the level of funding by the government.

The study reveals that AKADEP was operating on a high rate of shortfall in budgetary allocation and implementation. The shortfall for the respective years ranged from 40 – 80 per cent. The staff strength of the various sub-programmes in AKADEP generally improved but declined in 1995 and 1996. However, the manpower available at various levels of supervisory, intermediate and vocational cadres were grossly inadequate. Training of personnel through workshops, conferences and seminar declined except in 1995 that more personnel attended the training programme. Average farm size for the contact farmers was 2.5 hectares while that of the non-contact farmers was 0.5 hectare. The level of labour use, income and expenditure showed a similar trend.

Key words: Integrated Rural Development, IRD, AKADEP, PDA, NAFPP, OFN, manpower development, training, rural development project, farm size, Akwa Ibom State, Nigeria

Résumé

A diverses époques, plusieurs approches ont été adoptées par le Gouvernement nigérien afin de développer l'agriculture et améliorer la production vivrière. Parmi celles-ci figurent les Schémas d'Aménagement des Exploitations Agricoles - FSS, le Développement Rural Intégré - IRD, les Services de Liaison de la Recherche et la Vulgarisation Agricoles - AERL, le Projet National de Production Vivrière Accélérée - NAFPP, l'Opération dite "Plus de Nourriture pour la Nation" -OFN et l'Organisation de Développement du Bassin Fluvial - RBDA. Ces diverses approches comportaient chacune des imperfections et elles ont pris fin à l'exception de l'Organisation de Développement du Bassin Fluvial dont les objectifs ont subi des modifications. La plus récente et dernière de ces approches est le Projet de Développement Agricole - PDA qui couvre tout le pays et dont un volet a été seulement implanté dans l'État d'Akwa Ibom en 1988. La présente étude a été initiée entre les mois de mars et septembre 2000, dans le cadre du Programme de Développement Agricole de l'État d'Akwa Ibom (AKADEP), au Nigeria et dans le but d'évaluer la façon pratique dont le projet a été exécuté au cours des 10 premières années. L'étude a porté sur les aspects de recrutement du personnel, le développement de ressources humaines et son affectation et les subventions octroyées par le gouvernement. L'étude indique que l'AKADEP fonctionnait sur un taux élevé de déficit d'allocation budgétaire et son exécution. Pendant cette période, ce déficit est allé de 40 à 80pour cent. La performance du personnel affecté dans divers volets secondaires du Programme AKADEP s'est généralement améliorée mais elle a décliné en 1995 et 1996. Cependant, les ressources humaines affectées à divers niveaux des cadres supérieurs, intermédiaires et professionnels sont très inadaptées. La formation du personnel à travers des ateliers, des conférences et des séminaires a périclité, excepté pour l'année 1995 au cours de laquelle un grand effectif parmi le personnel a bénéficié du programme de formation. La taille moyenne d'exploitation pour des fermiers visés était de 2,5 hectares tandis que les fermiers ayant 0,5 hectares n'ont pas été contactés. Les niveaux d'utilisation de ressources humaines, de recettes et de dépenses ont montré une tendance similaire.

Mots clés: Aménagement des Exploitations Agricoles, IRD, AKADEP, PDA, NAFPP, OFN développement de ressources humaines, formation, projet de développement, taille d'exploitation familiale, État d'Akwa Ibom, Nigeria

Introduction

A number of approaches, both institutional and management, have been introduced to facilitate the development of Nigeria's agricultural industry. The organized extension services in Nigeria and scientific agriculture started with the advent of the British and the colonization of Nigeria. Williams (1978) states that this period is also the beginning of direct government involvement in the development of agriculture. But between 1910 and 1921, according to Akinbode (1982), government attention towards the development of agriculture was to grow export crops for the British markets. No efforts were directed to food crops. Therefore, scientific information was lacking in improvement of food crops. Having realized the need for training workers in general, and agricultural extension workers in particular, the government established two Schools of Agriculture at Ibadan and Zaria in 1921 and 1931 respectively.

Further, the ministerial structure of agriculture emerged and this gave rise to the establishment of Agricultural Extension Division (AED) further giving rise to a three-tier Ministerial Structure, one in the North, one in the East and the other in the West. A fourth Ministry of Agriculture was created in 1963 when the Midwest Region was established. In 1968, when 12 states structure was established, 12 Districts-States Ministry of Agriculture also emerged with only one Federal Ministry. Since then, increase in the number of states also brings about an increase in State Ministries of Agriculture.

But when the establishment of the Ministries of Agriculture failed to bring a solution to the food problem, the government saw the need of establishing organizations to see about the development of agriculture and food production. Among the organizations established was the Farm Settlement Scheme (FSS) in the 1960s; Young school leavers (settlers) were given farmlands, inputs like fertilizers and chemicals by the Federal Government and proceeds from the farms bought by Government to ensure that the settlers were making profit to sustain themselves. But the abrupt discontinuance of the scheme is sufficient evidence of its failure (Olatunbosun, 1967).

The FSS was followed by the Integrated Rural Development (IRD) instituted in the 1970s. The Federal Government through its planners saw that certain factors required for agricultural development such as good road network, health facilities, electricity, transportation and housing were lacking, which eventually led to the strategy of IRD. However, the success of the IRD depended on effective coordination of all the relevant agencies, but the concept failed because such coordination was lacking.

The Re-organization of Research Institutes in 1973 with the establishment of Agricultural Extension Research Liaison Services (AERLS) in 1975 was to create an effective linkage between Agricultural Research Institutes and Extension Agencies for effective research findings delivery system. This did not bring expected results.

The National Accelerated Food Production Project (NAFPP) was instituted by the Federal Government in 1975 with the main aim of increasing the yield of six major food crops in Nigeria. The crops included cassava, maize, wheat, sorghum, millet and rice. The major concern was to increase farmers' awareness and the use of improved agricultural practises in order to increase food production. Again, the project was abandoned with its own problems.

The NAFPP was immediately followed by a scheme called Operation Feed the Nation (OFN) in 1976. In 1977, the Agricultural Credit Guarantee Scheme Fund (ACGSF) was also established to guarantee loans given by Commercial Banks to farmers since this was seen to be necessary to enhance the economic status of farmers. The River Basin Development Authority (RBDA) which commenced in 1976 and was modified in 1977 and 1979 respectively was to provide water and irrigation facilities to farm communities for productive farming. The two schemes and the project above had their own respective short-comings.

Though the first generation enclave World Bank assisted Agricultural Development Projects (ADPs) in Nigeria started in Funtua, Gusau, Gombe, Lafia and Anyagba in the 1970s and moved to statewide ADPs in Bauchi, Sokoto, Kano, etc., in the 1980s, the project did not start in Akwa Ibom State until in 1988. The Akwa Ibom State Agricultural Development Project (AKADEP) was excised from the Cross River State Agricultural Development Project (CRADEP) and assumed its separate status on January 1, 1988. In 1998, the Akwa Ibom Agricultural Development Project was upgraded to a Development Programme.

In Nigeria, the agricultural extension service has remained an important public service institution with a broad range of responsibilities for agricultural and rural development (Modo *et al*., 1997; Idachaba, 2000). AKADEP, a public service institution covers six agricultural zones and reaches out to about 626,446 farm families in Akwa Ibom State. But have the farmers been part of the planning for the programmes or was a top-down approach adopted? It has been established by Amalu (1998) that the transfer of technology in a top-down, one way, government promoted direction from scientific research institutions to resource poor farmers can only be partially effective; and that if farmers are not part of planning, some of the programmes can fail.

The past schemes, projects and programmes in Nigeria had their shortcomings. Will the ADPs in general and AKADEP in particular follow suit? Could it be the level of funding by government that created problems for the past programmes? Will inadequate or over-staffing of the organization, that may also be applicable to AKADEP, result in poor performance of the organization? Or, were there training programmes to improve on the quality of staff and therefore efficiency of output? These are some of the questions that will be answered in the course of our discussion.

The issue of agricultural development, food production and the expected food target to be met by farmers may depend on how the Agricultural Development Programmes (ADP) in Nigeria in general, and Akwa Ibom State Agricultural Development Programme (AKADEP) in particular, are funded and how they manage their physical facilities and training of their personnel which will enhance the proper performance of their programmes.

More than ten years after AKADEP was instituted, it became necessary to asses the organization on how it has performed in the first ten years (1988 – 1998) in personnel recruitment and manpower development and the level of funding by the government. The study was conducted in Akwa Ibom State in the year 2000.

Methodology

Study area (Location, size and population)
Akwa Ibom State is located between latitude 4° and 5° and longitude 7°16′ and 8° 10′E in the humid rainforest zone of Nigeria. The State by 1992 National Population Census had an estimated population of 2.8 million people. The State has 31 local government areas with a land area of 7,081 square kilometres.

Climate, relief and vegetation
The climate is typically wet. The wet season occurs between March and November, while the dry season lasts for about three to five months. The mean annual rainfall is 2000mm with a daily minimum mean temperature of 33.5°C. The mean relative humidity is 85%. The predominant physical relief is generally flat with low lying land. The land is generally drained. Vegetation cover is determined by climate and edaphic factors. On the swampy coasts and creeks are the salt and fresh water mangroves. The tropical rainforest belt abound with green foliage of tropical hardwood trees and shrubs. However, the vegetation has been disturbed by man due to intensive cultivation.

People and occupation
The people of the State share certain characteristics in common such as food habit, social interaction, customs and beliefs. While some communities in the coastal areas concentrate on fishing, others in the mainland concentrate on crop farming and livestock. However, both the farmers and fishermen in the sector tend to remain at the lowest level of the socioeconomic stratum.

The study was conducted in an agricultural extension agency, Akwa Ibom State Agricultural Development Programme (AKADEP). The Agricultural Development Programme is a nationwide extension programme with a major function of disseminating improved agricultural practices to farmers. A structured questionnaire was administered to eight directors of the respective sub-programmes in AKADEP. Three out of the six agricultural zones were randomly selected and 126 and 86 contact and non-contact farmers respectively of AKADEP randomly selected from the three zones to take part in the study. A structured questionnaire to collect data on farm size, income level of farmers and resource base and gross margin was administered on the farmers. The data obtained was analyzed with descriptive and inferential statistics such as chi-square and t-test. The study was conducted between March and September of the year 2000.

Results and Discussion

Allocation of funds and actual implementation
The funding history of the programme from 1989 to 1996 is shown in Table 1. The Table shows that in 1989 there was a 87.62% gap, which slightly dropped to 82.78% in 1990 and subsequently dropped by about 5% in 1991 from that of 1990. In 1992 service year, N108,209,000 was allocated but only N12,760,810 or 11.79% was released for implementation leaving a gap of N95,448,190 or 88.21% gap.

Table 1 shows that the actual budget implementation during the period never reached an average of what was allocated except for 1994 and 1995, indicating that funds released were too meager. The increase in budget implementation for 1994 and 1995 was due to the preparation to upgrade the project into a programme.

The data in Table 1 however, reveal that actual implementation kept increasing slightly from 1989 through to 1991, increased appreciably for 1994 and 1995, and declined in 1996 with percentage gaps of 42.38, 40.71 and 63,72% for the three respective years. The implication is that the low budgetary implementation therefore resulted in scarcity of agricultural inputs, non payment of salaries, decrease in staff strength and many other problems which

weakened the efficiency of extension services by Akwa Ibom Agricultural Development Programme.

The study further reveals that AKADEP is underfunded and the inadequate funding has made it difficult to recruit more extension staff. It is feasible that increased agricultural production depends on the extent to which research findings reach the farmers quickly and effectively through the extension agents. However, extension agents are too few and thus resulting in a number of constraints in increased farm productivity. It is also expected that with the weak Naira currency during the period of study (from 1989 – 1996, Naira has been exchanged at N5 – N90 to US $1) funding of prgramme could have increased remarkably. The bleak funding position therefore could undermine the improved efficiency and output of programme.

The capital allocation to agricultural programmes is inadequate and implementation is very poor. Thus, given the vital role that agriculture plays in social and economic development of Nigeria, it becomes imperative that the agricultural extension agency like AKADEP must be adequately funded and actual implementation of budgetary allocation maintained.

Sub-programme personnel

There had been increases and decreases in the staff strength of the various sub-programmes in AKADEP from 1988 to 1996. For instance, at the inception of the prgramme, the total staff strength that stood at 476 increased to 772 in 1990. Between 1991 and 1993, the staff strength increased slightly but declined in subsequent years (Table 2). Staff strength in Management/Administration sub-programme increased from 60 in 1988 to 98 in 1990 but increased sharply from 87 in 1991 to 163 in 1992 and sharply dropped to 67 in 1996. The staff strength for Monitoring and Evaluation division remained stable between 1988 and 1991 and declined steadily from 1992 to 1995 but dropped sharply in 1996 as shown in Table 2. The Human Resources and Training sub-programme remained steady with a range of 4 – 7 staff for all years except for 1992 when they had two staff members and 1995 when they had three. Table 2, further shows that the Technical and Extension Service Divisions, however, had about 50% of the total staff strength in the respective years under review.

Generally, the staff strength improved for most divisions but declined 1995 and 1996 in all sub-programmes. Table 2 also shows the distribution of the staff strength in the various sub-programmes between 1988 and 1996. Data for 1989 was not available. Analysis of the staff data reveals that about 5.50% of the staff were in the senior cadre while 34.4% and 60.1% were in the intermediate and junior cadres respectively. A close examination of the staff situation reveals that with the six agricultural zones of AKADEP and with the 626,446 farm families clients, the Extension Division especially is overstressed. But inadequate funding restricts the recruitment of qualified staff.

Among constraints that constantly affect extension services in Nigeria is shortage of manpower. The manpower available in each of the sub-programmes at the various levels of supervisory, intermediate and vocational cadres is grossly inadequate for carrying out any meaningful extension services in the state, local government areas and villages. Therefore, inadequate contacts with farmers, low diffusion and adoption of innovations result in low farm output. A balance of extension worker – farmer ratio is perhaps, the most needed simple attempt to increase agricultural production in Nigeria. The proper staffing and funding of extension agencies in Nigeria will enhance the rapid transformation of low resources farm households and food production in Nigeria.

Table 1: Allocation of funds and actual implementation

Year	Allocation (N'000)	Actual implementation (N'000)	% Implementation	Gap (N'000)	% Gap
1989	13,184.53	1,631.74	12.38	11,552.79	87.62
1990	40,907.05	7,044.05	17.22	33,863.00	82,78
1991	52,492.00	12,077.30	23.00	40,414.70	77.00
1992	108,209.00	12,760.81	11.79	95,448.19	88.21
1993	125,269.79	14,988.33	11.96	110,281.46	88.04
1994	106,176.26	61,181.95	57.62	44,994.31	42.38
1995	130,351.61	77,281.54	59.62	53,070.07	40.71
1996	150,231.521	54,510.21	36.28	95,721.311	63.72

Source: Computed from field data, 2000

Table 2: Staff strength of various sub-programmes in AKADEP

Sub-programmes personnel	1988	1989	1990	1991	1992	1993	1994	1995	1996
Management/Administration	60	N.a	98	87	163	114	112	146	67
Monitoring & Evaluation	35	N.a	35	35	24	28	29	25	17
Human Resources & Training	4	N.a	6	6	2	6	7	3	7
Finance	18	N.a	18	26	24	28	28	21	19
Commercial services	46	N.a	26	176	82	123	94	31	15
Engineering services	47	N.a	48	48	119	117	70	70	61
Technical services	165	N.a	208	403	251	263	180	182	151
Extension services	101	N.a	333	343	432	430	318	318	311
Total	476		772	1124	1097	1109	838	796	648

Source: Computed from field data, 2000
N.a = Not available.

Personnel Training

Personnel Training is a very crucial programme in any organization if efficiency is to be desired. One of the objectives of the Akwa Ibom Agricultural Development Programme (AKADEP) and like other ADP's in the country is to strengthen capabilities for agricultural planning and programme execution. An attempt to accomplish this objective is made through training of staff for efficiency. The study reveals that staff training in AKADEP include indoor or in-house training which are Monthly Technology Review Meeting (MTRM), Fortnightly Training (FNT) and outdoor training in which staff members are trained at the International Institute of Tropical Agriculture (IITA), Agricultural and Rural Management Training Institute (ARMTI) and in other organizations.

The study reveals that 30 sessions of training programmes were conducted between 1992 and 1996. It therefore implies that about six training programmes were conducted or attended by some staff per year. Workshops formed 60% of the trainings conducted followed by orientation with 17%, seminar with 13%, and conference with 10% of the training programmes attended by the staff.

In 1992, a total of 522 members of personnel took part in training, 81 in 1993 and 123 in 1994. In 1995 and 1996, 375 and 50 members took part in training programmes respectively (Table 3). It could be observed from Table 2 that in 1992, a total number of staff for all sub-programmes was 1097 and 522 of then attended training programmes (Table 3). This was comparatively appreciating. In 1993, while the total number of personnel was 1109 including about 522 that had their training the previous year, only 81 or about 13% of 587 of those who had not attended any training programme did so. But in 1994 while the total staff strength declined to 838 due to retrenchment of staff, 123 took part in the training programme. There must have been the need to improve the status of the remaining staff for effective output.

Finally, in 1995 and 1996, 375 and 50 staff attended training programmes. A close examination of Table 3 shows that most staff attended workshops except in 1992 that 319 had orientation programmes.

Generally, the fluctuation in participation as observed may have been as a result in reduction in the number of staff, insufficient funds to organize training programmes, or management programmes.

So far, trained staff strength of AKADEP has not been very promising and needs to be improved to ensure an environment for an efficient built in monitoring and evaluation. The work performance or quality of staff has to be improved on series of training sessions. This will facilitate the process of problem identification and solution, thus providing an environment for easy programme planning execution. It is desirable to develop the manpower of an organization towards an effective administration.

While training may be regarded as time consuming, complicated, unnecessary and exorbitant, the negative consequences of poor training or no training at all are enormous. Lack of properly trained personnel may result in inefficiency and low performance. For instance, the functions of an extension personnel cannot be properly performed if he lacks adequate training and supervision. Besides, problems of low response of farmers to improved farming practices had been attributed to the trainers' inability to impart knowledge to the farmers. It therefore becomes explicit that for agriculture to attain its highest status of providing food and fibre to our teeming population, extension agents, supervisors and subject matter specialists should acquire

adequate and effective training. This will enable them as a team to develop farmers with high mental horizon, better production techniques and greater capacity which will result in high food and fibre production.

Table 3: Training programmes attended by staff

Programmes	1992	1993	1994	1995	1996
Orientation	319	0	0	0	0
Workshop	62	30	79	230	32
Conference	16	23	12	48	6
Seminar	125	28	32	97	12
Total	522	81	123	375	50

Source: Computed from field data, 2000

Farm size, income, resource base and gross margin

Farm holdings in Akwa Ibom State like in other parts of Southeastern zone of Nigeria are generally characterized by small size. The small size of farms seem to be a function of population density, land tenureship and fragmentation among both contact and non-contact farmers. The farm sizes cultivated by the respondents ranged from 0.1 – 1.2 hectare. With the meagre size of farms operated by both categories of farmers, it is expected that production may be low and as welll farm income. If all members of the respective farm families were to work on the farm, then the actual area cultivated by each one of them was actually too low. Consequently, some farmers must be involved in some non-farm activities in order to earn some additional income. In Table 4, the test of significance shows that there is a relationship between the level of adoption and farm size.

Table 4: Distribution of respondents according to farm size

Level of Adoption	Contact farmers Farm size (hectare)			Non-contact farmers Farm size (hectare)			
	0.1-0.5	0.6-1.1	1.2 &>	0.1-0.5	0.6-1.1	1.2 &>	Total
Low	19	7	2	2	6	6	42
Medium	24	8	3	7	8	10	60
High	38	17	8	21	10	16	110

$X^2cal = 23.5$, x^2 tab = 18.3 df ∞ 10 $p < 0.05$
*Source: Computed fr*om field data, 2000

The total farm income between the two groups of farmers was generally low. The net income ranged from just below ₦2,000 to just above ₦4,000 per annum. Data in Table 5 below shows that 1.59% of contact farmers and 18.6% of the non-contact farmers had net income below ₦2,000 per annum. However, 27% and 48.8% of the two respective groups of farmers had net income range of ₦2,000 – ₦2,999. Net income range of ₦3,0000 – ₦3,999 was reported by 42.1% of contact and 23.3% of the non-contact farmers. Finally, 29.4% and 9.30% of the two groups of farmers reported making a net income of ₦4,000 and above.

With the level of income as discussed above, and inspite of the obviously important role of farming in the economy of the state, the farmers in the sector tend to remain at the lowest level of the socioeconomic stratum. Data in Table 5 show significant difference between the two groups of farmers with regards to farm income. The significant increase in farm income of the contact farmers over that of the non-contact farmers is related to size of farm and level of adoption of the contact farmers. It is therefore commendable that AKADEP with its weak funding is capable of motivating farmers for positive results and should be funded adequately for more positive performances.

Table 5: Test of significance between contact and non-contact farmers with respect to farm income

Income level (N)	Contact farmers (N = 126)		Non-contact Farmers (N = 68)		Total	
	No	%	No	%	No	%
Below N2,000	2	1.59	16	18.6	18	8.50
2,000 – 2,999	34	27.0	42	48.8	76	35.8
3,000 – 3,999	53	42.1	20	23.3	73	34.4
4,000 and above	37	29.4	8	9.30	45	21.2
Total	126		86		212	

$t = 2.21$ df = ∞ $p \leq 0.05$
Source: Computed from field data, 2000.

The level of resource utilization shows substantial differences between contact and non-contact farmers. Average farm size for the contact farmers was 2.5 hectares while that of the non-contact farmers was 0.5 hectare. The level of labour use and expenditure showed a similar trend (Table 6). This translates in monetary terms with the contact farmers recording a gross margin of N2,513/ha against N250 by the non-contact counterparts. It should be noted however, that gross margin as used here could mean the same thing as net farm income since under the local conditions in which the farmers operate, fixed capital is virtually non-existence.

Table 6 shows the detail of comparative resource and income positions of the two sets of farmers. All the figures in the different columns were statistically significant when subjected to statistical analysis at 5% level of significance. This means that the impact of AKADEP activities is showing positive results which is capable of raising the standard of living of the rural farmers despite the poor funding of the organization.

Table 6: Comparative resource base and gross margin of contact and non-contact farmers

Resource	Contact Farmers	Non-contact Farmers	Difference
Average farm size (ha)	2.5	0.5	2.0
Average labour utilization (Av. man-days/ha)	73	32	41
Naira spent/ha of available inputs (₦)	1,400	600	800
Sales of farm produce/ha (₦)	3,913	850	3,068
Gross margin/ha (₦)	2,513	250	2,263

Source: Computed from Field Data, 2000

Summary and Policy Implications

A number of approaches for instance, Farm Settlement Scheme (FSS), Integrated Rural Development (IRD), Agricultural Extension Research Liaison Services (AERLS), National Accelerated Food Production Project (NAFPP), Operation Feed the Nation (OFN) and the River Basin Development Authority (RBDA) had been adopted by the Nigerian Government at various periods to develop agriculture and improve food production. The various approaches had their respective shortcomings and were folded up except the AERLS and the River Basin Development Authority whose objective had been modified. The most recent and last of the approaches is the Agricultural Development Projects (ADPs) which is a nationwide project but was instituted in Akwa Ibom State in 1988. The issue of agricultural development and food production by farmers may depend on how the Agricultural Development Programmes (ADPs) in Nigeria in general and Akwa Ibom State Agricultural Development Programme (AKADEP) in particular are funded and or recruitment and training of manpower.

The study was undertaken between March and September in the year 2000 in Akwa Ibom Agricultural Development Programme (AKADEP) in Nigeria to assess the organization in how it has performed in the first ten years in personnel recruitment, manpower development and the level of funding by the government.

The study reveals that AKADEP was operating on a high shortfall in budgetary allocation and implementation. The shortfall for the respective years ranged from 40 – 80 per cent. The staff strength of the various sub-programmes in AKADEP generally improved but declined in 1995 and 1996. However, the manpower available at various levels of supervisory, intermediate and vocational cadres are grossly inadequate. Training of personnel through workshops, conferences and seminars declined except in 1995 when more personnel attended the training programme. Average farm size for the contact farmers was 2.5 hectares while that of the non-contact farmers was 0.5 hectare. The level of labour use, income and expenditure showed a similar trend. Though the agency has tried to run training programmes for its staff, it is recommended that if budget allocation and implementation could improve, then a brighter future is feasible for the peasant farmers.

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SHORT COMMUNICATION

Effect of Different Temperature Regimes on Physiological Changes Associated with Early Growth of Cassava Stem Cuttings

S. O. Akparobi[1], M. O. Akoroda[2] and I. J. Ekanayake[3]

[1]*Department of Agronomy, Delta State University, Asaba, Nigeria*
[2]*Department of Agronomy, University of Ibadan, Nigeria*
[3]*International Institute of Tropical Agriculture, P.M.B. 5320 Ibadan, Nigeria*

Abstract

A growth chamber study was undertaken to measure the effect of different temperature regimes on physiological changes associated with sprouting of cassava stem cuttings. Four improved IITA clones (TMS 30555, TMS 91934, TMS 4(2)1425 and TMS 30572) were studied in controlled environments, set at 10/6°C, 15/10°C, 25/15°C and 35/25°C day/night temperatures, respectively and ambient conditions (32/22°C) as a control at IITA, Ibadan. All cassava stem cuttings grown below 15°C did not sprout. The growth of radicles and plumules were delayed at 25/15°C. Also, results showed that fresh weight of the mother sett gradually decreased within the first one month after planting and thereafter increased with the onset of tuberization in all the clones. High temperature regimes of 35/25°C and 32/22°C had significant ($P<0.05$) higher tuberous root number, tuberous root dry weight, leaf area and total biomass as compared to low temperature of 25/15°C. At low temperature of 25/15°C, the interaction with TMS 30572 and TMS 30555 had the highest values for the traits measured when compared to other clones. The reduction in fresh weight of mother sett in TMS 30572 and TMS 30555 was less compared to other clones. These two clones produced a higher leaf area, tuberous root number, tuberous root dry weight and total dry matter than other two clones across the temperature regimes. This result revealed that TMS 30572 and TMS 30555 performed better at low temperature regime of 25/15°C. The mother sett serves as a source of energy for the establishing new plants. And also, large-size mother sett at planting may result in high yield among improved IITA clones in low temperature.

Keywords: Stem cutting, stake, tuberous root, cassava, temperature, physiology

Résumé

Une étude en milieu contrôlé a été entreprise afin d'évaluer l'effet de différents régimes thermiques sur les changements physiologiques liés à la germination des boutures de la tige du manioc. Quatre clones sélectionnés par l'IITA (TMS 30555, TMS 91934, TMS 4(2)1425 et TMS 30572) ont été étudiés sous des régimes contrôlés avec des températures diurnes et nocturnes respectives de 10/6°C, 15/10°C, 25/15°C et de 35/25°C et en présence d'un témoin soumis aux températures moyennes ambiantes (32/22°C) enregistrées à la station de l'IITA, Ibadan. Toutes les boutures du manioc cultivées en dessous de 15°C n'ont jamais poussé. Des radicelles et des plumules des boutures cultivées à 25/15°C étaient rachitiques. Les résultats ont en outre prouvé que le poids frais des boutures mères chez tous les clones diminuait graduellement au cours du premier mois après plantation, pour ensuite augmenter avec le début de tubérisation. Les boutures soumises aux régimes de hautes températures de 35/25°C et de 32/22°C ont significativement ($P<0,05$) enregistré le nombre le plus élevé de racines tubéreuses, le poids sec des racines tubéreuses, la surface foliaire et la biomasse totale, par rapport à celles soumises à la basse température de 25/15°C. Dans le cadre des paramètres étudiés, les clones TMS 30572 et TMS 30555 soumis aux conditions de basse température de 25/15°C ont enregistré les valeurs les plus élevées par rapport aux autres clones. La réduction du poids frais de la bouture mère chez les clones TMS 30572 et TMS 30555 était minimal en comparaison des autres clones. Ces deux clones ont produit des surfaces foliaires, un nombre de racines tubéreuses et un poids sec des racines tubéreuses les plus élevés, en comparaison des deux autres clones pour tous les régimes thermiques étudiés. Ces résultats indiquent que les clones TMS 30572 et TMS 30555 étaient plus adaptés aux conditions de basses températures de 25/15°C. La bouture mère sert de source d'énergie pour la prise de nouveaux rejets. En outre, l'emploi d'une grande bouture mère au moment de la plantation pourrait conduire à des rendements élevés chez les clones de l'IITA, sélectionnés pour les régions de basses températures.

Mots-clés: bouture de tige, tige, racine tubéreuse, manioc, température, physiologie

Introduction

Cassava (*Manihot esculenta* Crantz) is the seventh most important crop of the world and constitutes a staple food for 800 million people around the world (CIAT 1993). The importance of cassava is increasing in Africa because of its diverse uses and its tolerance to environmental stresses such as drought, marginal soil fertility and its ability to produce some acceptable yield where many other crops fail (Hahn and Keyser, 1985; Nweke, 1996).

Cassava is commercially propagated vegetatively through stem cuttings known as setts or stakes. The mother sett supports the growth of shoot and root system until the new leaves assume the role of producing photosynthates and the roots start conducting water and nutrients from the soil to other parts of the plant. Thus, the carbohydrate and moisture status of the mother sett at the time of planting largely influence the establishment and early growth phase of cassava plants that are propagated by vegetative method. It has been reported that disease free stem cuttings from 8 to 12 months old plants with a stem thickness of 2-3cm are more suitable for growing cassava (Anonymous, 1983). Also, the procedure for selection of setts, for cassava cultivation has been described in detail (Lozano *et al.*, 1977).

Vegetative stem propagation confers the advantage of large carbohydrate reserves in the planted material, resulting in high vigour and better crop establishment under biotic and abiotic stress conditions. Stem storage in cassava is a persistent problem especially in areas with long dry or cold seasons. Loss of quality of planting material may be one of the most important intrinsic factors limiting cassava production worldwide. Preliminary studies have shown that cassava dry matter (primarily starch) may accumulate in the plantable stem at levels of 10-15% of the total root production (Gijzen *et al.*, 1990). This percentage is lost when lignified stem is not used as planting material (Gijzen *et al.*, 1990). The growth physiology of cassava under different environmental conditions has been reviewed in detail (Hunt *et al.*, 1977; Keating *et al.*, 1982; Cock, 1985) but little information is available on the effect of temperature regimes on the mother sett during and after the regeneration of young cassava plant.

The objective of this paper is to assess the effect of different temperature regimes on physiological changes associated with growth of improved IITA cassava stem cuttings and the role of mother sett on establishment growth.

Materials and Methods

Plant materials

Four improved IITA cassava clones (TMS 30555, TMS 91934, TMS 4(2)1425 and TMS 30572) were used in this study. These were selected based on their origin (local and improved), yield potential and broad adaptation to cassava growing conditions (Dixon *et al.*,1994). TMS 30572 has been released to the farmers by the IITA breeding unit and it is used as standard in the this study.

Growth facilities

Cassava plants were raised in growth chambers (Model Li-E15, Convirons, Controlled Environments Ltd, Winning, Manitoba, Canada) at IITA, Ibadan. There were four growth chambers set at 35/25°C, 25/15°C, 15/10°C, and 10/6°C day/night temperatures, respectively. Overhead light was supplied in each growth chamber by a combination of 12 fluorescent and 16 incandescent lamps. The average photosynthetic photon flux (400-700 nm) varied from 10 to 15 mmol s^{-1} m^{-2} and in each chamber, a 12-hour daylength was maintained. The relative humidity in each growth chamber ranged between 65 and 80%. The plants were grown in plastic pots (0.45 m diameter, 0.50 m deep, containing topsoil from IITA farmsite). The soil used as potting medium is classified as Oxic paleuestalf, Alagba soil series (Greenland, 1981).

Plant culture

Cassava stem cuttings of 0.20 m length with about 10 nodes were obtained from 12 months old mother plants at the middle part of stem and were planted in the plastic pots. For each clone, 48 stakes were selected and planted per temperature regime. One stem cutting was planted per pot. The fresh weight of stem cuttings of 58 grammes were recorded before being planted. Cuttings were planted inclined at about 40° and watered thrice a week. Immediately after planting the potted cuttings were transferred to different temperature regimes while other plants remained in ambient conditions as the control. In 1994/1995 crop season, cassava stem cuttings were planted on May 5, 1994 while in 1995/1996 crop season, cassava stem cuttings were planted on May 10, 1995. At each crop season, the plants were observed for five months. The average maximum temperature, minimum temperature, and relative humidity during the period were 28-32°C, 21-24°C and 65-85%, respectively for ambient conditions. Throughout this experiment, plants were watered regularly to field capacity (400 mililitre per pot). Hand

weeding and pesticide application of Perfekthion (Dimethoate 400 gramme per litre E C.) at 40 mililitre in 20 litre of water to control mealybug (Phenacoccus manihoti Matile-Ferrero) were done.

Experimental design and sampling

This experiment was a 4x4 factorial combination of clone and temperature, and arranged in a completely randomized design with three replications. Harvests were done sequentially at weekly interval during the first month and thereafter at monthly intervals. Three plants from each clone were randomly selected and then separated into leaves, petiole, stem, rootstock, fibrous root and tuberous roots. All leaves were detached and the leaf area of individual plants was measured with a portable leaf area meter (Model LI-3000, LI-COR, Inc., U.S.A.). Also, the data collected included fresh weight of mother sett, stem number, fibrous and tuberous root number. Dry weight of stems, leaves, leaf petioles and roots were determined after oven drying for 48 hours at 70°C. Data were subjected to statistical analysis using procedures outlined in the general linear model (SAS 1996) and mean differences determined by L.S.D. at 5% level of significance.

Results and Discussion

The fresh weight of the mother sett decreased during the first month after planting but increased gradually after then in all the temperature regimes (Figure 1) with the exception of the temperature regimes of 15/10°C and 10/6°C, in which all the mother setts died. Mother sett definition is a broader term since it gradually becomes an integral part of the young plant. Weight increase observed later in the season is due to expansive growth and deposition of stored materials. The initial loss in weight of mother sett is probably caused by the breakdown of stored carbohydrate in the mother sett while the gain in weight that become conspicuous at three months after planting coincides with onset of tuberization of some of the fibrous roots.

The result of combined analysis showed that the loss in mean fresh weight of the mother sett were 40, 49, 35 and 55% for TMS 30572, TMS 91934, TMS 30555 and TMS 4(2)1425, respectively at one month after planting and the gain in mean fresh weight of mother setts were 60, 43, 50 and 57% for TMS 30572, TMS 91934, TMS 4(2)1425 and TMS 30555 respectively at the final harvest (Fig. 1).

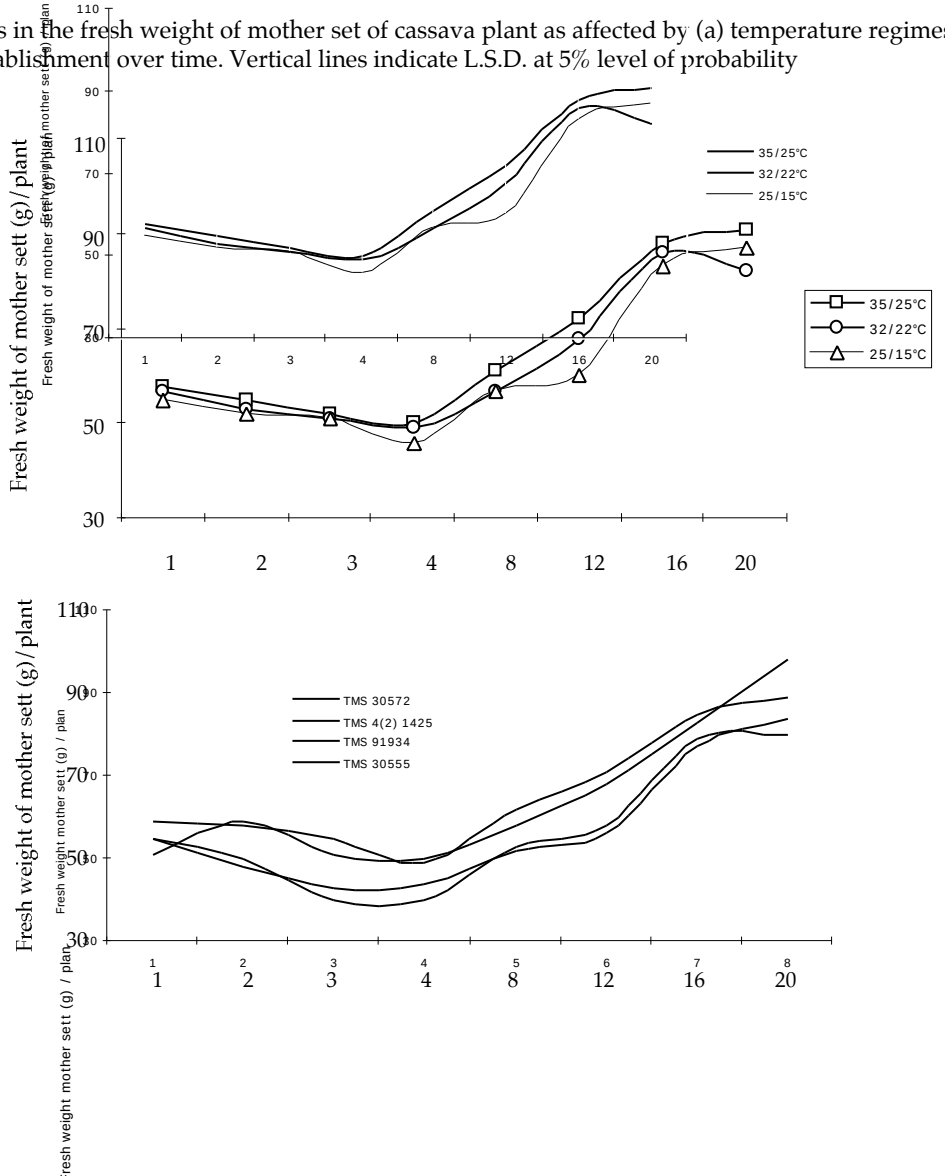
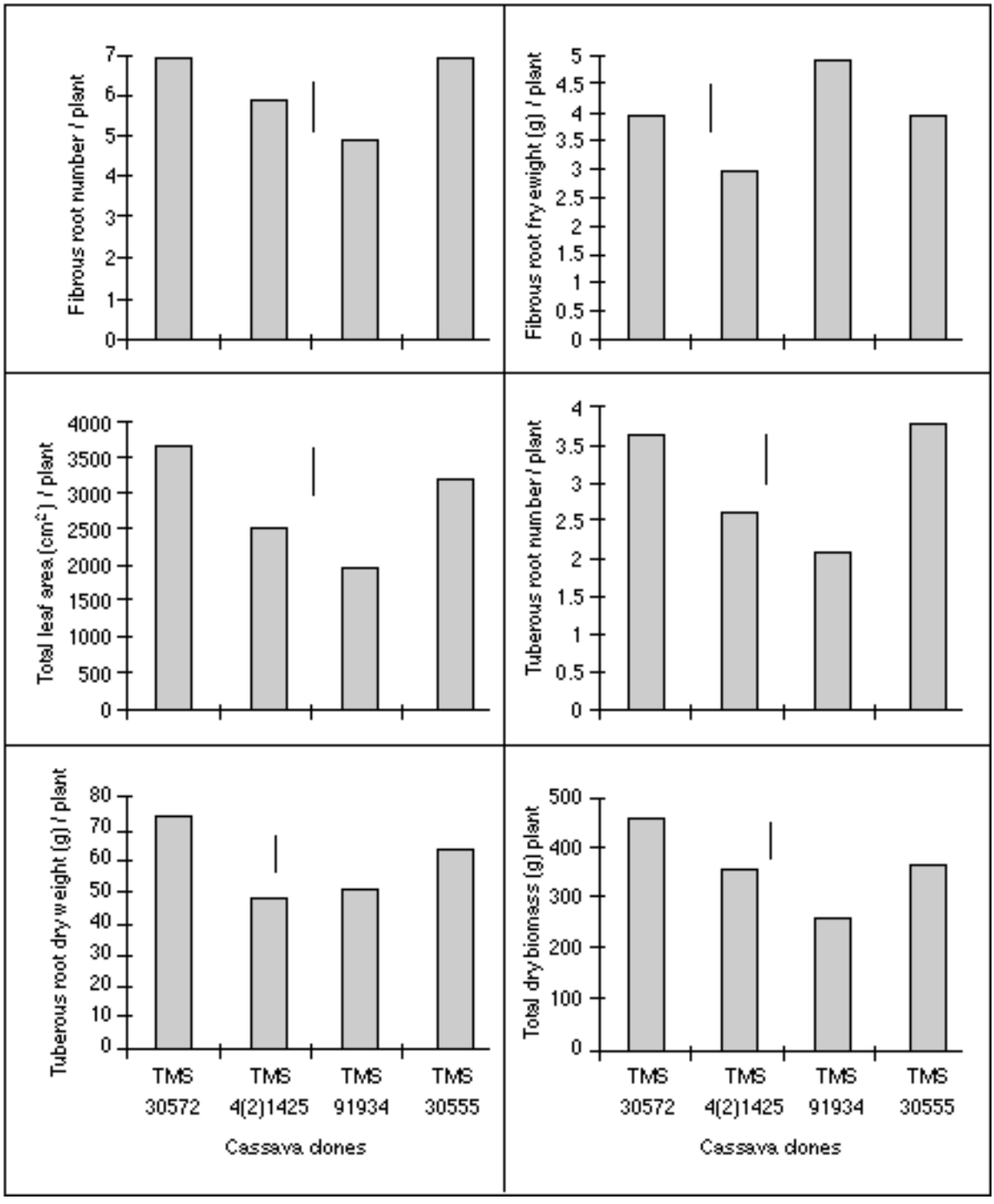


Figure 1: Changes in the fresh weight of mother set of cassava plant as affected by (a) temperature regimes, (b) cassava clones during establishment over time. Vertical lines indicate L.S.D. at 5% level of probability

The number of roots that occurred around the callus tissues were more than in any other part of the stake and few roots were observed at the nodes that are in contact with moist soil. Significant differences ($P<0.05$) among temperature regimes were observed in number of tuberous roots per plant (Fig. 2). The number of fibrous root and the total dry weight of fibrous roots decreased with plant age in all the temperature regimes (Fig. 2). These may be due to degeneration of the old roots and the conversion of some fibrous to tuberous roots.

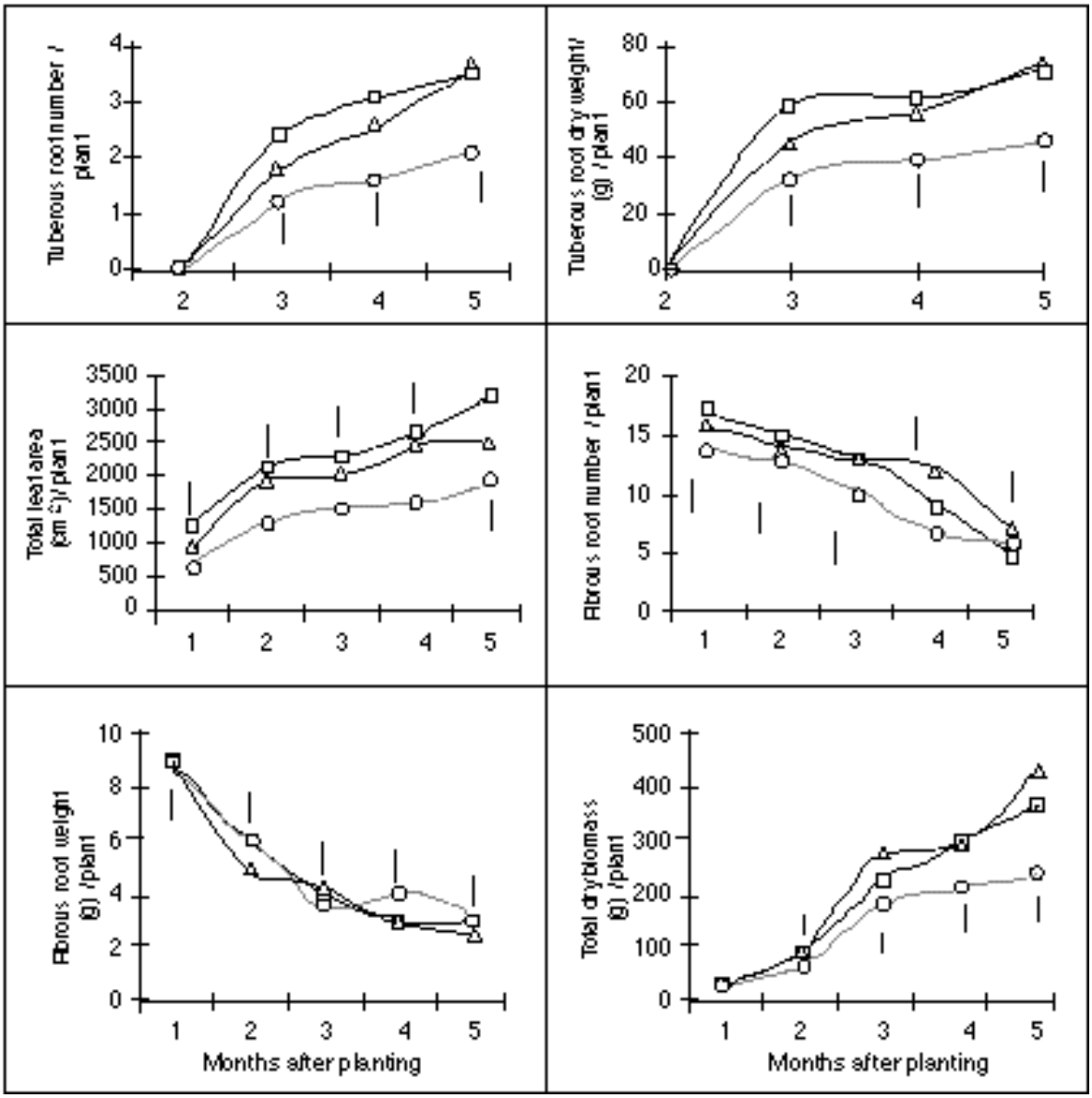
Figure 2: Changes in the parameters of eight cassava clones under different temperature regimes. Vertical lines indicate L.S.D. at 5% level of probability



The high temperature regimes (35/25°C and 32/22°C) favoured tuberous root production than low temperature regime of 25/15°C (Fig. 2). The data show that visible tuberous root differentiation was observed at three months after planting in high temperatures while bulking was delayed in low temperature of 25/15°C. Similar results have been observed by Sanjose and Mayobre (1982), and Manrique (1990) who reported that bulking in cassava starts after thre months of planting. The high temperature regimes resulted in a remarkable higher leaf area which was reflected in high tuberous root yield and total biomass when compared to low temperatures (Fig. 2). These findings agreed with reports of Manrique (1990) who observed that warm temperatures promoted leaf area development and dry matter production.

Also, significant differences ($P<0.05$) were observed between the clones for leaf area, tuberous root dry weight and total dry matter (Fig. 3). TMS 30555 had the highest for tuberous root number whereas TMS 30572 had the highest value for leaf area, tuberous root dry weight and total biomass. Similar results observed in cassava plants (William 1972; Hunt *et al.*, 1977) have shown clonal differences in growth parameters of cassava.

Figure 3: Clonal differences in combined analysys at five months after planting in growth parameters of cassava clones grown under different regimes. Vertical lines indicate L.S.D. at 5% level of probability



The temperature-clone interactions were significant at 5 months after planting for tuberous root number, leaf area and total dry matter per plant. At low temperature of 25/15°C, the interaction with TMS 30572 and TMS 30555 had the highest values for the traits measured when compared to other clones. The 25/15°C interaction with TMS 30572 had the highest mean values of tuberous root number (3.0), leaf area (630 cm^2) and total dry matter (205g) respectively. Also, 25/15°C interaction with TMS 30555 had mean values of tuberous root number (2.5), leaf area (580 cm^2) and total dry matter (190g) respectively.

These results reveal that TMS 30572 and TMS 30555 performed better at low temperature regime of 25/15°C. The mother sett serves as a source of energy for the establishing new plants. And also, large-size mother sett at planting may result in high yield among improved IITA clones in low temperature

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Nutritive Potentials of White Snails *Archachatina Marginata* in Nigeria

I. E. Ebenso

Heliciculture Research, Animal Production Unit, Department of Animal Science, University of Uyo, P. M. B. 1017 Uyo, Nigeria

Abstract

Presently, "white bodied" African giant snails A*rchachatina marginata* are not consumed due to cultural belief. Its nutritive potentials reveal that the amino acid contents compare with whole hen's egg and will serve as good protein supplement in predominately rural cereal diets. Increase in it's popularity and utilization are suggested.

Keywords: White bodied snails, snail meat colour, Ar*chachatina marginata,* Nigeria

Résumé

Actuellement le mollusque géant africain *Archachatina marginata,* couramment connus sous le nom de mollusques à coquille blanche n'est plus consommé pour des raisons purement culturelles. Son pouvoir nutritif montre que sa chair rivalise avec l'œuf de poule et qu'il peut servir de source de protéine pour la majeure partite des régions rurales qui ont des céréales comme aliment de base. L'augmentation de sa popularité et ses diverses utilisations sont discutées.

Mots clés: mollusque à coquille blanche, couleur de la chair de mollusque, *Archachatina marginata,* Nigeria

Introduction

With the decline in per capital income coupled with acute population pressure especially in developing countries like Nigeria, increasing attention is now shifting to the consumption of protein alternatives like edible mollusk flesh (Ndifon *et al*., 1997). Snails collected from the wild can easily be kept in cages to grow and gain weight. In rural communities, snails are sold to augment family income. Domestication, breeding and control are reported (Ebenso, 2002 a, b; Ebenso and Okafor, 2002; Ebenso *et al*., 2002; Ebenso, 2003; Ebenso, 2004).

Owen and Reid (1986) reported that in Nigeria, there exist "white bodied" *A. marginata,* rarely eaten by human population. White snails are considered taboo and are not consumed. The local belief is that they are used by witch doctors in their activities. Snail farmers do not domesticate white snails.

The giant snail could have restricted consumption linked to prejudices of snails as oriental medicine or special foreign cooking material and not on meat colour (Lee *et al*., 1994). Snails collected from open and unrestricted environments (from the wild), could be contaminated with heavy metals making their consumption dangerous as these are more stable in the edible muscle (Udosen, 2000). Consumption of sun-dried or smoked meat is uncommon (Ebenso, 2002). Moslems do not eat snails for religious reasons. *Achatina achatina* are white, yellow and gray coloured (Lee *at al*., 1994).

Although studies have been conducted on *Achatinade,* there appears to be no information on nutritive value of the white snails, hence the present study. It is hoped that the findings would be of benefit to snail farmers and consumers.

Methods

Ten mature *A.* m*arginata* white snails with a live weight of 100-120g were gathered from wild populations at Ikot Oku Ikono, Uyo, a rural community in the forest region of Nigeria (precipitation 1500 mm). Each snail was killed by gently breaking the shell with a stone and the meat separated by hand. In the laboratory, after peeling and eviscerating, mucous was removed according to methods of Lee *et al.* (1994). Oven-dried snail meat samples were used for analysis using methods of AOAC (1980) for proximate composition, and Spackman et *al,* (1958); Moore, (1963) for amino acids.

Results and Discussion

The proximate composition of African giant land "white bodied" snail A. m*arginata* is presented in Table 1. Ash content in the present study when compared with previous studies as in *Achatina fulica* samples is in inferior considering 1.39, 1.29 and 1.25g/100gDM for gray, yellow and white coloured (Lee *et al.,* 1994); 9.26g/100g DM (Creswell and Kompiang, 1981) and 11.76g/100gDM for *Limicolaria aurora* (Udo

et al., 1995) According to Aboua, (1995) *A. marginata* has low mineral composition indicated in its ash content.

Table 1: Proximate composition of "white bodied" snail *A. marginata*

Constituent	*Content
Moisture	80.13 ± 1.23
Crude protein	82.38 ± 1.83
Crude fibre	0.21 ± 0.01
Fat	1.06 ± 0.09
Ash	1.16 ± 0.16
Nitrogen free extract	15.19 ± 1.21

* mean (g/100gDM) + standard error

During experimentation, fat content recorded was 1.06gm/100gDM, which is low when compared with 9.6, 2.14 and 23.0% found in chicken egg, mutton and duck (Omole, 2000). This low fat content makes it useful for hypertensive patients and those that are obese (FAO, 1986).

Crude fibre value in Table 1, compared with that of periwinkle *(Pachymelania aurita),* which was non-existent in garden snails, *A. marginata, A. achatina* (Imevbore, 1990).

With emphasis on protein content, and as a cheap protein supplement for its dietary significance for rural dwellers, crude protein values of this study is 82.38g/100gDM, compare favorably with 83.88 and 85.56g/100gDM for yellow and white coloured snail meat (Lee *et al.*,1994), but, superior to values reported by Mba (1980) for land snail *(Vivapara quadrata)* 63.4g/100gDM; periwinkle *(Pachymelania byronenis)* 55.0g/100g DM; crayfish *(Paramonetes varians)* 69.5g/100gDM; Ifon and Umoh (1997) for clam *(Egreria radiata)* 61.0g/100gDM and Paul *et al.* (1976) for whole hen's egg 50.0g/100gDM. White snails gathered locally can supplement the costly table egg and a good source of animal protein.

Nitrogen free extract value of this study was less than 27.1g/100gDM reported by Udo *et al.* (1995).

The amino acid composition is presented in Table 2. The snail body is well balanced with amino acid content (Mead and Kemmerer, 1953). This study indicates that white snails contained all the amino acids naturally present in proteins and superior to those of other wild snails (Kim *et al,* 1983) and marine shellfishes (Ryu *et al,* 1985).

Table 2: [1]Amino acid composition of "white bodied" snail *A. marginata* compared with *Achatina achatina*

	A. marginata		[2]*Achatina achatina*	
Amino Acid	White	White	Yellow	Gray
Alanine	4.28	4.39	4.39	3.88
Arginine	7,03	7.05	7.00	7.57
Aspartic acid	8.51	8.09	8.73	8.37
Cystine	2.01	1.44	1.44	1.43
Glutamic acid	14.05	14.61	14.37	13.59
Glycine	6.20	6.23	6.27	6.38
Histidine	2.64	2.95	3.08	2.09
Isoleucine	4.31	4.85	4.83	5.35
Leucine	6.05	6.64	6.64	7.19
Lysine	4.46	5.00	4.95	5.33
Methionine	2.97	3.45	3.63	2.46
Phenylalanine	4.51	4.46	4.45	4.61
Proline	5.03	5.69	5.57	7.11
Serine	5.24	4.94	5.13	4.37
Threonine	5.06	5.00	4.93	4.91
Trytophane	0.78	0.65	0.53	0.68
Tyrosine	2.32	2.28	2.31	2.82
Valine	6.50	6.84	6.46	6.40

[1] g/100g protein
[2] Lee *et al.* (1994)

The concerns raised by Imevbore (1990) and Udo *et al.* (1995) that snails have low levels of sulphur containing amino acids, but superior in contents to limiting values in cereal based diets of rural communities, can be reassuring as revealed by results of this study (2.97 methionine and 2.01 cystine), which are comparable with whole hen's egg of 3.20 methionine and 1.80g/100gDM cystine reported by Paul *et al.* (1976).

Conclusion

Snail meat consumed by rural communities is governed by culture than by social status. It becomes worrisome that, being one of the cheapest animal protein supplement, the production and utilization of white snail in the food – feed systems of the country and indeed West Africa have been overlooked.

Processing of white snail meat, which results in increased protein digestibility and loss of trypsin inhibitor, with good nutritive potential, could increase its popularity, utilization on a continuing basis and for export to countries with no discrimination in snail meat colour.

It is a potential source of protein for monogastric farmers. Arable farmers are assured of manure for their home garden if white snails are domesticated.

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Indigenous Technology Initiatives in Finger Millet *(Eleusine Coracana)* Cultivation in Tanzania

D.G. Msuya

Graduate School of Asian and African Area Studies, Kyoto University, 46-Shimoadachi-cho, Yoshida, Sakyo-ku, Kyoto 606-8501, Japan

Abstract

Finger millet cultivation in Tanzania is appreciably based on indigenous production technologies. This paper attempts to put together some information on various traditional systems of producing the crop in the country. The various systems are characterized by methods of land preparation and soil fertility management, field crop management, labour economy, crop processing and utilization and crop improvement. The farmers' practices are discussed with scientific reasoning. It has been noted that farmers utilize ash either from wood in slash and burn systems or from weeds in cultivate and burn grassland systems as an important resource for soil fertility management. The burning practices also suppress weeds. "Cultivated fallow" systems provide fine soil structure favourable for seedling emergence and are very important in optimization of labour in peak periods. Impressive yields, farmers' maintenance of genetic materials and farmers' practices in crop processing invite scientific attention to their indigenous techniques.

Key words: Slash and burn, indigenous initiatives, kuvundika, ntumba, nkule, submersion and soaking processing

Résumé

En Tanzanie, la culture de l'éleusine ou coracan est en grande partie basée sur des technologies traditionnelles de production. Cet article essaie de passer en revue les informations disponibles sur les divers systèmes traditionnels de production de la culture dans ce pays. Les divers systèmes comprennent les méthodes de préparation du sol et la gestion de sa fertilité, les soins apportés à la culture en champ, la gestion de la main d'œuvre, la transformation de la récolte et son utilisation, de même que les aspects phytotechniques liés à l'amélioration de la culture. Les pratiques traditionnelles sont revues et interprétées avec une optique scientifique. On a constaté que les paysans utilisent les cendres résultant de la coupe et le brûlis des herbes et ligneux lors des activités de défrichement ou des cendres résultant du brûlis de mauvaises herbes lors du sarclage qui sert aussi de source essentielle pour la gestion de la fertilité du sol. Ces pratiques de brûlis comportent aussi d'autres avantages tels que l'élimination des adventices et le maintien de la fertilité du sol. Les systèmes de la jachère cultivée conduisent à une bonne structure du sol et stimulent la germination des graines et la levée des plantules, et ils s'avèrent aussi très importants dans l'optimisation de la main d'œuvre lors des périodes de pointe. Des rendements très intéressants et des procédés traditionnels de maintien du matériel génétique, de même que la transformation des récoltes doivent jouir de l'interprétation scientifique émanant de ces techniques traditionnelles.

Mots clés: défrichage, brûlis, pratiques traditionnelles, kuvundika, ntumba, nkule, transformation par submersion et trempage

Introduction

Finger millet (*Eleusine coracana* (L.) Gaertn.) is an important cereal crop particularly in East and Central Africa and Southern Asia. The crop is among few crops known to have been either wholly or partially domesticated in East Africa (Vavilov, 1951). There are indications that the crop is of very ancient cultivation in East Africa and according to Purseglove (1985), the crop is considered to have been introduced to India approximately 1000 years B.C.

In many parts where finger millet is grown, it serves as a staple food. The crop is a very convenient grain. It can be stored for longer periods than any other cereal without deterioration or use of any insecticide. As its seeds are small, they dry out quickly and insects cannot live inside them. Sufficient storage has been recorded for as long as ten years or more (Acland, 1971; Purseglove, 1985). Because of it's storage characteristics, finger millet is recognized as a very important famine crop.

Statistics for world finger millet production are not readily available. Combined data for finger and bulrush millet, however, show that world production in 1999 was approximately 26.35 million metric tons with 8.1 million tons from India and 12.93 million

tons from Africa. Tanzania produced 499,000 metric tons from an area of 240,000 hectares (FAO, 2000). In Tanzania, finger millet is grown in the southern highlands in Ruvuma, Mbeya, Rukwa; in the central plateau particularly Kondoa in Dodoma and Singida; in the northern highlands in Kilimanjaro and Arusha, and in north Mara area.

Being mostly a traditional crop with very limited distribution, finger millet cultivation practices, in Tanzania in particular, have remained more or less indigenous. Complex localized systems exist for the cultivation of the crop in various places. Very limited literature is however available detailing on the traditional cultivation practices. Little research has been conducted specific on this crop. Farmers' practices are localized in the various production areas and most of them have evolved as indigenous technologies. Little information is available, on the other hand, on potentials for sustainable, farmer acceptable improvement of the crop production practices. This paper attempts to put together information on some important indigenous practices of finger millet cultivation in Tanzania. Information presented here is based on a survey conducted in 2000/2001 in some areas of Tanzania where finger millet is produced. The areas were Mbeya (particularly Mbozi and Ileje Districts) and Sumbawanga in southern highlands of Tanzania, and Kondoa in central Tanzania. During the survey observations were made and information was collected on indigenous systems of finger millet cultivation. Field trials were also conducted in Mbozi District to test some of the indigenous technologies.

Farmer Initiatives

Production of finger millet in Tanzania, unlike with other crops, relies almost entirely on indigenous production methods and practices. These practices range from cultivation or field preparation and all subsequent operations to the utilization of the crop product. The practices seem to have developed through decades and probably centuries of accumulation of knowledge and experience within a closed system, without much external influence. In almost all situations especially in southern Tanzania, the crop is cultivated mostly in remote areas with extensive systems of cultivation and almost inherently excluded from any intensive cultivation system. In these areas, production resources arise from within the system with nothing from the outside and the production system is maintained through indigenous initiative. With many indications of rather innovative indigenous technology, the system attempts to make itself self-sustaining, sometimes with application of considerably "out-of-fashion" practices. There are many signals in the system which show detailed and well comprehended application of modern scientific principles of agriculture.

Cultivation and Land Preparation

Cultivation or land preparation for finger millet presents probably one of the most interesting aspects of indigenous farming systems especially in southern Tanzania. Through years of experience, farmers have developed methods of cultivation that make it possible to realize crop harvests without reliance on external inputs. Rather intricate traditional practices have been adopted that ensure sustainability of crop production under largely natural conditions. These cultivation systems include the slash and burn practice and fallow systems of various forms.

Slash and burn cultivation

The systems involve cutting of tree, shrub and grass vegetation and burning them after which they plant finger millet in the ash field. Farmers consider the ash obtained after burning the plant materials as a very important resource for soil fertility. As there is no chemical fertilizer used in these fields, farmers have observed that when finger millet is planted on ash it grows better and more vigorously. Farmers therefore consider ash as a very valuable resource particularly for finger millet cultivation.

After opening a slash and burn field, farmers are assured of obtaining high yields in the first year of cultivating finger millet in the field. The farmers can then repeat planting finger millet in the same field once, never more than twice as yields decline after the first year of cultivation. Farmers also claim some residual beneficial effect of ash on yield after the first year of slash and burn cultivation but these yields from residual effect are never as much as yields in the first year under direct influence of ash. According to farmers, yields from residual effects are closer to yields under no slash and burn in the first year of cultivation. In Table 1, statistics on yield under the influence of ash in a slash and burn cultivation experiment are presented. Even though this experiment was not designed to provide data on residual effect of ash on yield after the first year cultivation, such data are comparable with no burning conditions.

Table 1: Finger millet grain yield, soil reaction and soil's major plant nutrients under the influence of slash and burn cultivation

Slash and burn practice	Yield t/ha	Soil pH		%N		P (ppm)		K (m.e.q/100g)	
		A*	B	A	B	A	B	A	B
Uniform, complete burning	4.23	6.7	8.2	0.09	0.11	14.8	55.4	0.17	1.85
Patchy, partial burning	2.41	6.7	8	0.1	0.1	14.6	25	0.81	1.71
No burning	1.2	6.7	6.7	0.1	0.1	14.6	7.2	0.17	0.77
Mean	2.61	6.7	7.6	0.1	0.1	14.7	29.2	0.17	1.44
CV %	33.8	1.2	3.2	7.1	18.2	9	56.6	55.8	4.9
LSD0.05	1.29	NS	0.04	NS	NS	NS	28.6	NS	0.16

A* = Before sowing B = At sowing time

Table 2: Exchangeable bases Mg^{2+}, Ca^{2+}; NH_4^+-N and NO_3^--N content in the soil in relation with the slash and burn system of cultivation.

Slash and burn practice	Mg^{2+}		Ca^{2+}		NH_4^+-N		NO_3^--N	
	(m.e.q./100g)				(cmol(+)/kg			
	A*	B	A	B	A	B	A	B
Uniform, complete burning	1.25	3.58	4.85	20.6	0.30	0.38	0.63	0.59
Patchy, partial burning	1.31	3.25	4.61	18.27	0.28	0.29	0.67	0.72
No burning	1.27	1.81	4.67	7.16	0.32	0.25	0.41	0.53
Mean	1.28	2.88	4.71	15.34	0.30	0.31	0.57	0.61
CV %	9.2	30.3	10.0	16.5	14.9	14.4	49.3	27.4
LSD0.05	NS	NS	NS	4.37	NS	0.08	NS	NS

* A = Before burning B = After burning at sowing time

From Tables 1 and 2 evidence is presented on the influence of burning on soil fertility and consequently on crop yield. The data presents significant change in soil pH from 6.7 to as high as 8.2 after burning. Soil P increased from 7.2 to as much as 55.4 ppm as a result of burning; there was also significant increase in soil K^+, Ca^{2+} and NH_4^+-N. Undoubtedly therefore the increase in yield from 1.2t/ha in absence of burning to 4.2t/ha after burning must be in association with the increase in soil nutrients.

Many workers have reported on improvement in soil nutrients as a result of burning. Andriance and Koopmans (1984) present results on notable increases in soil P due to slash and burn practice. Stromgaard (1989) has reported increases in soil P, K, Ca and Mg in response to burning while Ellingson *et al.*, (2002) have reported increases in soil NH_4^+-N. Many other workers have reported increases in soil nutrients as a result of slashing and burning (Giardina, *et al.*, (2000); Van-Reuler and Janssen (1993); Stromgaard (1984).

The slash and burn practice is also associated with ability to suppress weeds. Under the slash and burn system, when finger millet has been planted in the same field for one or at most three years to grow the crop usually a new field must be opened by slashing and burning virgin or fallow land. While a new field is being opened usually there are previous fields that are under fallow to regenerate the vegetation lost by slashing and burning. Because of high level of ground cover by trash and decomposing organic matter, and because of the shading effect of trees, a virgin or long fallow land rarely has the problem of much weed infestation. Weed propagules that would later on compete with finger millet in such an ecosystem are therefore unlikely to be many, and the burning practice eliminates any of such propagules present or brought into the field by wind or other means.

The connection of the slash and burn practice and finger millet cultivation has been a subject of considerable discussion. Farmers usually use finger millet as an opening crop for any land that has not

been cultivated previously and not any other crop. It is not clear why there is significant impact of ash on finger millet after slashing and burning. For example, is not perceived by farmers in the same way for other crops. Nevertheless, finger millet benefits from ash. Insistence of finger millet as the opening crop is, however, probably based more on tradition than any scientific reasoning. Finger millet is the most traditional or ancient crop in the area of its cultivation. Farmers who cultivate finger millet tend to maintain ancient knowledge associated with cultivation of the crop. If conditions allowed, farmers interviewed would exclusively prefer slash and burn cultivation or at least virgin land conditions. Cultivation of other crops was adopted later with insistence that they could conveniently be cultivated on fields that were previously cultivated with finger millet. It is also true that finger millet is very responsive to soil nutrients and it is only in the slash and burn/ash system (or virgin land conditions) that soil nutrients are in abundance that support vigorous growth.

Fallow Systems

i. Ntumba system

A rather unique system of land preparation – the *ntumba* system – is practiced in south western Tanzania in Mbozi and Sumbawanga. The *ntumba* system is also recognized as the Fipa mound system. In the past, before the inception of ox-ploughing in 1950s, the system was widely practiced by the Fipa people in Sumbawanga. Nowadays it is much more found in the Unyamwanga area in the Ufipa plateau zone of Mbozi district. In this area the use of ox-ploughs is not yet much adopted by farmers.

The *ntumba* system involves a characteristic style of cultivating with turning the cut slice and heaping the soil in round conical hills that appear as mounds. During heaping, the slice (or plow) is turned upside down such that the surface soil and any organic material including grass and leaves of trees and shrubs are buried into the soil while the lower or supposedly bottom surface of the plow is exposed to air. Before ploughing, usually all grass in the field is slashed and collected somewhere outside the field or at specific spots within the field such as around stumps or bases of trees. The grass will eventually be burnt sometime after cultivation. Usually in the field there would be some scattered low growing trees. These are usually not cut prior to cultivation. The *ntumba* are made leaving the trees intact while scrapping the plow soil around the trunk of the trees so that the field is not left with uncultivated patches. The trees are cut later and burnt before breaking the *ntumba.*

The *ntumba* are made during the rainy season preceding the planting season, mostly in the period from March to early June. During this time the soil is soft and the farmer can maneuver the plow easily to turn it perfectly upside-down. The plow is usually full of interwoven roots of grass vegetation and this, coupled with the moist condition of the soil, gives the plow great flexibility and can be turned easily without breakage of soil clods. The mound is therefore made almost perfectly round on top and on the sides and this is enhanced by earthing up the sides with soil on the ground surface between adjacent mounds. The size of the mound varies from roughly 50–120cm diameter and 30–50cm height. Space between mounds can vary from 30–40 or 50cm depending on size of the mound.

Prior to planting finger millet in December/January, the mounds are broken and the field leveled by spreading the heaped soil evenly on the low spaces previously in-between adjacent mounds. Before breaking the mounds, weeds or fresh green, succulent vegetation that had grown in the *ntumba* after the onset of rains in late October are slashed and ploughed under into the soil during breaking *ntumba.* Thus the *ntumba* are broken in November/December after the field has stayed in cultivated condition for five to nine months or more. During this period any buried organic material would have decomposed thus improving the soil structure. A fine tilth appropriate for finger millet sowing is then obtained after breaking the *ntumba* and leveling the field.

Farmers' perception in practicing *ntumba* is that it improves soil fertility via organic matter incorporation thus increasing yield also. Morever, because of decomposed organic matter *ntumba* cultivation improves soil structure and under good rainfall conditions prior to sowing *ntumba* cultivation results in humic, well structured fine soil when the *ntumba* are broken for sowing. This humic structure is very good for sowing finger millet, results in good seedling emergence and vigorous seedling establishment. Table 3 presents experimental data showing changes in soil fertility as a result of *ntumba* cultivation. As we can see, the *ntumba* system of cultivation caused significant increase in soil's total %N and K^+. Soil reaction and the other nutrients measured were not significantly influenced by *ntumba* cultivation. Table 4 presents data on dry matter accumulation and grain yield under the influence of *ntumba* cultivation. Total dry matter accumulation as well as dry matter in leaf blades, stems and panicles increased significantly ($P < 0.05$) by the *ntumba* cultivation but grain yield and leaf sheath dry matter did not show any significant response.

Table 3: Concentration of soil nutrients and soil reaction (pH) in the *ntumba* system of cultivation (sowing time)

Cultivation practice	pH	%N	P (ppm)	K	Mg m.e.q./100g	Ca	NH_4^+-N	NO_3^--N cmol(+)/kg
Ntumba	5.8	0.11	31.3	0.34	0.92	7.15	0.79	0.38
Normal cultivation	6.5	0.2	40.8	0.89	1.49	7.89	0.96	0.36
Mean	6.1	0.15	36	0.61	1.2	7.52	0.87	0.37
CV %	11.8	21.1	30.5	39.1	36.9	47.1	30.2	35.2
Probability	NS	0.05	NS	0.05	NS	NS	NS	NS

Table 4: Dry matter accumulation (at physiological maturity) and grain yield of finger millet under influence of the *ntumba* system of cultivation

Cultivation practice	Dry matter accumulation (g/m^2)				Grain yield	
	Total	Sheaths	Blades	Stems	Panicles	g/m^2
Ntumba	227.8	28.7	54.6	47.9	96.5	120.6
Normal cultivation	145.0	20.6	35.5	28.4	59.4	85.4
Mean	186.4	24.6	45.0	38.1	77.9	103.0
CV %	15.6	36.6	23.3	20.0	17.0	35.1
Probability	0.002	NS	0.02	0.004	0.002	NS

ii. Cultivated fallow systems

In addition to the *ntumba* system, farmers practice a sort of "cultivated fallow" or "*kuvundika*" system that enables them to improve the soil and distribute farm labour more efficiently. This involves cultivating the field very early, during the growing season preceding the actual cropping season, then allowing it in a state of "cultivated fallow" until the next season when it is re-cultivated (*kuvundulua*) and planted. The field is cultivated during or towards the end of the rainy season (March – June). During this period, the soil is cultivable and there is a lot of green and succulent organic matter (weeds) to be incorporated into the soil. These organic materials are believed to add nutrients (N, exchangeable bases and P) into the soil. Cultivation during the growing (rainy) season of the crop also improves infiltration of water into the soil and reduces runoff losses.

The most common type of cultivated fallow land preparation is by the use of ox-plough. Most finger millet farmers in southern Tanzania use this method of land preparation. The field is cultivated with an ox-plough during the rainy season (March to late May) and it is not planted with any crop until the beginning of the next growing season which starts in November. The field is re-cultivated before it is then planted with finger millet towards the end of December to mid-January. Sometimes re-cultivation may be more than once, early during the rainy season after the first cultivation, or late in the beginning of the next growing season near planting. Repeated cultivation incorporates any green vegetation that grew in the field after the first cultivation, enhances breakdown of any un-decomposed organic matter in the soil, and provides a very fine soil structure. A fine soil structure is ideal for proper finger millet seed germination and seedling establishment because the finger millet seed is very small in size.

Another type of cultivated fallow is the ridge system. This involves cultivating by making ridges with hand-hoe. These ridges will later on be broken and finger millet planted. The ridges are usually, like the ox-ploughing cultivated fallow system, made in March–June before the end of the rainy season. Sometimes the ridges are planted with cassava, of which cuttings are planted at the lower sides of the ridge. During the next rainy season the ridges are broken and soil spread for finger millet sowing, which also serves as weeding for the cassava crop.

Nkule System

The *nkule* system is another characteristic technique of land preparation practiced in southern Tanzania. It is a "cultivate and burn" system practiced in plainland (*mbuga*) areas with grassland vegetation. The system

involves cultivating the soil and later on burning to ashes grass piled up within the cultivated soil when the grass is dry. In so doing both the grass and soil are perfectly burnt before the resulting soil and ash mixture are spread for finger millet planting. Usually the grass in the *mbuga* area forms a dense, low growing cover on the soil. Its roots are also very dense, tightly interwoven in the soil such that upon cultivation clods become very stable and also very resistant to breakage. Because of the density of roots when fire is set, the soil clods burn perfectly with both the roots and the above-ground shoots burning to ash. The burning proceeds slowly and all plant material particles and the surrounding soil are heated to remain with ash only on the burnt spot. Prior to sowing finger millet the burnt soil/ash mixture is spread evenly in the field by breaking the piles of burnt material. This is done in late October or November after the first rains. By then, the burnt soil/ash mixture would have been in the field for about two or three months.

The cultivation of the *nkule* field starts in June/July after rains have ceased. The plain areas (*mbuga*) are swampy during the rainy season due to high water table and accumulation of rainwater. It is only after the water has dried up that it is possible to cultivate the field. After cultivation in June/July, the grass and soil clods are left to dry completely, then the soil clods are collected and piled up-side down to form mounds of up to 1.0 m diameter and about 0.5m high. The piles or mounds are arranged so as to cover the whole field to ensure adequate distribution of ash all over the field after burning.

The burning process normally takes several days, about two to three days. Once fire has been set, burning proceeds slowly from within the mound because of the grass and roots covered in the mound. The burning seems to be slightly anaerobic with a lot of black smoke coming out from within the mound. When all plant materials have been burnt, the fire in the mound goes off by itself. During burning, soil is earthed-up from the sides of the mound to cover any areas where the burning materials are exposed and smoke is originating not from deep within the mound. In so doing burning becomes slow and the slightly incomplete burning (anaerobic condition) is retained for a longer period. .

The *nkule* system is also referred to as the *ihombe* system in some places. The *nkule* or *ihombe* system is very productive. Average yield of five tons per hectare field has been recorded under this system of cultivation (Table 5). The yield was 7.9t/ha when plants were harvested exactly from the area on which plant materials were burnt (the mound or locally known as *pilyala* or *pitoi*) and only 1.4t/ha when harvested from adjacent areas that just received ash and burnt soil spread from the *pilyala (*pilyala spread or *apamsilinsi).* It is not evident that such a huge difference arises from the effect of ash or burning on soil fertility only. Normal finger millet yields are reported to be less than one ton per hectare though yields of up to 4.5-5.0t/ha have also been recorded (Purseglove, 1985; Acland, 1971). Duke (1978) reports average seed yield of five tons per hectare under intensive cultivation practices with chemical fertilizers and optimum management. Normal yields in southern Tanzania are within the range of 0.5-2.0t/ha but as much as 5.0t/ha are known (Mwambene, 1986) but are very rare.

Table 5: Grain yield of finger millet in *nkule* (*ihombe*) system of cultivation

Cultivation particulars	Yield (kg/ha)
Nkule (ihombe) system	5004
Pilyala/pitoi (mound)	7936
Pilyala spread/apamsilinsi	1356
Mean	4765
S.E. ±	58.0
C.V. %	1.7
LSD0.001	657.9

Source: Field trials in Zelezeta village, Igamba, Mbozi District, 2001

The burning of *nkule* mounds also eliminates the problem of weeds. In the wet plainland fields no other method of cultivation would manage to suppress the weeds other than the *nkule* burning method. Weeds in these areas are very dense with dense roots and underground stolons such that they form an interwoven soil mat with very little soil mass in the soil clod upon cultivation. Breaking these clods by harrowing after cultivation cannot remove all the stolons and other growing structures and very little soil is obtained by trying to break them.

Under the indigenous conditions, burning is the only effective way of getting rid of the weeds. In the burning process not only the vegetative weed propagation structures are eliminated but also all weed seeds. The *nkule* fields therefore become very free from the severe weed problem that would be prevalent without burning. Burning also seems to eliminate soil-borne pathogens that would later on influence the crop. It is well perceived among farmers who cultivate in the *mbuga* area that there is absolutely no finger millet crop growth in the area if cultivated and sown without burning (*sesa* system). The problem starts right from the seedling emergence stage and among factors responsible could be infection with soil-borne pathogens. If the seedlings emerge, they rarely grow beyond the two leaf stage; instead they

become very stunted, then yellowing and withering away; while in burnt plots they flourish and grow very vigorously. The reason for this is complicated and is a subject for investigation; it may range from soil micronutrient fertility/toxicity, soil reaction to soil biological factors such as allelopathy.

Comparative seedling and crop plant performance in the *mbuga* area under burning and no-burning (*sesa*) conditions are presented in Table 6. As can be seen from the Table, farmers have been able to tackle the problem of utilizing the *mbuga* land in quite a simple technique, increasing plant growth substantially. Duke (1981) reported dry matter yield of up to 9tons/ha which is quite close to the dry matter yield achieved in the *nkule* system (676.7g/m^2 or about 6.8t/ha) three months after sowing (Table 6). In trials conducted in 2001 at Zelezeta, there was absolutely no growth where there was no burning therefore nothing for comparative assessment. In the 2002 trial as it can be seen in the Table it can be concluded that finger millet growth in absence of burning (*sesa*) was negligible.

The *nkule* system is an indigenous breakthrough in the utilization of *mbuga* area particularly for finger millet production. As already mentioned earlier, finger millet is an ancient crop in the area of this research and farmers during the time of inventing *nkule* system of cultivation had nothing to involve themselves much with crops other than finger millet which was an almost exclusive staple food. *Nkule* cultivation resolved the difficult environmental problem of utilizing the *mbuga* area. Due to weed problem, it is almost impossible to cultivate the *mbuga* without burning because weed propagules are very difficult to remove. Since burning takes a reasonably long time, the heat from the burning mound dries even weed propagules that are very deep in the soil and then burn them. The *nkule* field therefore becomes very clean with substantially reduced infestation of weeds that are usually very difficult to remove without burning.

Nkule cultivation is also a very good indication of indigenous practice of crop rotation that is also almost automatically pre-determined by environmental limitations. As it does not pay to repeat growing finger millet in the same field after harvesting the *nkule* crop (because of difficulty in weeding and lack of crop establishment and growth) farmers growing finger millet must open another field after harvesting the previous *nkule* field. The harvested *nkule* field may then be allowed to remain in fallow condition for about three to five years during which period re-growth of the grass (weed) vegetation takes place to a suitable state for *nkule* cultivation. Repeated cultivation of the *nkule* system in previously cultivated field is only possible or convenient when the grass vegetation has formed a dense mat which provides abundant raw material for the burning process. The proportion of vegetative materials in the soil clods that are piled up for burning is usually much more than soil (volumewise) and this allows perfect burning of the *nkule* mounds. Without high proportion of vegetative materials in the soil clods, burning does not become very effective.

Burning of *nkule* alters soil reaction leading to reduction in soil acidity. Table 7 presents data on soil reaction and soil nutrients concentration from *nkule* experiment. As it can be seen from these data, soil pH was raised and was signicantly different ($P < 0.001$) from pH in the control (no burning or *sesa*) plots. There was no soil nutrient whose concentration showed significant increase as a result of burning the *nkule*; and this leaves questions of what is responsible for good crop establishment and high yield in the

Table 6: Comparative seedling and crop growth performance in the *mbuga* cultivation under burning (*nkule*) and no burning (*sesa*) conditions.

Cultivation practice	Seedling emergence count (m^{-2})	Seedling dry weight (g/m^2)	Plant count 1 month (m^{-2})	Plant height 1 month (cm)	Plant dry wt. 1 month (g/m^2)	Plant Count 3 months (m^{-2})	Plant height 3 months (cm)	Plant dry wt. 3 months (g/m^2)
Nkule	269	0.725	171.8	7.7	3.9	189.8	81.4	676.7
No burning (sesa)	234	0.075	104.8	1.3	0.16	78	8.6	2.3
Mean	251.5	0.4	138.3	4.5	2.03	133.9	45	339.5
S.E.+	98.9	0.15	49.9	0.88	2.31	27	3.06	38.4
CV (%)	55.6	53	51	27.5	-	28.5	9.6	40.5
LSD0.05	NS	0.368	NS	2.14	NS	66.1	7.48	93.9

Source: Field trials in Kakozi village, Ndalambo, Mbozi District, 2002

Table 7: Soil reaction and soil nutrients in nkule system of cultivation (2001).

Cultivation practice	pH		%N		P(ppm)		K (m.e.q./100g)		Mg (m.e.q./100g)		Ca (m.e.q./100g		NH_4^+-N(cmol(+) kg	NO_3^--N(cmol(+)/kg
	A*	B	A	B	A	B	A	B	A	B	A	B	B^	B^
Nkule	6.1	6.5	0.43	0.17	14	5.1	0.4	1.21	4.31	2.24	9.83	8.49	0.95	0.76
Control (sesa)	5.7	5.8	0.62	0.53	5.2	10.7	0.42	0.88	3.97	3.97	11.13	120	1.39	0.51
Mean	5.9	6.1	0.52	0.35	9.6	7.9	0.41	1.04	4.14	3.1	10.48	8.84	1.17	0.63
CV %	27.8	14.6	32.2	9	16.3	29.4	7.7	67.2	16	25.9	34.2	21.6	31	61.1
Probability	0.05	0.001	NS	0.001	NS	0.05	NS	NS	NS	0.05	NS	NS	NS	NS

* A = Before sowing B = After sowing ^ Pre-sowing samples not analysed

Table 8: Soil reaction and soil nutrients in nkule system of cultivation in 2002 (sowing time)

Cultivation practice	pH	%N	P	K^+ (ppm)	Mg^{2+} m.e.q./100g	Ca^{2+} m.e.q./100g	NH_4^+-N	NO_3^--N cmol(+)/kg
Nkule	6	0.11	26	0.75	1.05	2.9	1.01	0.35
Control (sesa)	5.6	0.18	15.4	0.66	1.36	1.36	0.58	0.28
Mean	5.8	0.14	20.7	0.7	1.2	2.13	0.79	0.31
CV %	2	22.6	27.4	39.4	32.8	3.36	5.7	0.42
Probability	0.003	0.004	0.038	NS	NS	0.023	0.0001	NS

nkule but not in normal (*sesa*) cultivation. Without burning there is evidence of some environmental stress that reduces seedling emergence, seedling establishment and crop growth in absence of *nkule* burning. This is a subject of further research.

Table 8 presents more soil fertility data from *nkule* system of cultivation in a trial conducted in 2002. In this trial *nkule* cultivation was as usual responsible for a very significant reduction in total soil percentage nitrogen and increase in soil pH. Significant increases in soil P, Ca^{2+} and NH_4^+-N were also recorded. These nutrients must have supported better crop growth performance where there was *nkule* burning but cannot explain why seedling establishment and crop growth were absent where there was no burning.

Field Crop Management

Critical aspects of finger millet crop growth in the field are soil fertility, soil water availability and weed management. Under indigenous cultivation systems the methods of cultivation have taken into consideration all these aspects. Slashing and burning or burning in the *nkule* system provide soil fertility through ash. The cultivated fallow methods are also believed to increase soil fertility through decomposing organic matter (subject to more investigation), and the cultivated fallow condition helps to conserve water in the soil. Both burning and repeated cultivation in the fallow methods have great control on the weed problem. Field seedling emergence and seedling growth are also critical factors though awareness of this is often masked by soil fertility. Evidence of the crucial impact of seedling emergence or seed germination and seedling establishment has been seen in the *nkule* system where usually no crop is harvested in the absence of the burning practice because of poor seedling emergence and/or seedling growth. Inspite of the masking effect, however, all land preparation practices seem to focus on the problem of poor seedling emergence and crop establishment in the field. This is among farmers' basic reasons for repeated cultivations in cultivated fallow systems; realizing that finger millet seed needs properly prepared seedbed for good germination/seedling emergence and seedling establishment. Slashing and burning substantially also improves seedling performance just like the burning in the *nkule*

system as already stipulated earlier (Table 6). Lack of proper seedling establishment in the *nkule* system where there is no burning can be attributed to pathological effects, among possibly other factors. High organic matter content (decomposing) is predisposing to these pathological effects.

Distribution of Labour

The economics of labour utilization is an important aspect of finger millet production in southern Tanzania. Because farm activities are many and farmers have to cultivate extensively to have any reasonable harvest from their no-input agriculture, farmers must distribute their family (household) labour force judiciously to cover the peak and slack periods of the year. At the onset of rains in late October and early November, they prepare maize fields. Maize is the most important food crop therefore receives first priority in terms of labour. When they have finished planting maize in late November, they start preparing the seedbeds for sowing finger millet. Sowing of finger millet starts in Mid-December up to Mid-January (rarely up to February).

In December, they may also be planting beans, on ridges made early in the month or in November. January and February are critical periods for weeding almost all crops. It is the period when rainfall is at peak and weeds have grown very vigorously since the beginning of their establishment soon after sowing the relevant crops (maize, finger millet, beans, etc). Weeding must therefore be immediate and may continue up to early March.

From mid-March, farmers may start harvesting beans and preparing fields for replanting beans in late March or early April. During this time preparation of "cultivated fallow" finger millet fields starts. The labour peak for crops already in the field starts to decline and continues to decline up to early May. In April few farmers may start harvesting groundnuts but groundnut fields are quite small. Because of the slack labour peak, it becomes therefore very convenient to prepare the *ntumba* or other "cultivated fallow" fields during the period March–June. This distribution of labour over time allows the household much more cultivation thus more acreage, production and cash income. During the period of March – April, the soil is also very cultivable because of the rains. From June and later on until the next rainy season the soil becomes very hard.

The *ntumba*, ox-plough and ridge cultivated fallow practices are the primary tillage activities. They make the subsequent seedbed preparation activities easy and saves a lot of time in preparing the field for immediate sowing when the rain has started. It would be almost impossible to prepare the *ntumba* at the beginning of the rains because it is a heavy manual activity and there would not be adequate time for the household labour force to make any sizable *ntumba* field within the short time period available before planting. Land preparation would neither be as good for sowing as with just breaking the *ntumba* that were made in the previous season and sowing the finger millet crop. Making the *ntumba* or cultivated fallow fields during the growing season of the previous crop therefore utilizes the time available most economically while saving much labour that would be necessary for primary tillage operations at the onset of rains if the crops were planted without cultivated fallow practice.

Crop Harvesting and Processing

Finger millet bears its grains (the useful product) in panicles. Conventionally, therefore, harvesting involves cutting and drying of the panicles and threshing them to obtain the grains. Some farmers however do not practice this method of harvesting and processing the crop. They find it difficult to detach the grains from the panicles by threshing dry panicles because it is a heavy physical labour activity. Much involvement is also necessary for adequately drying the panicles for threshing. In some places the crop may mature while rains haven't yet ceased. Because sun drying is used, harvesting the crop during wet conditions and failing to dry it immediately leads to sprouting or germination of the seeds while still in the panicles. Farmers in Ileje have therefore opted to a wet method of processing the crop after harvest. They have adopted two systems of wet-processing the crop – soaking and submersion.

In the soaking system panicles are harvested and piled up on a platform made of wood (*kichanja*) to soak in the rain water for about two weeks to one month. Banana leaves or any convenient grasses are put on the platform before piling the panicles, and also on top of the pile to cover the panicles. This ensures a permanent moist condition in the pile and prevents any possibility of any panicle to dry up during the processing or curing period. Any dry condition in the panicles will lead to sprouting (seed germination).

The other method is submersion which involves harvesting the crop then submerging the panicles permanently under water surface for about four to six weeks. In this method, not only the panicle is harvested but also part of the stem, up to about one foot from the tip of the panicle. This is then soaked

upside-down into water collected on a trough dug on a flat surface. The trough may be about 50cm deep or more, and before filling it with water, banana leaves are arranged to form a mat at the bottom. Water is then allowed into the trough while arranging the harvested finger millet panicles upside-down until the trough is full. The trough may be several square meters in area (usually about 1.5m x 1.5m to 2.5m x 2.5m) depending on quantity of the crop harvested. When the trough is filled with water together with the harvested crops a permanent stream of water is allowed into the trough so that the water level remains constant. There is an outlet from the trough to prevent water rising above the optimum level.

When the harvested crop has soaked with water for the relevant period of time (4 – 6 weeks), the panicles become soft and the grains become loosely attached to the spikelets/glumes. They are then taken out of water (or from the *kichanja)* and washed in water just by abrasion as if washing clothes. The grains become detached and settle down at the bottom of water in the washing container. These are then rewashed to clean them completely from any chaff, then immediately spread under the sun to dry. It is extremely important to ensure immediate and adequate drying of the wet grains otherwise they germinate at once.

Crop Utilization

In most parts of Tanzania finger millet is utilized to a less extent as a food crop, but more extensively for making local brews. The various types of local brews range from by local names *common, kimpumu, kihambule, kindi, diesel* and *mbege*. Some of these brews are made purely from finger millet only (especially *kimpumu*) while in others, finger millet is used only as malt. Farmers from different places have different ways of making the brews. There is no strict formula for making any of the local brews as you move from one place to another. Farmers in different places vary the ratios of different components that make the brew such as maize and finger millet flour, and may also vary the duration of fermentation that is necessary for beer making; hours of cooking or boiling the products and the ratios of water and flour. Through the various initiatives, farmers are able to brew by themselves the various products that satisfy the local market.

Among the local brews *kimpumu* and *mbege* are more popular and fetch more money. *Kimpumu* is made purely from finger millet without any other ingredients. *Mbege* is made from a combination of finger millet and ripe bananas with finger millet as the malt. Both are traditionally high value brews with good alcoholic quality. Details of making any of the local brews vary extensively. Basic processes for making the brews regardless of the type and place are however more or less similar. Most important processes involve pre-germinating the seeds (finger millet or, frequently, maize) then drying the grains and making flour from them. Different fermentation specifications then follow to make either malt or the brew. Finger millet is a necessary ingredient for most brews (probably all brews involving cereal grains) and other ingredients (if any) vary depending on type of brew. Tables 9 and 10 provide an example of details of the different processes and ratios of different ingredients in brewing of the most traditional finger millet alcoholic drink in Southern Tanzania, *kimpumu.* Different process specifications varied among different respondents depending on their own experiences. Further study to assess the quality of the products from different respondents and effectiveness of each specification seems to be necessary.

Table 9: Variation in duration of different processes of local beer (*kimpumu*) making among different finger millet farmers

Process	Duration in days						
Respondent	1	2	3	4	5	6	7
Soaking of seeds	1	1	1	1	-	-	1
Germination of seeds	4	3	3	2	-	-	4
Drying after germination	2	1	1-2	-	-	-	1
Fermentation	10-14	5	7	-	3	3	7
Making of starter, bulk preparation and final processes	1.5	1.5	-	1	1	1.5	1

Table 10: Variation in ratio of different components during local brew *kimpumu* making

Process	Ratio				
	Respondent 1	2	3	4	5
Fermentation	Flour + hot water until thick porridge	Flour + hot water until thick porridge	Flour + hot water until stiff porridge	Flour 1.5kg + hot water 2*l* (stiff porridge)	Flour + hot water until thick porridge
Making of starter	Thick porridge + hot water until thin porridge	Thick porridge undisturbed	Stiff porridge + hot water until thick porridge	Stiff porridge + hot water until thick porridge	Thick porridge + hot water until thin porridge
Making of bulk preparation	1*l*. Starter + 20*l*. Unfermented thick porridge	10*l*. starter + 50*l*. Unfermented normal porridge	10*l*. starter + 20*l*. normal porridge	2*l*. starter + 20*l*. thin porridge	Starter + unfermented normal porridge
Final processes	10*l*. bulk preparation + 50*l*. Hot water	30*l*. bulk preparation + 10*l*. Hot water	30*l*. bulk preparation + 20*l*. Hot water	No additional process	Bulk preparation + water until dilute (watery) preparation

On-Farm Cultivar Development

In Tanzania, finger millet is mostly a traditional crop. Farmers' own initiatives predominate the production practices for the crop. In southern Tanzania for example, only very few farmers may use any chemical fertilizer on finger millet. They rather manage fertility of finger millet fields through rotation and fallow systems and by incorporation of ash into the soil. The farmers use indigenous varieties of the crop, majority of whose yielding potential seems to be quite acceptable. Under heavy incorporation of ash into the soil some indigenous cultivars have been able to give rather high experimental yields of up to almost eight tons per hectare (Table 5). Interestingly, such cultivars are being developed by farmers without any definite breeding plan through years of selection of desirable plant types and saving seed. Few farmers, however, can trace the history and origin of some of the currently cultivated finger millet types. In Kondoa, for example, farmers use what they describe as a good quality, high yielding cultivar known as *Mtaalam.* They can trace the origin of this cultivar from previously cultivated indigenous cultivars some of which are now extinct. This farmers' genetic track of the cultivars is illustrated below:-

Selective on–farm development of finger millet cultivar *Mtaalam* according to farmers' historical experience (oral description)*

Selection sequence	Cultivated type	Use situation
Original parent	Mwela	Previously cultivated. Now extinct
↓	↓	
1st generation selection	Ntukala	Previously cultivated. Now extinct.
↓	↓	
2nd generation selection	Mbege	Sparingly mixed with other varieties
↓	↓	
Current cultivar	Mtaalam	Currently mostly cultivated type

* No record of yield or years relevant to the time when each cultivated type was dominant

Conclusion

Impressive indigenous technical innovations have been in operation for a long time in the production of finger millet crop and its utilization. The various ways that farmers prepare their fields to ensure maximum seedling emergence and put under control severe weed problems, the incorporation of ash into the soil to serve as a source of fertilizer nutrients, the soaking methods of processing the crop after harvest and the various ways of brewing liquor from the crop are aspects that signify great creativity of farmers in dealing with their indigenous challenges. Great effort has also been going on (without any definite genetic plan) in maintaining indigenous cultivars of the crop that meet local preferences and give good yields. These farmers' initiatives need to be supported with more scientific enquiries to improve their likely discrepancies and increase the farmers' capacity in solving their indigenous production problems.

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Biochemical and Microbiological Changes in Plantain (*Musa paradisiaca*) at Various Stages of Ripening

B. O. Agoreyo,[1] I. F. Obuekwe[2] and D. O. Edosomwan[1]

[1]*Department of Biochemistry, Faculty of Science, University of Benin, Benin City. Nigeria*
[2]*Department of Pharmaceutical Microbiology, Faculty of Pharmacy, University of Benin, Benin City. Nigeria*

Abstract

The variations in biochemical and microbiological constituents of the fruit of *Musa paradisiaca* (plantain) were investigated at different stages of ripening. Microbiological analysis of the pulp showed that the mean aerobic bacterial loads were 8.4×10^3; 9.4×10^6 and 3.44×10^9 colony forming unit (cfu) per gram respectively, at the unripe, ripe and overripe stages; while fungal loads were also 1.3×10^3; 2.34×10^5 and 3.32×10^9 cfu/g respectively; Organisms isolated include *Staphylococcus aureus, Klebsiella*, *Proteus*, *Bacillus* and *Lactobacillus* species as well as *Aspergillus niger*, *Aspergillus fumigatus*, *Penicillium*, *Fusarium* and *Saccharomyces* species.

The biochemical analyses also showed that the overripe pulp had the highest moisture content, 77.165 ± 0.258g/100g fresh weight; highest protein: 1.490 ± 0.013g/100g fresh wt.; highest lipid: 1.270 ± 0.021g/100g fresh wt.; highest reducing sugars: 11.375 ± 0.124g/100g fresh wt.; but lowest starch content of 18.660 ± 0.424g/100g fresh wt. There was a relative increase in both biochemical and microbiological constituents of plantain during ripening. The results of this study have shown that the presence of microorganisms in all ripening stages of plantain could be attributed to the post harvest handling and biochemical changes observed.

Key words: Biochemical, microbiological, plantain, *Musa paradisiaca*, ripening stages

Résumé

Les variations dans la composition des substances biochimiques et microbiologiques du fuit de la banane plantain Musa par*adisiaca* ont étaient étudiées à différents niveaux de mûrissement. L'analyse microbiologique de la pulpe a montré que le nombre moyen des jeunes colonies de bactéries aérobies était respectivement de 8.4×10^3; 9.4×10^6 et de $3{,}44 \times 10^9$ par gramme de la pulpe verte, mûre et trop mûre. Le nombre de champignons par gramme de la pulpe verte, mûre et trop mûre était respectivement de 1.3×10^3; 2.34×10^5 et 3.32×10^9 Les espèces de bactéries isolées incluaient *Staphylococcus aureus, Klebsiella*, *Proteus*, *Bacillus* et *Lactobacillus* et celles de champignons comprenaient *Aspergillus niger*, *Aspergillus fumigatus*, *Penicillium*, *Fusarium* et *Saccharomyces*. Les analyses biochimiques ont aussi révélé que les pulpes trop mûres avaient un taux d'humidité très élevé *de* 77.165 ± 0.258g/100g de poids frais; la teneur la plus élevée en protéines: 1,490± 0,013g/100g de poids frais; en lipides: 1.270 ± 0.021g/100g poids frais et en sucres réducteurs: 11, 375±0,124g/100g de poids frais, mais qu'elles avaient de basses teneurs en amidon: 18.660± 0.424g/100g de poids frais. On a constaté que les substances biochimiques et microbiologiques augmentaient à la fois au fur à mesure du mûrissement de la banane plantain. Les résultats de la présente étude montrent que l'existence des microorganismes dans le plantain à tous les stades de mûrissement peut être attribuable aux conditions de stockage post-récolte et aux changements biochimiques observés.

Mots clés: substances biochimiques et microbiologiques, banane plantain, *Musa paradisiaca,* étapes de mûrissement

Introduction

Plantain (*Musa AAB*) is an important food crop in the tropics, providing more than 25% of the daily carbohydrate intake (Vuylsteke *et al*, 1993). It is a staple diet of people in this region. Apart from its nutritive values, plantain also has a number of medicinal applications (Lewis *et al*, 1999).

The carbohydrate present in unripe plantain is mainly starch, which is converted to sugars during ripening. Plantain also contains lipid and protein in both the ripe and unripe stages, although these

biochemical constituents are present in small amounts (Ketiku, 1973). Fresh, mature, unripe plantain can be consumed boiled or fried into chips or sun-dried and milled into flour, which could be used as an emulsifier and thickener in a food system (Fagbemi, 1999). Wine that has high vitamin content is also produced from plantain (Gowen, 1995). Plantain has a special place in diets low in fats, because of its low lipid and high – energy value. Plantain like banana is recommended for obese and geriatric patients (Gasster, 1963).

Ripening in fruit is associated with biochemical and physiological changes in colour, texture, flavour and biochemical constituents. The colour of plantain changes from green to yellow during ripening, while the texture changes from hard green to soft yellow. The flavour becomes sweeter and pleasant due to the synthesis of flavouring agents. The levels of biochemical constituents like starch, sugars, lipids and proteins also change during ripening. These biochemical and physiological changes associated with ripening increase the susceptibility of the fruit to microbial attack (Wills *et al*, 1989).

This study examined the biochemical and microbiological changes that take place in plantain at various stages of ripening.

Methodology

Plant material

Intact plantain bunches were bought in an open market in Benin City, Nigeria. Mature bunches were dehanded under aseptic conditions and kept in a storage compartment. Concentrated ethanol (98%) was used to clean and sterilized the storage compartment before storing the plantain fingers. The sterilization was carried out to prevent contamination of the plantain fingers by the storage compartment but not from environmental microbial contamination. The temperature of the storage compartment was maintained at 28°C–32°C (room temperature) and proper ventilation was ensured to avoid accumulation of the phytohormone ethylene during ripening.

Ripening was assessed by randomly selecting plantain fingers from the hands of a bunch. Fingers of plantain were then peeled under aseptic condition. Some were dried and used for moisture content and crude lipid estimations, while others were macerated fresh and samples used for microbiological analysis, as well as for proximate estimation of starch, reducing sugars and total protein. The above procedures were carried out on unripe (green), ripe (yellow) and overripe (yellow with large black patches) plantain. The plantain fingers were stored for a period of twelve days. The analysis of the microflora that were associated with the pulp of the plantain fruit at each stage of ripening was also made.

Microbiological Analysis

Enumeration of microorganisms in the plantain pulp

Ten grammes of fresh plantain pulp were aseptically macerated and added to 90ml of 0.9% sterile (normal) saline. Serial dilutions up to 107 were made. The pour-plate technique was used to isolate as well as enumerate the microorganisms. Nutrient Agar (Oxoid) was used for the bacteria, while potato dextrose agar (PDA) was used for the enumeration of fungi. An aliquot (0.1ml) of each sample dilution was added in triplicates into sterile Petri dishes. This was followed by pouring warm, sterile agar and rocking the plates gently and effectively so as to ensure even distribution of the inoculum in the medium. The plates were then incubated at a temperature of 37°C for 24 hours for bacteria and at room temperature (28°–32°C) for 4 – 7 days for the fungi. Uninoculated plates served as the control. Biochemical analyses which included catalase, coagulase, urease and hydrogen sulphide tests, Gram staining techniques as well as spore stain were also further used to identify the microorganisms.

Biochemical Analysis

i. Determination of moisture content

Thirty grammes of plantain pulp were placed in a crucible, weighed and contents heated in an oven until a constant weight was obtained. The moisture content of the plantain pulp was then calculated as percentage moisture loss.

ii. Estimation of reducing sugars

The reducing sugars of the plantain pulp were extracted by the method of Hansen and Moller (1975). 0.5g of the plantain sample was homogenized in 10ml of 80% ethanol and percolated with 25ml of 80% ethanol at the rate of 5ml per hour. 0.1ml of the percolate was used for the estimation of reducing sugars using the Nelson – Somogyi method, (Plummer, 1978).

iii. Estimation of starch

Starch content of the plantain pulp was extracted by the Clegg – Anthrone method (Yemn and Willis, 1964). One gram of plantain sample was homogenized and percolated with 1ml of 80% ethanol and 30ml of 35% perchloric acid at the rate of 5ml/hr. The percolate obtained was diluted (1:100) and 1ml was used for starch estimation, also using the method of Hansen and Moller (1975).

iv. Estimation of total protein

Total protein of the plantain samples was extracted according to the method described by Adamson and

Abigor (1980). Fifteen grammes of plantain pulp were homogenized with 3.75g of polyvinyl pyrolidone (PVP) in about 60ml of ice cold 0.05M sodium phosphate buffer at pH 6.5. The homogenate was centrifuged for 10min at 10,000g and the supernatant was used to estimate total protein using the method described by Lowry *et al* (1951).

v. Estimation of total lipid

The soxhlet extraction method was used for the quantitative determination of lipid from the plantain samples as described by Joslyn (1970). Thirty grammes of wet plantain samples were dried to constant weight and ground to fine particles. The ground sample was introduced into the soxhlet extractor while extraction was carried out for seven hours using n–hexane as the extracting solvent at 68°C boiling point.

Results

The results of the microbiological studies carried out on the plantain pulp at different ripening stages showed that bacterial and fungal loads were highest (3.44×10^9 cfu/g and 3.22×10^9 cfu/g respectively) during the overripe stage and least (8.4×10^3 and 1.3×10^3 cfu/g respectively) during the unripe stage (Table 1).

Table 1: Mean microbial counts from plantain pulp at different ripening stages

Stages of ripening	Organisms	Mean count (cfu/g)
Unripe	Bacterial load	8.4×10^3
	Fungal load	1.3×10^3
Ripe	Bacterial load	9.4×10^6
	Fungal load	2.34×10^5
Overripe	Bacterial load	3.44×10^9
	Fungal load	3.22×10^9

Table 2: Bacterial and fungal isolates from plantain pulp at different stages of ripening

Stages of ripening	Bacterial isolates	Fungal isolates
Unripe	*Bacillus* spp.	*Fusarium* spp. *Saccharomyces* spp.
Ripe	*Bacillus* spp. *Klebsiella* spp. *Staphylococcus aureus*	*Fusarium* spp. *Saccharomyces* spp. *Aspergillus fumigatus*
Overripe	*Bacillus* spp. *Proteus* spp. *Lactobacillus* spp.	*Fusarium* spp. *Saccharomyces* spp. *Aspergillus fumigatus* *Aspergillus niger* *Penicillium* spp.

Table 2 shows the bacterial and fungal isolates from the plantain pulp at different stages of ripening. *Bacillus*, *Fusarium* and *Saccharomyces* spp. were isolated in all the three stages. Table 3 shows the result of the biochemical analysis carried out on the plantain at different stages of ripening. Overripe pulp had the highest moisture content (77.165 ± 0.258g/100g fresh weight); highest lipid (1.270 ± 0.021g/100g fresh wt); highest protein (1.490 ± 0.013g/100 fresh wt); highest reducing sugars (11.375 ± 0.124g/100g fresh wt) but lowest starch content (18.6000 ± 424g/100g fresh wt).

Discussion

The susceptibility of plantain to microbial attack observed during ripening (Table 1) may be attributed to profound changes in the structure of the cell wall, which result in a loss of cohesion between cells and increased permeability to molecules or microorganisms during ripening (Knee, 1973; 1975; 1978). The activities of cell wall degrading enzymes such as pectin esterase, cellulase and hemicellulase have been found to increase during the climacteric (Smith, 1989). The increased activities of pectin

Table 3: The biochemical constituents of plantain pulp at various stages of ripening

Stages of ripening	Moisture	Lipid	Starch	Reducing sugars	Protein
		(g)			
Unripe	58.665 ± 0.237	0.34 ± 0.028	33.225 ± 0.265	1.873 ± 0.62	1.154 ± 0.04
Ripe	61.575 ± 0.301	0.78 ± 0.028	22.995 ± 0.180	10.780 ± 0.148	1.372 ± 0.042
Overripe	77.165 ± 0.258	1.27 ± 0.021	18.600 ± 0.424	11.375 ± 0.424	1.490 ± 0.013

Results ± SEM for three determinations, were recorded as gram per 100g fresh weight of plantain pulp.

esterase in ripening fruit has also been shown to be involved in the degradation of the pectin of the middle lamella, resulting in the weakening of the cell walls which undoubtedly facilitates the penetration and invasion of microorganisms (Agrios, 1972).

There is also an increase in membrane permeability during ripening (Izzo *et al*, 1995). This membrane breakdown is due to the action of lipolytic enzymes such as phospholipases and lipoxygenase (Leshem *et al*, 1986). Grossman and Leshem (1978) demonstrated that ripening or senescence was accompanied by a marked increase of lipoxygenase. The lipoxygenase reaction is a free radical process which leads to the breakdown of polyunsaturated fatty acids (PUFA) of the membrane. The wealth of free radicals formed as a result of lipoxygenase action can cause leakiness in membranes (Leshem *et al.*, 1986). In typical physiological disorders such as brown spot in apples, a key role has been assigned to lipoxygenase which is particularly high in peel and core tissue and increases during storage (Feys *et al*, 1980). Sacher (1973) therefore suggested an increase in membrane permeability with storage or ripening, which might permit the release of nutrients to the cell surface, thereby providing nourishment for the microorganisms and consequently resulting in an increased susceptibility to microbial attack as observed in this study (Table 1).

Certain microorganisms can also secrete cutinase and cell wall degrading enzymes which degrade cuticle and cell wall. The degradation of cell wall may be favourable to these microorganisms, and besides facilitated penetration, it may serve as a means for obtaining food (Olutiola, 1978).

Bateman and Basham (1976) have emphasized that most microorganisms produce enzymes that can macerate tissues held together by intercellular materials composed mainly of pectic polysaccharides. Susceptibility to microbial attack therefore depends on the capability of the microorganisms to secrete enzymes that can depolymerize these insoluble pectic polymers, thereby leading to a loss of tissue coherence and separation which is referred to as tissue maceration (Eckert, 1979; Eckert and Ratnayake, 1983; Mount 1978). Tissue maceration, apart from allowing the penetration and invasion of these particular microorganisms, also results in increased microbial load because of the entry of other opportunistic microbes which can only penetrate the tissue after the enzymatic degradation of the cell wall, by those microorganisms that secrete cell wall degrading enzymes. This is known as secondary infection (Tables 1 and 2). In general, the microbial enzymes disintegrate the structural components of host cells and breakdown inert food substances in the cell which may be used as substrates for growth by the microorganisms.

Some of the microflora isolated in the ripe and overripe plantain (Table 2) have been found to be associated with fruit rot in banana (Shillingford, 1977). The green (unripe) plantain also contained some microflora (Table 2), which may have been introduced through natural openings, or by direct penetration of uninjured plant surfaces. Bacteria and certain fungi enter plants through natural openings and many fungi penetrate the intact surfaces of plant (Roberts and Boothroyd, 1975). They may also have been introduced during the development of the fruit on the tree. Some microorganisms can infect the plantain while still immature and attached to the plant. The infection is then arrested and remains quiescent until after harvest when the resistance of the host decreases and conditions become very favourable for growth, especially when the fruit commences to ripen. Such 'latent' infections are important in the post harvest wastage of many tropical and subtropical fruits, for example the crown rot of banana and plantain. It is also possible for these microorganisms to have been introduced by mechanical injury such as inconspicuous fingernails scratches during handling and cut stems. The damage is often microscopic but is sufficient for microbes present in the environment and in the packing house to gain access (Wills *et al*, 1989).

Plantain destined for the market are also sometimes carelessly handled, resulting in mechanical injury that allows microbial infection thereby leading to a lot of wastage. Mechanically injured plantain will normally deteriorate rapidly and should never be used for longterm storage (Coursey and Booth, 1972). Mechanical injury of plantain is also accompanied by lipoxygenase increment (Serhan *et al*., 1981). The presence of microorganisms in all stages of ripening of plantain in this study showed that microbial infection could occur at anytime in the plantain fruit, so care must be taken to avoid microbial attack during fruit development, post harvest handling and storage.

Increase in the biochemical constituents of plantain observed during ripening in this study (Table 3), correlated with the work of Ketiku (1973), though he sampled only once during ripening. Marriott *et al* (1981), also studied the changes in biochemical constituents of plantain. Our study, apart from correlating with the work of Marriot *et al* (1981), that sugar content increased continuously during ripening of plantain, also showed that there was a continuous increase in the lipid and protein contents of plantain during ripening until the fruits were very senescent. The high level of biochemical constituents observed

in the overripe plantain compared to the ripe, could be attributed to why some tribes in Nigeria prefer using the overripe plantain rather than the ripe to prepare a meal known as "Upo Ogede", which is very sweet.

There was a marked increase in the reducing sugar level as the unripe plantain turned ripe, unlike the ripe to the overripe stage. The slight increase in the reducing sugar content at the overripe stage is probably due to the utilization of the sugar during fermentation by the microorganisms and the high respiratory activity in plantain which is a climatic fruit. This increase in respiration is also accompanied by an enhanced synthesis of proteins and turnover of pre-existing proteins (Brady and O'Connell, 1976) presumably to play a role in the transport and enzymic transformations associated with ripening. Increase in protein content observed in this study may therefore be attributed to the enhanced synthesis of enzymes involved in the ripening process. Inhibitors of protein synthesis have been found to lower enzyme activities, prevent degreening, softening and slows both respiration and degradation of starch during ripening (Chang and Hwang, 1990b; Gowen, 1995). Marked increase in the reducing sugar level may also have enhanced lipogenesis which resulted in an increase in lipid content during ripening, as observed in this study. Increased moisture content of plantain during ripening as observed in this study will also favour susceptibility to microbial attack in plantain.

Conclusion/Recommendation

Plantain can be infected by microorganisms in the green (unripe) ripe and overripe stages. This could be as a result of infection that occurred during fruit development, when the plantain was still immature and attached to the tree or during post harvest handling and storage. Pre-harvest and post harvest infections have been a major cause of post harvest wastage of plantain.

This study then recommends that control of post harvest wastage of plantain should commence before harvest in the field wherever possible sources of infections should be eliminated.

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Canopy - Air Temperature Differential of Wheat Varieties Grown Under Different Soil Moisture Regime on Semi-Arid Sudan Savanna

Onyibe, J.E[1], M.K. Ahmed[2], A.M. Falaki[2] and A.A. Ramalan[3]

[1] *NAERLS, Ahmadu Bello University, P.M.B. 1067, Zaria, Nigeria*
[2] *Department of Agronomy, Ahmadu Bello University, Zaria, Nigeria*
[3] *Department of Agricultural Engineering, Ahmadu Bello University, Zaria, Nigeria*

Abstract

Field experiments were conducted during the dry seasons of 1995/96 and 1997/98 at Kadawa, in semi-arid Sudan savanna of Nigeria (11° 39'N 08° 27'E, 500m above sea level) to study the effect of various moisture regimes on canopy temperature of two wheat cultivars. Moisture regime was imposed using Neutron scattering technique while canopy temperature was monitored with an Infrared Thermometer (IRT). The result shows that canopy-air temperature of wheat expressed as stress degree-day (SDD (*Tc-Ta*)) increased with decrease in soil water content (SWC). SDD was negative for plots irrigated at 60, 75 and 90% available soil moisture (ASM) but positive for zero irrigated plots. SDD ranged from –3.5 to –3.0°C at field capacity and between +4.0 to + 4.5°C at permanent willing point. The relationship between grain yield and cumulative stress degree-day (CSDD) was linear, inverse and consistent irrespective of variety and season. For every 1°C increase in CSDD a reduction in grain yield of 16.18kg/ha was indicated. As much as 5.2mm of irrigation water was found to induce a 1°C change in CSDD. Both SDD and CSDD indicate that irrigation at 60% ASM may be appropriate for wheat cultivation in the semi-arid Sudan savanna.

Keywords: Canopy-air temperature, stress degree-day, moisture stress, wheat, yield

Résumé

Des essais en milieu réel ont été conduits au cours des saisons sèches 1995/96 et 1997/98 à Kadawa, dans la savane soudanaise semi-aride du Nigeria (11° 39'N et 08° 27'E, à 500 mètres au-dessus du niveau de la mer). Ces essais avaient pour but d'étudier l'effet de divers régimes d'humidité sur la température du couvert végétal chez deux cultivars de blé. L'humidité a été relevée en utilisant la technique de dispersion de neutrons tandis que la température du couvert végétal était enregistrée au moyen d'un thermomètre à infrarouge. Les résultats obtenus prouvent que l'environnement thermique dans le couvert végétal, c.à.d la température de l'air exprimée en degrés journaliers de stress du blé - SDD (Tc-Ta) augmentait avec la diminution de la teneur en eau dans le sol -SWC. Le SDD était négatif dans des parcelles irriguées contenant 60, 75 et 90% d'humidité relative du sol - ASM, tandis qu'il était positif dans les parcelles non irriguées. Le SDD allait de –3,5 à –3,0°C dans des conditions naturelles de rétention hydrique et de +4,0 à +4,5°C au point de saturation maximale constante. Le rapport entre le rendement en grain et le niveau cumulatif de stress journalier - CSDD était linéaire, inverse et stable indépendamment de la variété et de la saison. Pour chaque augmentation d'un 1°C de CSDD, on a observé une réduction de 16,18 kg/ha en rendement de grain. Une irrigation d'au moins 5,2mm d'eau était capable d'induire un changement de 1°C du CSDD. Le SDD et le CSDD indiquent à la fois que l'irrigation à 60% de l'ASM serait appropriée pour la culture du blé dans les conditions de la savane soudanaise semi-aride du Nigeria.

Mots-clés: température atmosphérique du couvert végétal, niveau du stress journalier, stress hydrique, blé, rendement

Introduction

Plant response to varying degrees of soil moisture regime has been a subject of considerable study and review (Slatyer, 1967; Maurya and Sachan, 1985; Khehr *et al.* 1996, Salter and Goode 1967). Yet the question of how moisture regime interacts with other cultural practices to affect growth, yield and quality of crops remains one of the important problems to be resolved in crop agriculture. Current emphasis however appears to be on understanding the plastic responses of crop-genotypes to soil water status and the determination of climate-plant and soil relationships (Benbi, 1994) that would enhance appropriate moisture supply regime in irrigated crops.

The temperature of a plant depends on the balance between the energy gained and that lost. A dynamic balance exists between net short wave and long wave (or thermal) radiation, the sensible and latent (evaporation) energy lost by the plant, and the

storage of heat within the tissue (Hatfield and Printer, 1993). Monteith and Szeicz (1962) have derived an equation to describe this equilibrium. Plants with adequate water status have cooler temperatures than water stressed plants because their transpiration rates are correspondingly higher. Jackson *et al.* (1977) demonstrated the usefulness of this concept in the determination of crop water requirement. Hatfield and Pinter (1993) observed that in climates where moderate to high atmospheric demand requires irrigation during part or all of the growing season, canopy-air temperature differentials up to 6 – 8°C or more between well watered and moderately stressed plants were common. Studies by Keener and Kircher (1983) showed that in humid regions, the differential is smaller by several degrees. In the semi-arid savanna zone of Africa, studies on the air-canopy temperature differential under various soil moisture regimes have not been undertaken. Hatfield and Pinter (1993) have shown how canopy-air temperature difference for different moisture regimes varies with relative humidity and net radiation. There is need to ascertain the application of such a concept to irrigation scheduling in the semi-arid savanna of Africa because of the simplicity of the approach. At present the base data for such endeavour is lacking.

The current study was initiated to determine the effect of wheat canopy-air temperature differential and moisture regime.

Materials and Methods

The experiment was conducted at Kadawa (11° 39'N, 08° 15E and 500m above sea level) at the Irrigation Research Station of the Institute for Agricultural Research of Ahmadu Bello University, Zaria, Nigeria in 1995/96 and 1997/98 dry seasons. The location is within the semi-arid Sudan Savanna ecological zone of Africa. Kowal and Knabe (1972) described the climate and vegetation of the Sudan savanna. Composite soil samples were collected from the experimental sites at the beginning of each season after land preparation for the analysis of physicochemical properties of the site. Soil samples were collected at three depths (0-20, 20-40 and 40-60 cm) using a soil auger. The experimental site was stratified into twelve blocks in each year and two composite soil samples were collected from each block and later the entire samples were bulked. Table 1 shows the characteristics of the soil of the semi-arid Sudan savanna. Each data is a mean of three replicates.

At the commencement of the trial, a calibrated Troxler Neutron Probe was used to estimate Field Capacity (FC) and Permanent Wilting Point (PWP) of the experimental site (using tomato as a test crop). Based on work by Falaki (1994) and Anon (1979) that most of the roots of recommended varieties of wheat grown in Nigerian Sudan savanna occur in top 55 cm,

Table 1: Physical and Chemical Properties of Soils of Experimental Sites 0-60 cm depth at Kadawa (1995 – 1998 dry seasons)

Characteristics Soil Properties	1995/96a	1996/97b	1996/97c	1997/98b
Physical Properties				
Sand%	79.8	81.9	83.3	81.3
Silt%	7.3	6.9	7.1	7.4
Clay %	12.9	11.2	9.6	11.3
Textural Class	Loamy Sand	Loamy Sand	Loamy sand	Loamy Sand
Chemical properties				
pH (in H_20)	8.5	7.9	7.8	7.7
pH (in 0.0IM.$CaCl_2$)	8.0	7.3	7.2	7.3
Exchangeable Cations				
Na^+	0.182	0.165	0.159	0.152
K^+	0.202	0.214	0. 268	0.255
Ca^{++}	2.160	2.883	2.671	2.939
Mg^{++}	1.027	1.221	1.317	1.109
Total P (ppm)	29.67	31.22	29.36	33.38
Total N% in 0.048N H_2S0_4	0.041	0.042	0.044	0.048
CEC (meg/100g)	6.21	5.97	5.89	5.67

a: ICRISAT Field, b: IAR field, c: River Basin field.

estimation of soil water content (SWC) was limited to 0-70 cm. SWC at a time was derived from summation of water content measured at three depths, 20, 40 and 60 cm. Usually SWC in the top 10 cm of soil is difficult to measure by Neutron scattering techniques.

Jackson *et al.* (1977) reported that to account for this top 10 cm water, it should be assumed that the volume fraction of water measured at 20 cm depth multiplied by 30 gives a fair approximation of the of water depth in the top 30 cm soil. This assumption was applied in this experiment. The volume fraction at 40cm depth was multiplied by 20 to account for depth of 30-50 cm. That at 60 cm was multiplied by 20 to account for the water in 50-70 cm depth. The values for the three depths were then summed to yield the total water content in 0-70 cm root zone. From these data moisture depletion curves (rates) were calculated and used to impose four irrigation treatments viz, irrigation at 90% Available Soil Moisture (ASM) till 42 days after sowing (DAS) then irrigation was cut off completely (0%), irrigation at 60, 75 and 90% ASM till physiological maturity. The four treatments were replicated three times. The volume of water applied was determined using a water flow meter based on the calibration curve obtained at the on-set of the experiment. From the curve, water content of the soil at field capacity at 0.2 bar averaged 21.87 cc and 9.46 cc at permanent wilting point. By subtraction, available soil moisture was 12.41 cc. Each plot was irrigated when the desired level of available soil moisture depletion was attained. A hosepipe that was fitted with a water flow meter was used to apply irrigation water evenly to each plot. Ground water contribution to root zone was assumed to be zero. Depth of water table monitored from four observation wells situated within the experimental area was below 1.5 m. No rainfall occurred for eight weeks prior to and during the experiment. Also, in each month, stress degree-day moisture relationship was determined from four plots in which irrigation was cut off after attaining field capacity for 28 days. Two varieties Siete ceros and Pavon 76 were used in each season. The crop was sown in basins on November 20 in each season. The plots used for stress degree-day and soil water content (SDD-SWC) relationship were sown at different dates on 20th November, 15th December and 10th January. Data on SDD-SWC relationship for January was derived from the four plots sown in November. Those for February and March were from the plots sown in December and January respectively. The treatments were laid out in complete randomized block design. Plot size was 4 x 3 m each. To avoid any seepage effect, the borders of the basins were compacted and un-irrigated strip of 0.5m width was left between each plot. All other cultural practices were as recommended for wheat in the zone.

Plant canopy temperature was measured in each plot shortly after measuring soil moisture with a portable Omega-052S Infrared Thermometer (IRT). The IRT was calibrated as described by Walker and Hatfield (1979). The 9V battery of the IRT was replaced with new one weekly. Canopy temperature (Tc) was measured daily at the same time as air temperature (*Ta*) and shortly after measuring soil moisture at 1 hour after noon starting from 49 DAS when booting had advanced remarkably and full canopy closure had been attained. The IRT was clamped to a 1.5 m height wooden pole at angle of 135°C (of a vertical semi circle) from the zenith during field measurement. The wooden pole was positioned mid-way at either the northern or southern border during measurement of each plot. Recording of canopy temperature was terminated at 84 DAS. Air temperature was recorded from an automatic weather station adjacent to the experimental site at about the same time canopy temperature was recorded. The Feekes scale, as illustrated by Large (1954) was used to determine growth stages and maturity. Physiological maturity was attained at 85 DAS in Pavon 76 and 91 DAS in Siete cerros. Grain yield was determined by measurement of weight of grains obtained after threshing and winnowing from 7m≤ net plot. Water use was determined by summation of all irrigation water applied to each plot from planting. Stress degree-day (SDD) was calculated as defined by Walker and Hatfield (1979) as:

$$SDD = (Tc - Ta)\, i \qquad (1)$$

Where *Tc* is canopy temperature and *Ta* is the air temperature measured around one hour after Solar noon on day *i*. Where SDD is summed over N days beginning from day *i*. In this study day i was 49 days after sowing and N is maturity.

Thus cumulative SDD (CSDD) in the experiment =

$$\Sigma SDD = \sum_{49}^{m} (Tc - Ta)\, n \qquad (2)$$

Where m= maturity and end of summation. Cumulative Stress Degree Day (CSDD) and yield relationship was determined as described by Walker and Hatfield (1979) where:

$$\text{Yield} = \alpha - \beta\left[\Sigma^{e}I = \text{SDDI}\right] \qquad (3)$$

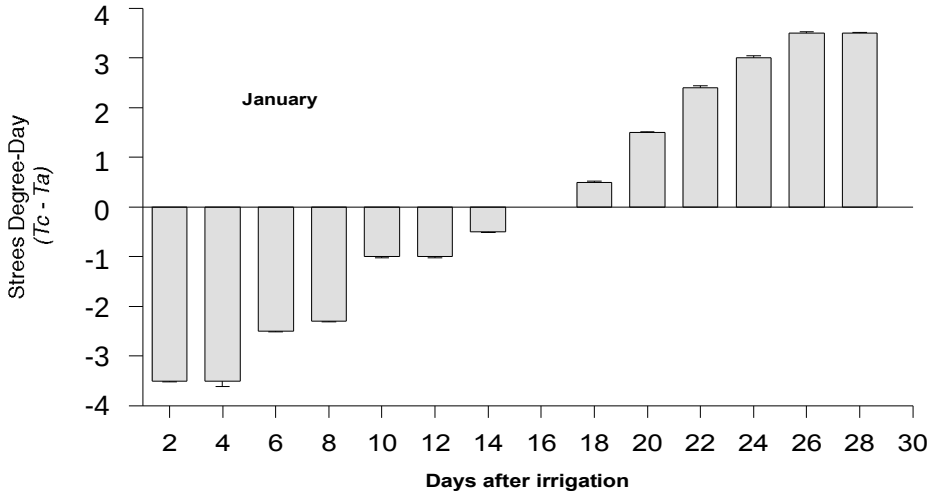
The same equation was applied to total water use and CSDD relationship. Yield of the two varieties and their water use data were regressed against CSDD for the two seasons.

Results and Discussion

Soil water content and plant canopy relationship

The trends of the relationship between Stress Degree-Day (Tc-Ta) and Soil Water Content (SWC) are presented in Figures 1-3. The result shows that SDD values increased with decrease in SWC. At two days after irrigation (DAI) (FC), SDD was negative and between – 3.5°C to – 3.0°C (Figs 1 and 3a). The maximum SDD of + 4.0 to + 4.5°C was obtained at SWC of less than 7.00 cm^3/70 cm^3 (Figs 2 and 3a). Between SWC values of 8.72 cm^3/70 cm^3 to 9.21 cm^3 /70 cm^3, SDD was close to 0.0°C. All SWC values less than this range gave positive SDD while all SWC higher gave negative SDD. The increase in stress degree-days following decreases in soil water content suggest that changes in canopy temperature reflected the crop response to moisture stress in the Sudan savanna ecology. Several workers have noted similar response in America (Carlson e*t al*, 1972; Jackson *et al*, 1977 and 1981; Idso *et al*, 1977; Hatfield, 1983 and Erhler, 1973), and in Mexico, India and Brazil (Reynolds *et al*, 1994).

Figure 1: Trend of stress degree-day at Kadawa in 1996



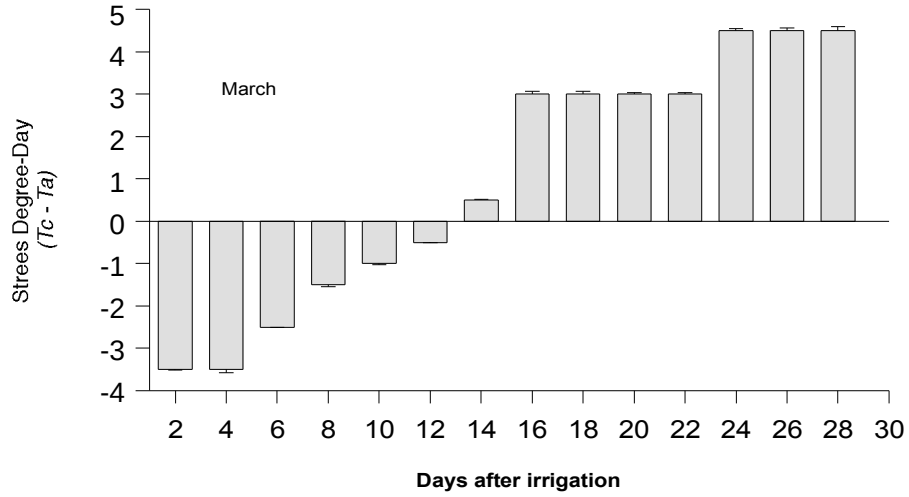


Figure 2: Relationship between stress degree-day and soil water content at Kadawa in 1996

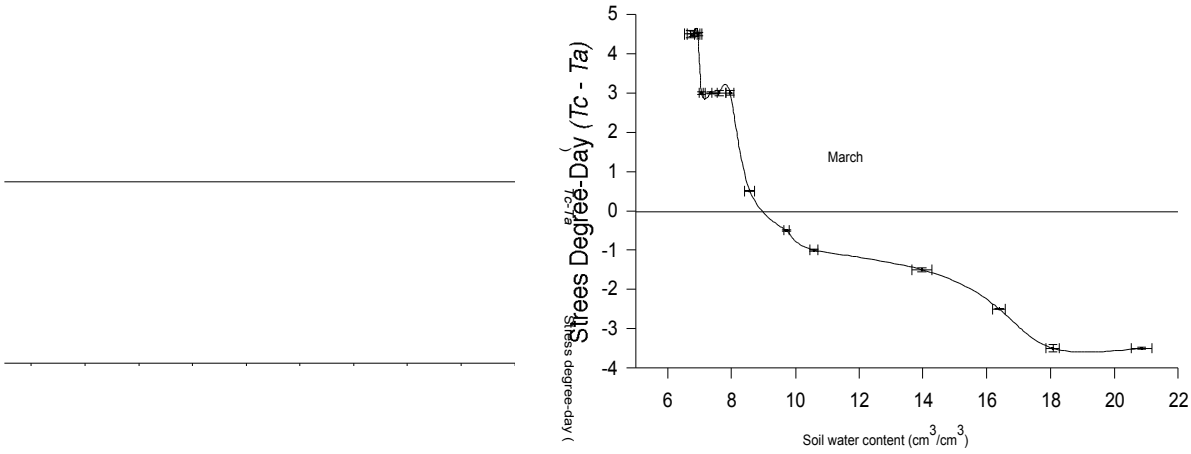


Figure 3a: Trend of stress degree-day at Kadawa in 1998

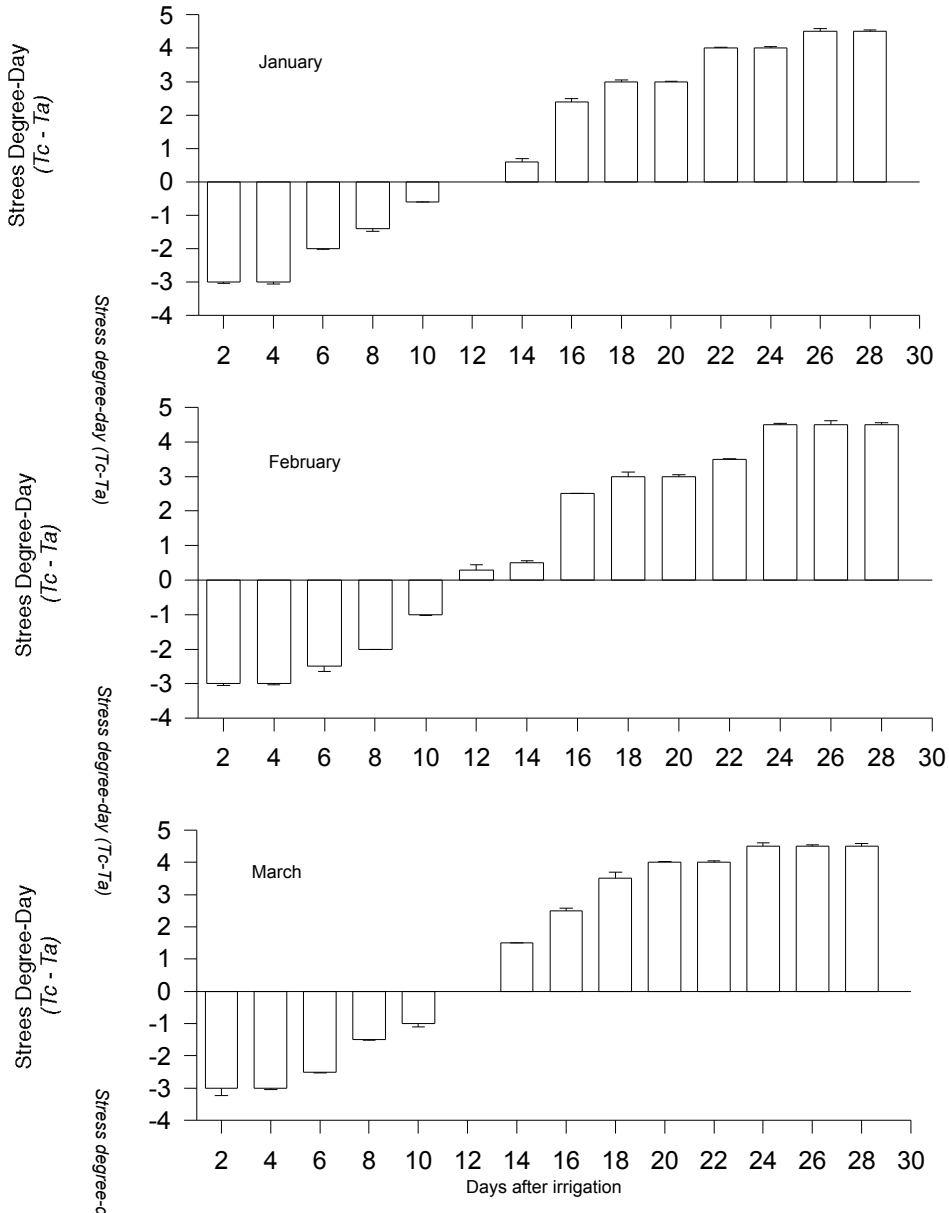
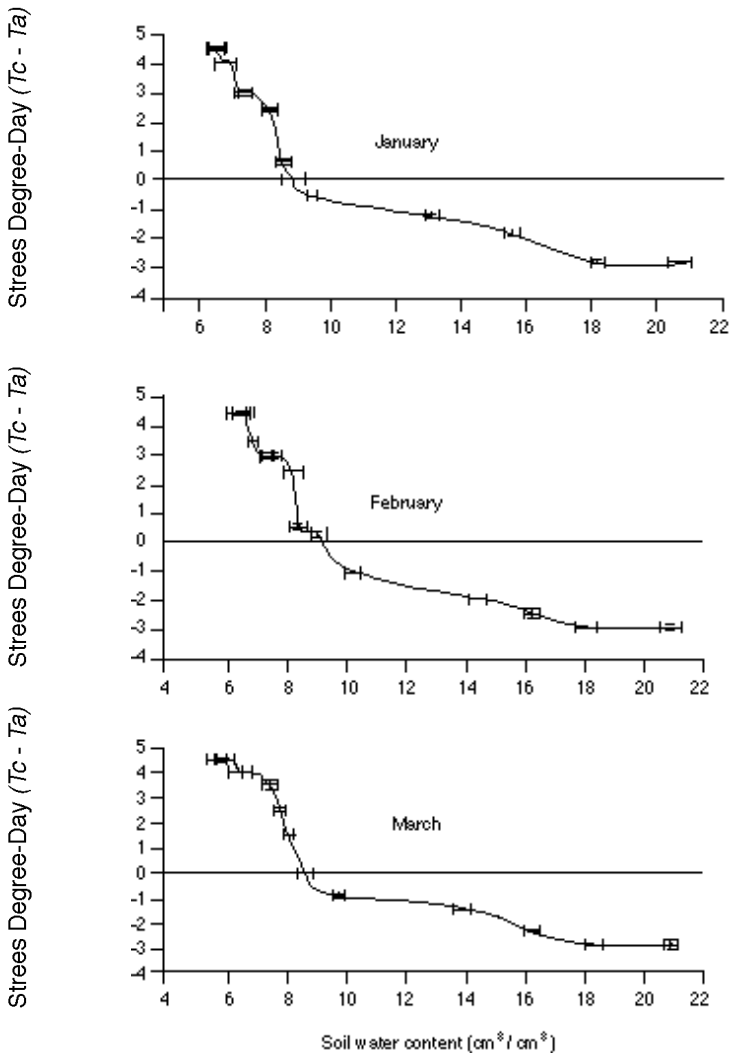


Figure 3a: Trend of stress degree-day at Kadawa in 1998

Figure 3b: Relationship between stress degree-day and soil water content at Kadawa in 1998



A negative SDD indicates that the crop was not under serious stress at the corresponding SWC. Similarly, a positive SDD indicates that the crop was under stress because plant canopy temperatures exceeded the air temperature. This is in agreement with Pinter *et al* (1990) who observed that plants with adequate moisture status have lower temperature relative to air temperature. The duration to attainment of positive SDD varied between months because of the differences in the rate of eva-transpiration in each month.

The results indicated that SDD ranged between (-ve) – 3.5 to –3.0°C at field capacity and between (+ve) + 4.0 to + 4.5°C at SWC of less than 7.00 which was about the soil water content at which permanent wilting point was achieved at the calibration of the field measured apparatus.

These ranges are closed to +3.0°C obtained by Tanner (1963) between irrigated and non-irrigated potatoes that could be used as an index for wheat (irrigation water requirement) in the Sudan. Kumar and Tripathi (1991) also demonstrated that non-irrigated wheat had constantly higher temperature than irrigated plants and found differences up to 3.9°C while Blum *et al* (1982) found maximum SDD in wheat genotypes to range from 4 - 8°C. These findings are in agreement with the result obtained.

Cumulative stress degree-day and moisture regime relationship

Cumulative Stress degree-day values obtained under four irrigation regimes are shown in Figure 4. These results indicate that increase in moisture stress from 90% ASM to zero irrigation increased CSDD. When irrigation was maintained at 60, 75 or 90% ASM throughout, CSDD was negative irrespective of when the assessment was made. Furthermore, the trend was consistent irrespective of the variety used (Figure 4). A linear relationship was observed between irrigation water use and CSDD (Figure 5). The result shows that CSDD was positive at high water stress level (low water use) but negative when water use was high. As much as 5.2 mm of irrigation water was required to induce a 1°C change in CSDD.

Figure 4: The trend of cumulative stress degre-day and irrigation treatments at Kadawa (mean of 1995/96 and 1996/97 seasons)

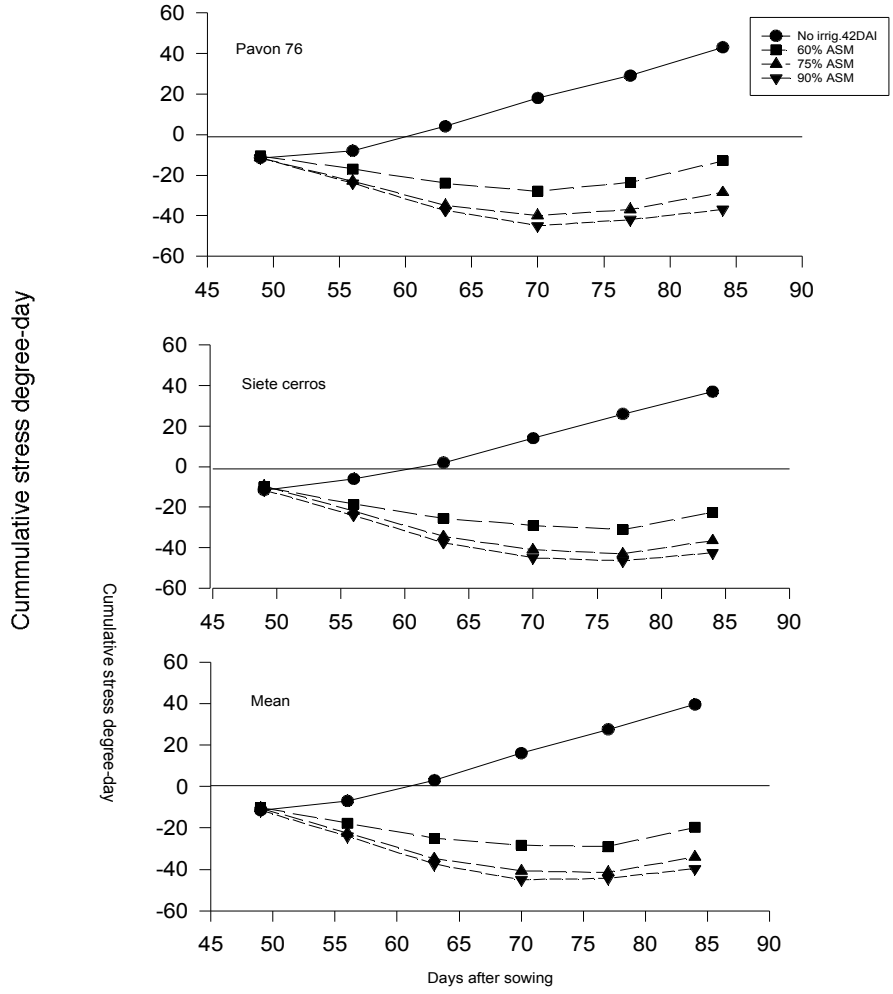


Figure 5: Relationship between stress degree-day and water use

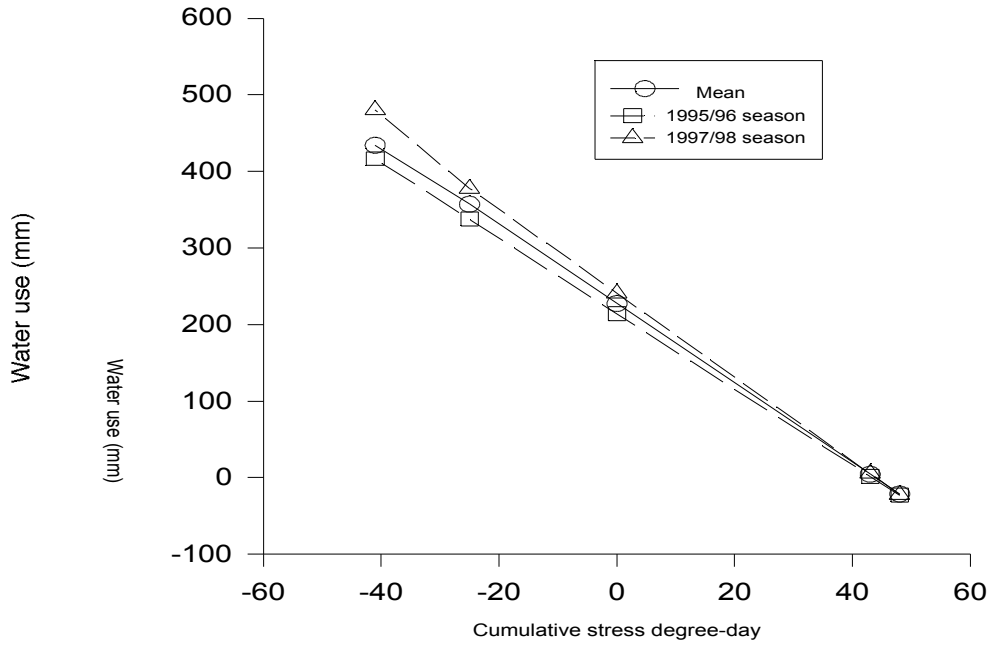
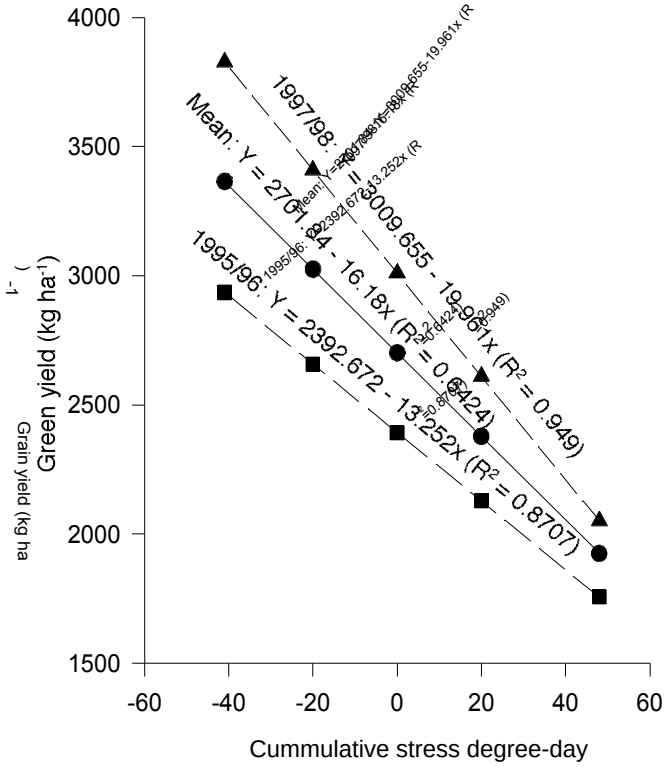


Figure 5: Relationship between stress degree-day and water use

A positive cumulative stress degree-day suggests that the crop was under moisture stress while the negative CSDD indicate that crop was not under severe moisture stress. Removal of irrigation at 42 DAS gave positive CSDD from 63 DAS. This indicated the onset of moisture stress for this treatment. Irrigating at 60, 75 and 90% ASM gave sustained negative CSDD indicating that the crops were not under severe moisture stress at these irrigation levels. Jackson *et al* (1977) reported that if CSDD is not positive, then serious water stress had not been attained. They also found that canopy temperatures were consistently less than air temperature in no stress irrigation treatment that supports the current result. The trend of the canopy-air temperature difference indicates that irrigation at 60% ASM may be appropriate for wheat cultivation in the semi-arid Sudan savanna. At this irrigation regime the grain yield achieved is higher than the average (2.5 t/ha) for Nigeria (Anon, 1979) and that obtained by Falaki (1994) at 75% ASM.

Figure 6: Relationship between stress degree-day and grain yield at Kadawa



Predicting grain yield from cumulative stress degree day

The relationship between CSDD and grain yield is as shown in Fig. 6. The trend in the response indicated a linear (R^2 = 0.6424) relationship. From the figure, decrease in CSDD increased grain yield significantly. Grain yield was very low when CSDD was negative. On average, every 1°C reduction in CSDD induced an increase in grain yield of 19.14kg/ha. The result also indicated a highly significant negative correlation (r = -0.8015**) between grain yield and CSDD. CSDD had a highly significant negative correlation with irrigation water use and grain yield in both 1995/96 and 1997/98 season unlike that (r= 0.964**) between grain yield and water use that was positive. A negative correlation, and a linear relationship between CSDD and water use, and between CSDD and grain yield indicate that yield was strongly dependent on water use.

Thus CSDD reflected the water requirement of the tested wheat cultivars. Walker and Hatfield (1979) and Jackson *et al* (1977) reached similar results and conclusions. The result of this study also revealed that the relationship is consistent irrespective of season and variety of wheat use and thus enhances the prospects for use of portable infrared thermometer in timing the irrigation of wheat in the Sudan savanna ecology.

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Correlation of Relative Density and Strength Properties with Anatomical Properties of the Wood of Ghanaian *Celtis* Species

J. K. Ocloo[1] and E. Laing[2]

[1]*Building and Road Research Institute (CSIR), Kumasi, Ghana*
[2]*Department of Botany, University of Ghana, Legon, Ghana*

Abstract

The relative density (RD) and mechanical strength properties of the wood of four Ghanaian *Celtis* species have been studied. There were significant differences between the relative densities of the wood of the species. The wood of *Celtis mildbraedii* was significantly heavier (RD = 0.872) than those of *C. adolfi-friderici* (RD = 0.685), *C. wightii* (RD = 0.771) and *C. zenkeri* (RD = 0.789). *Celtis adolfi-friderici* was the lightest among the four species. There was good correlation between the relative density and some of the strength properties of the species. The wall thickness of the vessels and fibres, the fractional wall volume of the vessels and fibres of the wood were the major contributors to the density and strength of the wood of *C. adolfi-friderici, C. mildbraedii* and *C. zenkeri.*

Key words: celtis species, properties, variations

Résumé

La densité relative (DR) et la force mécanique du bois de quatre espèces ghanéennes de *Celtis* ont été étudiées. Les recherches ont prouvé qu'il y avait des différences significatives des densités relatives du bois entre ces espèces. Le bois de *Celtis mildbraedii* était sensiblement plus dense (DR = 0,872) que celui de *C. adolfi-friderici* (DR = 0,685), *C. wightii*. (DR = 0,771), et *C. zenkeri* (DR = 0,789. Le bois de *Celtis adolfi-friderici* était le plus léger des quatre espèces. Il y avait une bonne corrélation entre la densité relative et certaines propriétés mécaniques des espèces. L'épaisseur de la paroi vasculaire et des fibres, le volume fractionnel de la paroi vasculaire et des fibres du bois étaient les éléments principaux déterminant la densité et la force mécanique du bois des espèces *C. adolfi-friderici, C. mildbraedi,* et *C. zenkeri.*

Mots-clés: espèces de *Celtis*, propriétés mécaniques, variations

Introduction

Density of wood is of practical importance in the utilization of wood because it is the best criterion of strength (Desch, 1980). The strength of wood varies with density or relative density since the load that a wooden substance can bear is determined to a great extent by the amount of cell-wall substance it contains per unit volume (Brown *et al.*, 1952; Desch, 1980).

The relative density of an actual wood substance is, for practical purposes, the same for all species but anatomical elements greatly influence the amount of wood substance per unit volume. In addition to the influence of anatomical elements, the presence of extraneous materials such as resins and gums affect the relative density of wood. The presence of moisture in wood is another important factor affecting the relative density of wood. The higher the moisture content of the wood above zero moisture content, the lower the relative density of the wood substance (Brown *et al.*, 1952). The modifying effect of moisture content of wood on its relative density makes it necessary to state the moisture content of wood when its relative density is given. Above the fibre saturation point – moisture content of 25 to 30 per cent (Lavers, 1974; U.S. FPL. 1987, 1999) increase in relative density has no effect on the strength of wood.

This paper briefly reports the second part of the work on the Ghanaian *Celtis* species and deals with relative density and mechanical properties of the species. The first part was on the anatomical properties of the species (Ocloo and Laing, 1991). The correlation between the relative density, mechanical strength, and anatomical properties is discussed in the present paper. A comparison between some of the properties of the wood of the Ghanaian Cel*tis* and those from other parts of Africa is also presented.

Materials and Methods

The *Celtis* species occur in the Closed Forest and Savannah woodland of Ghana. *Celtis adolpfi-friderici, C. mildbraedii, C. wightii* and *C. zenkeri* are found in

the Closed Forest with the highest frequency in the moist semi-deciduous and dry semi-deciduous types of forests. *Celtis Africana* and *C. integrifolia* are Savannah woodland species. This paper is on wood of the four forest species.

The sample trees from which test materials were cut for the strength properties study were selected from natural stands in two forest reserves: Tinte Bepo Forest Reserve (6° 54′ - 7° 3′ N; 1° 55′ - 2° 5′W) and Afram Headwaters Forest Reserve (7° 14′- 7° 18′N; 1° 25′ - 1° 32′W). The Tinte Bepo is a moist semi-deciduous forest-type in the *Celtis-Triplochiton* Association, while the Afram Headwaters Forest Reserve is a dry semi-deciduous forest in the *Antiaris-Milicia* Association.

Two trees of each of the species *Celtis adolpfi-friderici, C. mildbraedii* and *C. zenkeri* from each of the above forest reserves were studied. To investigate the axial variations in the strength properties of the timber of each species, the test samples were taken from three different heights.

The clear bole of each tree, that is, the distance between the point where the buttresses terminated and the point where the branches began, was divided into three equal logs. From each, a smaller piece 75 cm long was cut for the study. The billets were numbered serially 1, 2, 3 with increasing height above the ground in each tree. Trees of merchantable sizes were used. The mean girth of the 12 trees above the buttresses ranged between 0.94 m and 2.09 m.

A diameter board, 10cm thick, was taken from each 75cm log. The test specimens were not taken from defined radial zones. Instead, sticks from which the individual test specimens were obtained were selected at random in such a manner that the probability of obtaining a stick at any distance from the centre of a cross-section of a log was proportional to the area of timber at that distance. Priority was given to the compression test piece when selecting the test specimens from each stick. The sticks from which the test specimens were prepared were air dried for eight weeks and then stored under controlled temperature and humidity conditions (20 ± 3° C and 65 ± 2% relative humidity) until they attained constant weight.

The strength properties were determined from tests carried out on small clear specimens, the specimens being prepared in accordance with the British Standards No. 373 of 1957.

In the radial direction of a tree, reports indicate that the variation in the density of wood may be considerable (Brown *et al.* 1952), and in hardwoods, at a given height, wood of low or high density may be produced at any stage in the life of the tree, depending on the growth conditions prevailing at the time the wood was formed (Brown *et al.* 1952).

In the work reported here on the Ghanaian *Celtis* species, the variation in the radial direction of the relative density of the wood just above where the buttresses terminated in the tree was studied. The relative density was studied in two trees of *Celtis mildbraedii*, one tree each of *C. adolfi-friderici, C. wightii,* and *C. zenkeri,* all from the Afram Headwater Forest Reserve, two trees of *C. mildbraedii* and one tree of *C. adolfi-friderici,* from the Pra-Anum Forest Reserve. The Pra-Anum Forest Reserve (6° 12′– 6° 19′N; 1° 9′– 1° 17′W) is a moist semi-deciduous forest in the *Celtis-Triplochiton* Association. The sample trees in this case were not felled. Four 5.5 mm diameter cores were extracted with a Pressler increment borer from each tree in the North, South, East and West directions, each extraction extending the full radius or diameter of the sample tree. The mean diameter of the eight trees at the sampling height ranged between 27 cm and 40 cm.

The relative densities of the materials obtained with the increment borer were determined as follows. Each extracted core was cut into 10mm length pieces and the pieces numbered serially from the sapwood to the centre of the tree. The pieces were oven dried at 105°C until they attained constant weights. Each piece was then weighed, after cooling for some time on an analytical Mettler Balance, which could weigh accurately to one-thousandth of a gram. The samples were then returned to the oven again and dried again for some time. After this, each sample was again removed and while still warm, it was immersed in hot melted paraffin and quickly taken out to keep the coating of paraffin as thin as possible. The immersion in the melted paraffin was done to seal the pores of the wood piece so as to prevent any absorption of liquid when the volume of the piece was being determined by the liquid displacement method. The piece was again weighed to determine the amount of paraffin coating. The volume of the coated piece was then measured with a volumeter using mercury. To correct for the volume of wax (paraffin) coating the mass of the wax was divided by the density of the wax. This volume was deducted from the total volume given by the volumeter to obtain the true volume of the piece. The density of each test piece was then calculated by dividing the oven dry weight of the piece by its true volume in cubic meters. The RD of each piece was obtained by dividing the density by the density of water, that is, by 1000 kg m^{-3}.

Results and Discussions

Relative density in the radial direction

In the discussions below, relative density refers to the value at zero per cent moisture content, that is, the

value obtained from the oven dried weight and volume of the test specimen.

The results of the radial variation of the relative density of the wood of each species indicate that it fluctuates about a mean value for each species (see Figure 1). Comparison of the mean values in the four perpendicular directions of the trees of the species shows that only in few cases are the mean values significantly different. The overall mean relative density for each species at the sampling height is given in Table 1. The wood of the four species differ significantly in their densities. The density was highest in *Celtis mildbraedii* followed by *C. zenkeri, C. wightii,* and *C. adolfi-friderici* in that order. *Celtis zenkeri* showed the least variation in density with a coefficient of variation of 3.2%. Figure 2 illustrates the spread of the relative densities of the four species. *Celtis wightii* shows the widest range of variation in the density of the wood (coefficient of variation, 10.3%). The closeness in the mean densities of the wood of C. *zenkeri* and *C. wightii* suggests some similarities in the anatomical properties of the two species and this appears to be supported by the closeness of the vessel wall thickness and ray height. The mean vessel wall thickness of *C. zenkeri* and *C. wightii* are 4.8m and 4.6m respectively (Ocloo and Laing, 1991). The corresponding values for *C. adolfi-friderici* and *C. mildbraedii* are 5.2 m and 6.2 m respectively. The mean height of the rays for *C. wightii* and *C. zenkeri* are 343m and 349m respectively, which are again much closer than they are to those of *C. adolfi-friderici* (382 m) and *C. mildbraedii* (379 m).

Table 1: The means and standard errors of the relative densities of the wood of *Celtis species occu*rring in the Afram Headwaters and Pra-Anum Forest Reserves. The overall mean value for each species is also given.

Afram Headwaters		Pra - Anum	
Celtis species	Relative density	Celtis species	Relative density
C. adolfi-friderici	0.662 ± 0.005	*C. adolfi-friderici*	0.707 ± 0.006
C. mildbraedii	0.860 ± 0.005	*C. mildbraedii*	0.884 ± 0.004
C. wightii	0.771 ± 0.012		
C. zenkeri	0.789 ± 0.004		

Overall mean relative densities

Celtis adolfi-friderici:	: 0.685 ± 0.004
C. mildbraedii	: 0.872 ± 0.003
C. wightii	: 0.771 ± 0.012
C. zenkeri	: 0.789 ± 0.004

Figure 1: The relative density variation in four radial directions at right angles to each other in one tree of *Celtis adolfi-friderici* from Afram headwaters Forest Reserve

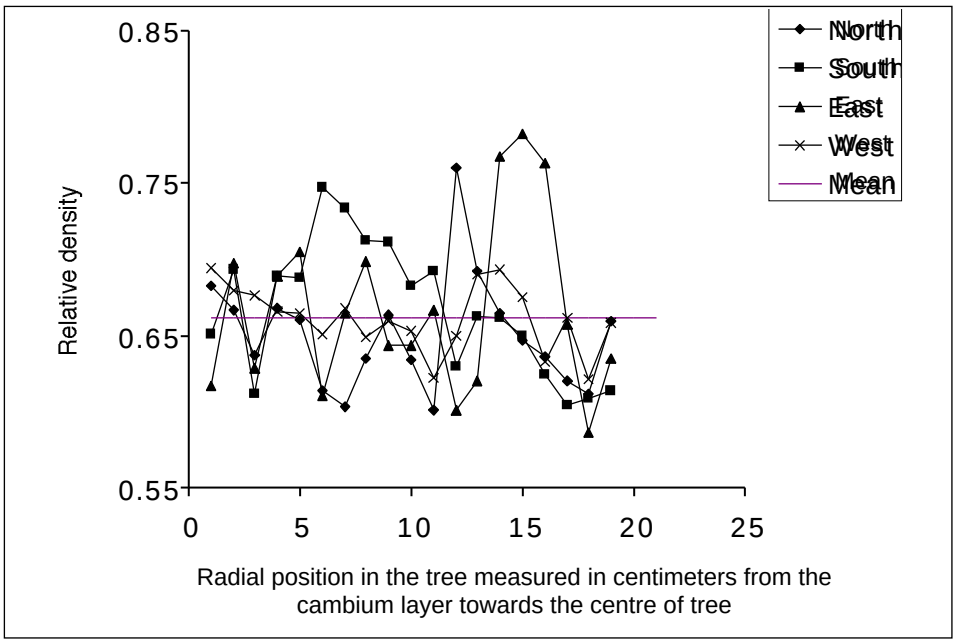

Figure 2: Percentage frequency distribution of relative density in four species of Ceiltis: *C. adolfi-friderici* (CEA);*C. milbraedii* (CEM); *C. wightii* (CEW); *C. zenkeri* (CEZ)

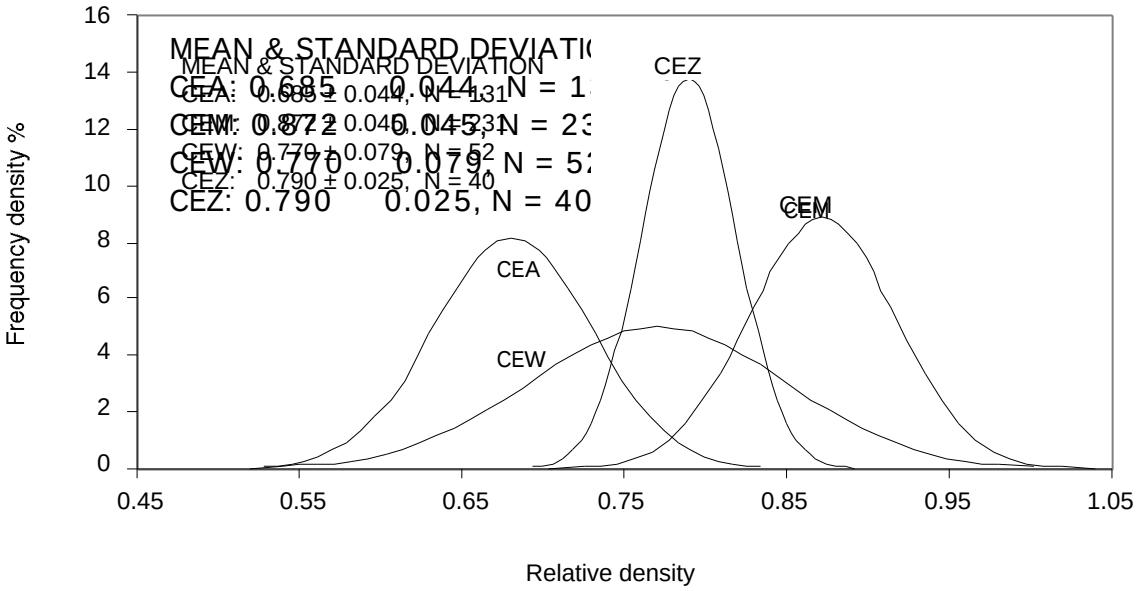

Table 2: Correlation coefficients between the relative density Y, and anatomical property X

Celtis Species	Anatomical Property X					
	X1	X2	X3	X4	X5	X6
adolfi-friderici,	0.483*	-0.557*	0.636**	0.066	0.582*	-0.602*
mildbraedii	0.320	0.107	0.616**	0.864***	0.601*	-0.806**
wightii	0.538*	0.900***	0.160	0.668***	0.539*	-0.673**
zenkeri	0.225	0.659*	0.676**	0.640**	0.658*	-0.141

X1 = vessel wall thickness; X2 = vessel wall fractional volume;
X3 = fibre wall thickness; X4 = fibre wall fractional wall volume;
X5 = length of fibre; X6 = number of vessels per mm^2

Significance of the coefficients are indicated as follows:
*** indicates p = 0.001;
** indicates p = 0.01;
* indicates p = 0.05.

Correlation between relative density and anatomical properties

The anatomical properties considered in examining the relationship between relative density of the wood substance and its anatomy has been published earlier (Ocloo and Laing, 1991). They include the number of vessels per square millimetre of the transverse section; vessel wall thickness; vessel wall fractional volume; fibre wall thickness; fibre wall fractional volume; and the length of the wood fibre. The relative densities corresponding to each of these anatomical properties have also been determined and reported elsewhere (Ocloo, 1989).

Table 2 gives the coefficient of correlation between the relative density and each of the anatomical properties for the four *Celtis* species. With the exception of the number of vessels per unit area, almost all the other anatomical properties positively

correlate to the relative density of the wood of each species. The positive correlations in many cases are significant (see Table 2).

The relative density of the wood of the four species decreases with increase in the number of vessels per square millimetre. The negative correlation between the two properties is due to the empty spaces in most of the vessels. Only a few of the vessels have deposits in their lumen which contribute to the density of the wood. The negative correlation is significant in three of the species ($p < 0.05$).

Multiple linear regression analyses of the data show that more than 85% of the variation in the relative density of the wood of each species is accounted for by the differences in the anatomical properties of the wood of the species. The fractional wall volume of the vessels and the fibres, and the length of the fibres appear to be the three major contributors to the density of the wood.

The above results confirm what Dinwoodie (1974), Desch (1980) and Haygreen and Bowyer (1996) reported that density of wood is related to the relative proportions of the various cell types and that this varies considerably between different species.

Mechanical strength properties

The mechanical strength properties discussed below were obtained from static tests. Most of the properties were those in the direction parallel to the grain direction of the wood. The compressive strength perpendicular to the direction of the grain can be estimated from the values of the side hardness of the wood (Lavers, 1969; 1974).

Table 3 gives the summary of the results of the physical and mechanical strength tests on Ce*ltis adolfi-friderici, C. mildbraedii* and *C. zenkeri.* Because the trees of *Celtis wightii* sampled in the two forest reserves (Tinte Bepo and Afram Headwaters) were not of merchantable sizes, they were not included in the mechanical strength tests. The value for each strength property in the table represents the mean of the values at the different heights in the trees of the species. Though the mean values of the strength properties at the different heights differed significantly, there was no consistent pattern in the variation of the properties in the axial direction of trees of the species studied.

Table 3a: The Physical and mechanical properties of *Celtis adolfi-friderici (CEA), C. mildbraedii CEM), and C. zenkeri (CEZ).*

Celtis Species	Moisture Content %	Nominal Relative Density	Density	Static bending Central loading		Impact Bending	Comp. Parallel to grain	Side Hardness	Shear parallel to grain	Cleavage In radial plane N/mm width	Cleavage In tangential plane N/mm width
		Oven dry wt. and vol. at test	at 12% m.c kg/m3	MOR	MOE	Maximum Drop m (metre)	Max. crushing strength N/mm^2	N	N/mm^2		
CEA	13.2										
Mean		0.599	671	88	10 700	0.56	51.0	5 991	12.0	8.8	14.4
Std. Dev.		0.056		13	1 300	0.14	5.9	1 437	0.9	2.2	2.8
No. of tests		39		24	24	21	39	25	30	16	16
CEM	13.0										
Mean		0.627	702	88	9600	0.60	47.6	7 304	13.7	9.0	13.0
Std. Dev.		0.051		20	1 750	0.14	7.3	1 630	1.4	2.0	1.9
No. of tests		36		21	21	17	36	21	44	21	21
CEZ	13.4										
Mean		0.583	693	91	10 900	0.64	51.9	5 710	11.4	7.0	12.2
Std. Dev.		0.046		21	1 620	0.05	8.4	1190	0.8	1.6	2.3
No. of tests		44		33	33	26	44	33	56	30	30

Sample trees for the tests were from Afram Headwaters and Tinte Bepo Forest Reserves.
MOR = Modulus of Rupture in Nmm^{-2}; MOE = Modulus of Elasticity in Nmm^{-2}; MC = Moisture Content.

Table 3b: Mean mechanical strength properties in axial direction of trees of three *Celtis* species of Ghana. Strength values uncorrected for shear stresses and are at 12% moisture content. Log 1 was taken just above the buttresses, Log 2 from the middle part of the the tree, Log 3 from below the crown

Celtis species	Axial position in the tree	Nominal Relative Density	Modulus of rupture Nmm^{-2}	Modulus of elasticity Nmm^{-2}	Compressive stress Parallel to grain, Nmm^{-2}
adolfi-	*1*	0.598	92	11 200	59.3
friderici	2	0.595	83	10 100	56.4
	3	0.610	82	9 300	46.3
Mildbraedii	*1*	0.649	97	10 600	55.7
	2	0.608	91	9 700	52.2
	3	0.593	69	7 600	43.0
Zenkeri	1	0.613	107	12 200	60.8
	2	0.567	89	10 600	54.1
	3	0.602	108	11 900	59.9

Correlation between strength and relative density

The correlation between the different strength properties and the nominal relative density (i.e. relative density based on oven dry weight and volume of specimen at test) has been investigated and found to be quite high. It was also found that linear equations best fitted the relationship between the strength properties and the nominal relative density.

Figures 3-5 illustrate some of the relationships. Some of the samples tested had high density but low strength. The presence of cross and wavy grain in the samples and possible differences in micro-fibrilla angles may explain this.

According to Desch (1980) there is a reduction of about 4% in bending strength when the grain is 2.3° to the vertical, 7% reduction when the grain is 2.9° to the vertical; 45% reduction when the grain is 11.5° from the vertical axis.

Apart from the modifying effect of the micro-fibrilla angle on the strength properties of wood, the presence of resins, gums and crystals such as oxalate also affect the strength-relative density relation. These extraneous components add to the weight of the wood but contribute little, if anything, to the strength (Lavers, 1969; 1974).

Within species of the *Celtis,* there is excellent positive correlation between each of the strength properties and the relative density of the wood of the species (see Table 4). The correlation is not so good when the data on the different *Celtis* species are considered together. The mean relative density of the wood of *Celtis mildbraedii* is higher than those of *C. zenkeri* and *C. adolfi-friderici.* This seems to suggest that *C. mildbraedii* on the whole will be stronger than the other two species. The results in Table 5 however indicate the contrary.

Table 4: The correlation coefficients for the relationships between the nominal relative density and the bending stress (√b), modulus of elasticity (E), compressive stress parallel to grain (√c), and shear stress parallel to grain of the wood (*f*s).

Celtis species	Correlation coefficient			
	√b	E	√c	*f*s
adolfi-friderici	0.704***	0.775***	0.513***	0.467***
mildbraedii	0.880***	0.823***	0.890***	0.539***
zenkeri	0.811***	0.906***	0.896***	0.587***

Significance of the coefficient is indicated as follows:
***, indicates significance at p = 0.001

Figure 3: Relation between modulus of rupture (bending strength) and nominal relative density of *Celtis zenkeri* from Tinte Bepo Forest reserve

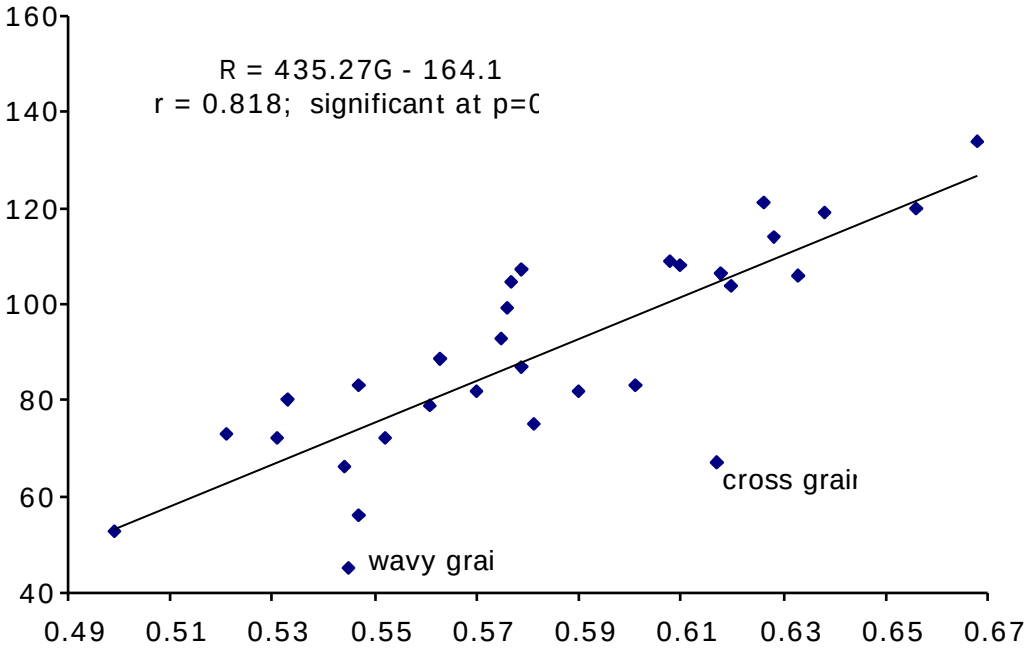

Figure 4: Relation between modulus of elasticity (stiffness) and nominal relative density of *Celtis zenkeri* from Tinte Bepo Forest reserve

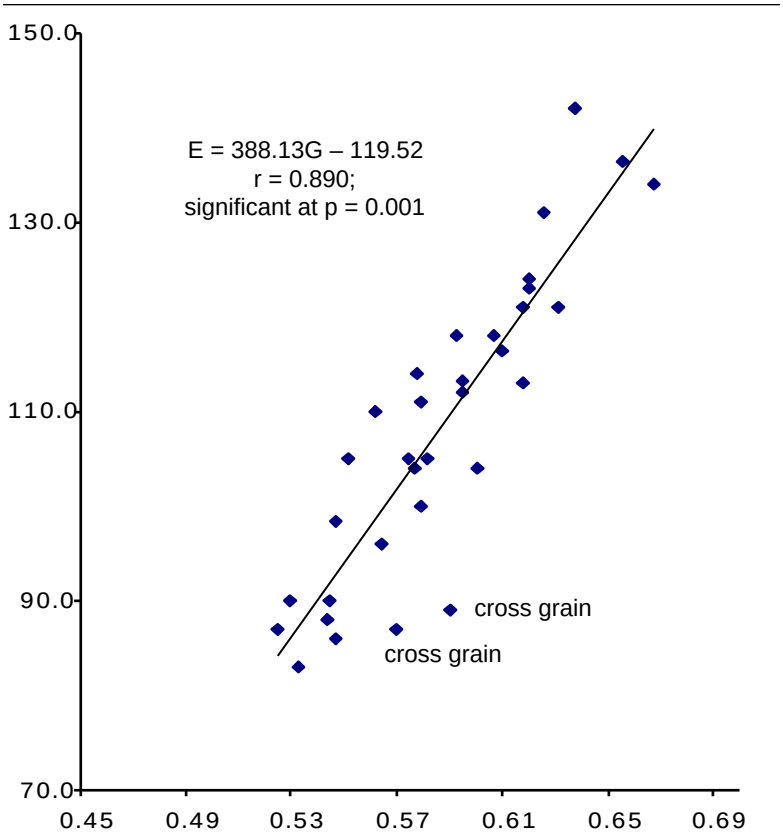

Figure 5: Relation of maximum compressive stress to nominal relative density of *Celtis adolfi-friderici* from Tinte Bepo Forest reserve

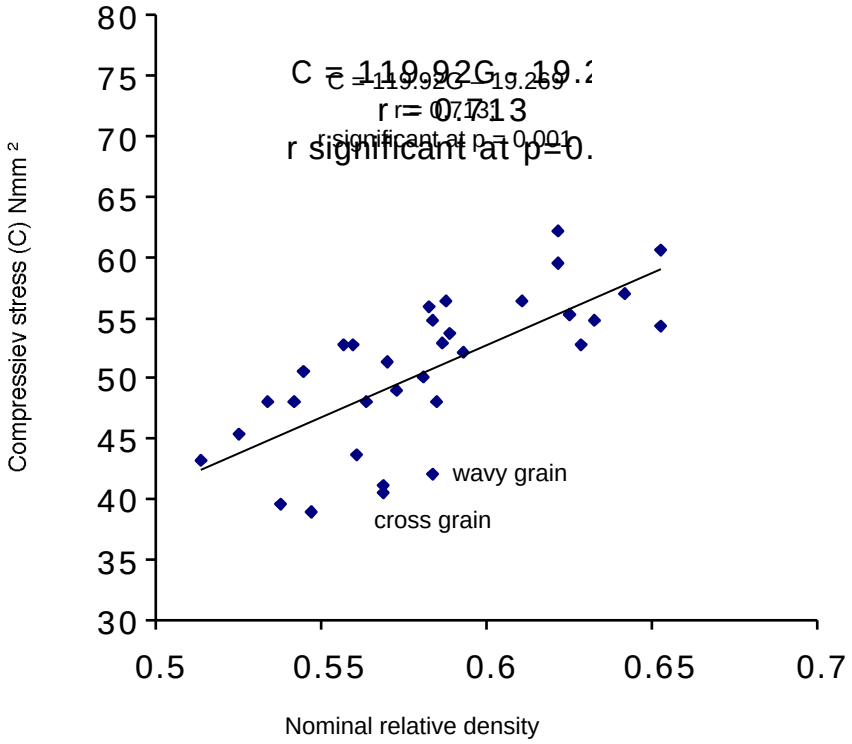

Table 5: Comparison of three strength properties of *Celtis adolfi-friderici, C. mildbraedii* and *C. zenkeri.*

Property at 12% Moisture Content	*Celtis* Species		
	adolfi-friderici	*mildbraedii*	*zenkeri*
Modulus of rupture, Nmm^{-2}	92.3	91.6	92.2
Modulus of elasticity, Nmm^{-2}	11 000	9 900	11 200
Compressive strength parallel to grain, Nmm^{-2}	54.8	50.5	56.4
Relative density	0.671	0.702	0.653

Both *C. zenkeri* and *C. adolfi-friderici* are stronger than *C. mildbraedii* in stiffness and compression. Apparent lack of good correlation between strength and relative density when the data on the three species are considered together may be due in part to possible presence of cross grain, differences in the micro-fibrilla angles, and cell length of the wood of the species. Desch (1980) reported that in clear, straight-grained wood both the longitudinal tensile strength and the stiffness are markedly affected by the micro-fibrilla angle; as the angle to the vertical axis increases so the tensile strength and stiffness quickly decrease. The remaining strength properties, however, appear to be only slightly affected by the angle of orientation of the micro-fibrils. He also reported that cell length is important in determining strength. According to him, a minimum length of cell is necessary in order to ensure sufficient overlap with the cell above and below it in order to transfer stresses from one cell to the next. The mean fibre length of *C. mildbraedii* is greater than those of *C. zenkeri* and *C. adolfi-friderici* (Ocloo and Laing, 1991) yet *C. mildbraedii* is weaker in compression and stiffness than the other two. This may be due to the long fibres of C. *mildbraedii* not overlapping sufficiently enough to enable effective transfer of stresses as might be with the other two species.

Correlation between strength and anatomical properties

Three main strength properties were considered in investigating the relationship between the anatomical and strength properties. These were: compressive strength parallel to the direction of the grain of the wood, bending strength and modulus of elasticity parallel to the direction of the grain. The anatomical properties were: vessel and fibre wall thickness, the fractional volumes of the walls of the vessels and fibres, and the length of the fibres.

Simple linear and additive multiple regression models were used in examining the relationship between strength and the anatomical properties. The results of the simple linear regression of the strength property on each of the anatomical properties show that each of the latter has a positive effect on the strength of the wood. In the additive multiple regression analyses, each strength property (i. e. the modulus of rupture, modulus of elasticity, and compressive stress) was regressed on the fractional wall volumes of the vessels and fibres. The coefficient of multiple determination, R^2, showed that a high percentage of the variation in each strength property was explained by the model.

The variance ratios, F, also showed a good fit of the model to the data in most cases. Table 6 gives the values of R^2 and F. The thickness of the walls of the fibres and vessels, and the fractional wall volumes of these cells were the major contributors to the strength of the wood of the species. The positive correlation between strength and the anatomical properties considered confirms Dinwoodie's (1974) report that strength of wood is related to the relative proportions of the various cell types and even more so to the wall thickness of any one type.

Table 6: The coefficient of multiple determination (R^2%) and variance ratio (F) for the multiple regression analysis

Celtis species	*Strength Pro*perty	R^2 %	F
adolfi-friderici	Compressive strength	88.9	4.789
	Modulus of rupture	94.8	17.788*
	Modulus of elasticity	97.4	22.265*
mildbraedii	Compressive strength	98.1	31.426**
	Modulus of rupture	97.6	24.614*
	Modulus of elasticity	97.5	23.713*
zenkeri	Compressive strength	98.9	52.783**
	Modulus of rupture	98.8	47.942**
	Modulus of elasticity	98.8	248.338***

Levels of significance are indicated as follows:
*** indicates F significant at p = 0.001
** indicates F significant at p = 0.01
* indicates F significant at p= 0.05

Comparison of the physical and strength properties of the Ghanaian Celtis species with those from other parts of Africa

Compared to the density ranges quoted by Bolza and Keating (1972) the relative densities obtained for the Ghanaian *Celtis* species are nearer to those of the countries close to Ghana. Bolza and Keating (1972) gave two ranges for the densities at 12% moisture content for each of the species - *Celtis adolfi-friderici*, *C. mildbraedii* and *C. zenkeri.* The density range appears to depend on site or geographical area. Thus the range for *C. adolfi-friderici* in Togo is 650 to 720 kg/m^3, which is lower than the range in Liberia (730 to 800 kg/m^3). Allowing for the 12% moisture content at which the densities quoted by Bolza and Keating were determined, the relative density range (0.641 to 0.729) for the wood of the Ghanaian *C. adolfi-friderici* is closer to that of Togo which is geographically nearer to Ghana than Liberia.

The Ghanaian *Celtis mildbraedii* appears to be heavier than those of Cote d'Ivoire (Ivory Coast) and Nigeria. Bolza and Keating gave the density ranges as 580 to 640 kg/m^3 for Cote d'Ivoire materials and 650 to 720kg/m^3 for the Nigerian timber. In the "Gold Coast (Ghana) Timbers" (Anon. 1949; 1966), the average relative density of the wood of the Ghanaian *C. mildbraedii* is 0.784 with a range of 0.72 to 0.80 at 15% moisture content. In the work reported in this paper, the average relative density is 0.872 with a range of 0.827 to 0.917 at zero per cent moisture content. The increase in the values at the lower moisture content is due to the shrinkage that affects the volume of the wood (U.S. FPL.1987, 1999). Below the fibre saturation point (25 – 30% moisture content, see Lavers, 1974, and U.S. FPL,1987; 1999), the relative density increases as the moisture content decreases (U.S. FPL, 1987; 1999; Haygreen and Bowyer 1996).

The range of density quoted by Bolza and Keating (1972) for Celti*s zenkeri* is less than the range found in the work reported here. For Uganda and Democratic Republic of Congo (former Zaire), the ranges at 12% moisture content are 650 to 720 kg/m^3 and 730 to 800 kg/m^3 respectively. The relative density range found in the present work for the Ghanaian species at zero per cent moisture content is 0.765 to 0.815 with a mean of 0.790. Usher and Ocloo (1979) found the average relative density of the wood of the species to be 0.81 at zero per cent moisture content.

Comparing the strength values given by Bolza and Keating (1972) for Ce*ltis adolfi-friderici* in Togo and Liberia with those of the same species in Ghana, it is observed that the Ghanaian species is closer in strength to the Togolese one than to the Liberian species. The wood of the Liberian species is about 10

– 20% heavier and stronger than those of Ghana and Togo (see Table 7). The wood of the Ghanaian C. *mildbraedii* is 12 – 18% denser and about 8 – 30% stronger than that of Cote d'Ivoire but more than 20% weaker than those of Nigeria and Zaire. Compared with the Kenyan *C. mildbraedii*, the Ghanaian wood is about 20% weaker in stiffness. The wood of the species of the Central African Republic appears to be about 16% weaker in bending and 9% weaker in compression parallel to the grain of the wood (see Table 8). The wood of the Zairean C. *zenkeri* is about 20% stronger in bending and stiffness, and about 10% stronger in compression parallel to the grain than the Ghanaian wood that is slightly superior in compressive and bending strengths to the Ugandan species (see Table 9).

Table 7: Average of some mechanical strength properties of *Celtis adolfi-friderici* in Ghana, Liberia and Togo. Values for Liberia and Togo were obtained from Bolza and Keating (1972)

Property at 12%	Country		
Moisture content	Ghana	Liberia	Togo
Modulus of rupture (Nmm^{-2})	92.3	114.0	93.7
Modulus of elasticity (Nmm^{-2})	11 000	14 200	12 400
Comp. Parallel to grain (Nmm^{-2})	54.8	62.0	53.4
Air dry density, kgm^{-3}	610 - 730	730 - 800	650 - 720

Table 8: Average of some mechanical strength properties of *Celtis mildbraedii* in Ghana (GH), Cote d'Ivoire (CV), Nigeria (N), Central African Republic (CAR), Kenya (K), and Zaire (DRC) (Z). Values for CV, N, CAR, K, and Z are from Bolza and Keating (1972)

Property at 12%	Country					
Moisture content	GH	CV	N	CAR	K	Z
Modulus of rupture (Nmm^{-2})	91.6	67.2	114.0	79.2	93.7	114.0
Modulus of elasticity, (Nmm^{-2})	9 800	9 100	14 200	10 700	12 400	14 200
Comp. parallel to grain (Nmm^{-2})	50.5	40.0	62.0	46.2	53.4	62.0
Air dry density (kgm^{-3})	650 - 760	580 - 640	650 - 720	650 - 720	650 - 720	730 - 800

Table 9: Three strength properties of *Celtis zenkeri* in Ghana, Uganda, and Zaire (DRC). Values for Uganda and Zaire are from Bolza and Keating (1972)

Property at 12%	Country		
Moisture content	Ghana	Uganda	Zaire (DRC)
Modulus of rupture, (Nmm^{-2})	96.2	93.7	114.0
Modulus of elasticity, (Nmm^{-2})	11 200	12 400	14 200
Comp. Strength parallel to grain (Nmm^{-2})	56.4	53.4	62.0
Air dry density (kgm^{-3})	600 – 710	650 - 720	730 - 800

Conclusion

The wood of the four *Celtis* species occurring in the Tropical High Forests of Ghana differ significantly in their densities. *Celtis mildbraedii* is the heaviest and *C. adolfi-friderici* is the lightest. The relative density of the wood of the species positively correlated with the wall thickness of the vessels and fibres, the fractional wall volumes of the vessels and fibres, and the length of the fibres. The major contributors to the strength of the wood of *C. adolfi-friderici, C. mildbraedii*, and *C. zenkeri* are the wall thickness of the vessels and fibres, the fractional wall volumes of the vessels and fibres and the length of the fibres. Some of the strength properties of the three species significantly correlated with the relative densities of the wood of the species.

The differences between some of the species strength properties are statistically significant. The shear stress of C*eltis mildbraedii* is 13.7Nmm^{-2} which is significantly higher than that of *C. adolfi-friderici* which is 12.0 Nmm^{-2} (t = 6.355, significant at p = 001). In a design where shear condition is the governing factor, a shear stress difference of 1.7 Nmm-^{2} is large enough to justify selecting *C. mildbraedii* in preference to *C. adolfi-friderici* for same size timber of both species. If stiffness on the other hand is the governing factor then *C. adolfi-friderici* of modulus of elasticity of 10 700 Nmm^{-2} is superior to *C. mildbraedii* of modulus elasticity of 9 600 Nmm^{-2}. The general practical implication of this is that it is not safe to treat the three C*eltis* species (*C. adolfi-friderici*, *C. mildbraedii* and *C. zenkeri*) as having same strength properties as far as their use for structural purposes is concerned. If the individual species cannot be distinguished, then for design purposes, the least value of a particular property of the three species should be used.

Acknowledgements

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Enalapril Increases Postischaemic Cerebral Oxygen and Glucose Consumption in Cats

Isaac Julius Asiedu - Gyekye*[1] and Daniel A. Antwi[2]

[1]*Department of Pharmacology, University of Ghana Medical School, P.O. Box 4236 Accra, Ghana*
[2]*Department of Physiology, University of Ghana Medical School, P.O. Box 4236 Accra Ghana*

* corresponding author

Abstract

The purpose of this study was to investigate whether enalapril - an angiotensin converting enzyme inhibitor – has an effect on oxygen consumption and glucose utilization by the brain after ischaemia.

The experiments were carried out on anaesthetized cats under artificial respiration and autohemoperfusion of the brain with a constant volume of blood using a resistograph. Tissue levels of oxygen and glucose were determined using a radiometer and their consumption was determined by the arterio-venous differences taking into account the blood flow rate. Brain ischaemia was simulated by 15-minutes arrest of the autohemoperfusion pump and reducing the arterial pressure to 40-30 mm Hg by haemorrhage.

In the postischaemic period in the cat brain, control experiments proved that consumption of oxygen and glucose by the brain falls drastically with the development of metabolic acidosis. Intravenous infusion of enalapril (0.25 mg kg^{-1}) ten minutes into the postischaemic period increased oxygen and glucose consumption by the brain.

The result of this study suggests that enalapril improves oxygen and glucose consumption, changes the degree of acidosis of the postischaemic brain and the important role of the renin-angiotensin system in the occurrence of postischaemic cerebrovascular events was implicated.

Key words: Enalapril, ischaemia, oxygen, glucose consumption

Résumé

L'objectif de cette étude était d'approfondir si l'enalapril - un inhibiteur enzymatique de l'angiotensine, a un effet sur l'assimilation de l'oxygène et l'utilisation du glucose par le cerveau, au cours de la période post-ischémique**.** Des essais ont été effectués sur des chats anesthésiés et sous une respiration artificielle et une autohémoperfusion du cerveau avec un volume constant de sang en utilisant un résisteographe. Les différents niveaux du taux d'oxygène et du glucose dans le tissu ont été déterminés à l'aide d'un radiomètre tandis que l'assimilation des deux éléments a été déterminée par les différences artério–veineuses tenant compte du débit de sang. L'ischémie du cerveau a été simulée par l'arrêt pendant 15 minutes, de la pompe d'autohémoperfusion réduisant ainsi la pression artérielle à 40-30 mm Hg, par hémorragie. Au cours de la période post-ischémique dans le cerveau du chat, des expériences servant de témoin ont montré que l'assimilation de l'oxygène et du glucose par le cerveau baissait sérieusement avec l'apparition de l'acidose métabolique. L'infusion intraveineuse de l'enalapril (0,25 mg par kg) pendant 10 minutes au cours de la période post-ischémique augmentait l'assimilation de l'oxygène et du glucose par le cerveau. Les résultats de cette étude conduisent au constat que l'enalapril stimule l'assimilation de l'oxygène et du glucose, et change le niveau d'acidose post-ischémique du cerveau. Les mêmes résultats stipulent le rôle du système réinino -angiotensine dans l'occurrence des processus cérébro-vasculaires post ischémiques.

Mots-clés: enalapril, ischémie, assimilation d'oxygène et du glucose

Introduction

It is known that angiotensin converting enzymes (ACE) take part in the conversion of angiotensin I (A1) to angiotensin II (A11), the most active vasoconstrictor agent which is then metabolized to angiotensin III (A111). Besides, ACE - inhibitors activate the depressor (kinins) system of the organism (Chen Ke and Zimmermann, 1994). A11 on the other hand, indirectly stimulates secretion of noradrenaline, aldosterone and antidiuretic hormone. Under the influence of ACE-inhibitors, bradykinin degradation is reduced (Chen Ke and Zimmermann, 1994; Rhaleb and Yang, 1994). Experimentally, ACE - inhibitors have been proven to decrease angiogenesis and cellular proliferation and at the same time, protect against ischaemic events especially the cerebral ones because they favour the rapid recruitment of collateral circulation, which could explain the protective effect of ACE-inhibitors against cancer (Fournier, *et al*., 1999).

The brain is very sensitive to lack of oxygen and glucose and at the same time, the major consumer of glucose. During ischaemia, there is a drastic change in the ability of the brain tissues to utilize oxygen and glucose, which most often is very detrimental. Literature sources on the action of ACE - inhibitors on the oxygen and glucose utilization are scanty and often controversial. However, reports have been made concerning the effect of captopril and enalapril on oxygen consumption of guinea-pig tissues (Andelchovich and Obradovich, 1989) and the capability of losartan and enalapril to prevent and reduce cerebral oedema and proteinuria in stroke-prone spontaneously hypertensive rats (Asiedu-Gyekye and Antwi, 2003; Blezer *et al.*, 2001) while Asiedu-Gyekye and Gaevy (2001) reports that losartan enhances cerebral blood flow in spontaneously hypertensive rats before and after cerebral ischaemia.

Since hypertensive diseases are most often accompanied by ischaemic episodes, we decided to study the effect of the second generation ACE - inhibitor - enalapril on the oxygen and glucose utilization in the cerebral cortex in cats. Concerning myocardial ischaemia, there is overwhelming evidence for the beneficial action of ACE-inhibitors on the processes of metabolism, peroxide oxidation of lipids and the state of the endogenic antioxidative system (Chen Ke and Zimmermann, 1994; Takase *et al.*, 1996). It was decided, therefore to study the influence that enalapril could exert on oxygen and glucose consumption in the ischaemic brains of cats.

Materials and Methods

Experiments were performed on 32 male cats (2.3 - 2.4 kg body weight) under pentobarbital (Nembutal) anaesthesia (40 mg kg^{-1}) and artificial respiration. Before the experiment, the cats were fasted for three days without food but water was made available. The cats were kept under standard environmental conditions before the experiment.

Autohemoperfusion was produced by means of a resistograph - a special device designed to maintain a stable volume of blood (Gaevy and Maltsev, 1977). The carotid arteries peripheral vessels are cannulated and connected to the autohemoperfusion pump that ensures blood is pumped into circulation since the various anastomoses in the neck region have been tied up. Novocaine (1ml of 1% solution) and heparin (1000 IU kg^{-1}) were injected intravenously to reduce pain and prevent blood coagulation respectively.

Transitional brain ischaemia was simulated by the 15-minutes arrest of the autohemoperfusion pump, tying various anastomoses in the neck region and reducing the arterial blood pressure (ABP) to 40-30 mm Hg by haemorrhage with the following reinfusion of the shed blood after which enalapril was introduced intravenously in a dosage of 0.25 mg kg^{-1} and the various parameters monitored within a period of two hours. The ambient temperature was maintained at 37°C during the surgical procedure. In control experiments, instead of enalapril, an equivalent volume of isotonic solution of sodium chloride was injected under the same conditions as for experimental animals above. Consumption of oxygen and glucose was determined by the arterio-venous difference taking into consideration the rate of cerebral blood flow with the help of an acid-base nomogram (Thews, 1967).

Determination of cerebral oxygen consumption

In determining the oxygen consumption by the brain, the blood gas tension of oxygen and pH in both the arterial and venous blood were measured by a gasometrical way using the device "Radiometer" Radelkis - Russia. The amount of hemoglobin was determined by means of a hemometer of the GS-3 type.

Arterial and venous blood (0.2 ml) was collected from the common carotid arteries and the venous stocks sinus. In each experiment, the rate of cerebral blood flow was measured. This was determined by measuring the amount of blood collected within a minute from the carotid artery when it was disconnected from the autohemoperfusion pump in one minute (Gaevy and Maltsev, 1977).

The percentage of blood oxygen saturation was calculated using the nomogram (Thews, 1967) and taking into account the values of pH, the arterial and venous blood gas tension of oxygen. By combining these parameters and in accordance with the Fick principle (Rushmer, 1955), the oxygen consumption by the brain was determined by using equation 1:

$$Q = \frac{1{,}34\ (C_a - C_v) * H_b * V}{100} \qquad (1)$$

Where Q is the consumption of oxygen by the brain in ml/100g/min, *1.34* is Gufneras Constant, C_a is the percentage of arterial blood oxygen saturation, C_v is the percentage of venous blood oxygen saturation, H_b is the amount of haemoglobin in 1ml in grammes and V is the rate of cerebral blood flow in ml/100g/min.

Determination of glucose utilization by the brain

In determining the concentration of glucose in the blood, the ortho-tholuidin method was utilized (Menshikov, 1973). Blood samples (0.1ml) were taken simultaneously from the common carotid arteries and the venous stocks sinus of the brain. The amount of

glucose utilized by brain was determined by the arterio-venous difference with respect to the rate of volume of cerebral blood flow (Menshikov, 1973; Gaevy and Maltsev, 1977).

In all cases values are given as means ± SEM of eight animals. Statistics were performed by paired Student's t-test, (* means $p < 0.01$).

Results

Control experiments showed that in the postischaemic period (120 min), after brain ischaemia both the oxygen (Figure 1, Table 2) and glucose consumption (Figure 2, Table 2) by the brain decreased which was evidenced by the negative values obtained.

Table 1: Changes in some parameters of the oxidative exchanges in the brain of anaesthetized cats in control experiments.

Oxidative exchange parameters		Time after introduction of normal saline	
Time (min.)	Initial data	30-45	90-120
Oxygen tension in arterial blood (pO_2) (mm Hg)	107.96.7	+5.63.2	-2.32.4
Oxygen tension in venous blood (pO_2) (mm Hg)	62.04.9	-3.42.6	+1.52.3
Arterial pH Venous pH	7.300.03	-0.90.6	-0.70.4
Arterial oxygen saturation (S%)	98.20.5	+3.21.7	-1.50.8
Venous oxygen saturation (S%)	84.71.7	-2.31.7	-3.32.1
Consumption of oxygen by the brain (ml $100g^{-1}min.^{-1}$).	2.10.2	-0.70.4	0.91.2
Amount of glucose in arterial blood (mmol l^{-1})	8.30.6	+1.60.7	+1.31.6
Amount of glucose in venous blood (mmol l^{-1})	7.60.4	+2.22.6	+3.32.1
Glucose utilization by the brainmol $100g^{-1}$ $min^{-1.}$	65.37.2	-3.61.7	-4.23.2

Figure 1: Changes in oxygen consumption after ischaemia in control experiments and under the influence of enalapril

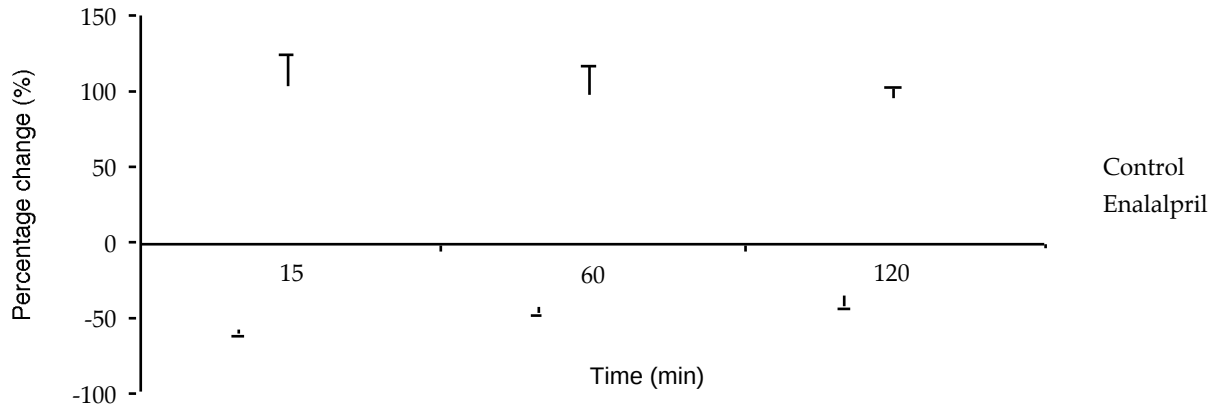
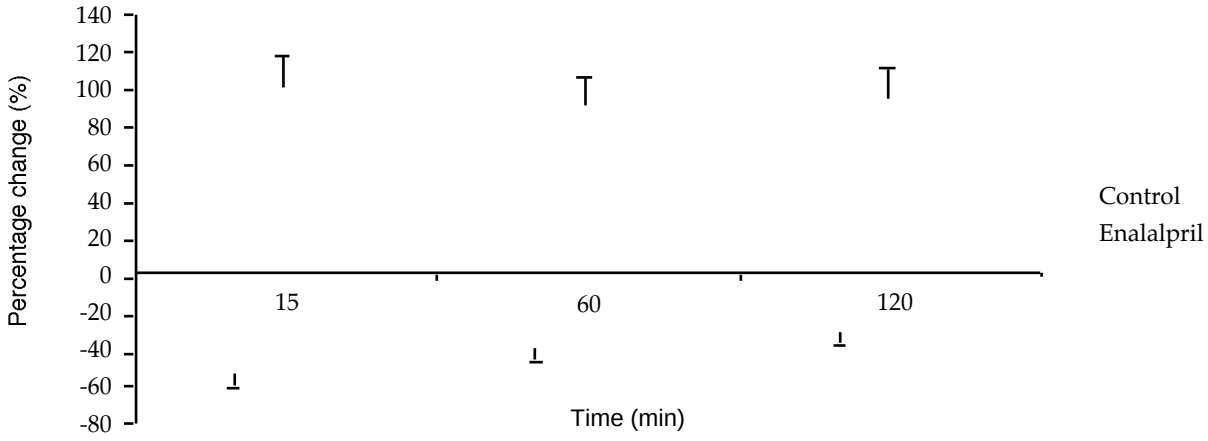


Table 2: Changes of some parameters of oxidative exchanges of the brain in the postischaemic period in control experiments (with 1 ml of a normal saline solution injected intravenously).

Oxidative exchange parameters		Time after introduction of normal saline		
Time (min.)	Initial data	15	60	90-120
Oxygen tension in arterial blood (pO_2), (mm Hg)	122.010.1	+7.78.2	+4.87.5	+5.710.7
Oxygen tension in venous blood (pO_2) (mm Hg)	62.04.9	+35.09.0*	+20.04.3*	+15.25.14*
Arterial pH	7.380.01	-2.20.4*	-1.560.4*	-1.60.4*
Venous pH	7.290.09	-1.50.7	-1.30.4*	-1.10.5
Arterial oxygen saturation (S%)	98.20.5%	-1.30.6	-1.20.7	-1.20.6
Venous oxygen saturation (S%)	84.71.7%	+7.52.0*	+5.51.9*	+3.31.2*
Consumption of oxygen by the brain (ml $100g^{-1}min.^{-1}$).	1.60.2	-5.73.6*	-40.85.7*	-33.88.1*
Amount of glucose in arterial blood (mmol l^{-1})	8.400.4	+50.38.0*	+58.516.7*	+55.722.1*
Amount of glucose in venous blood (mmol l^{-1})	7.640.4	+60.78.6*	+68.317.9*	+65.024.1*
Glucose utilization by the brain (mol $100g^{-1}min^{-1}$)	63.86.2	-50.78.2*	-35.28.7*	-40.58.7*

* means $p< 0.01$ from 8 experiments.

Figure 2: Changes in glucose consumption after ischaemia in control experiments and under the influence of enalapril



During enalapril administration, it was observed that there was an increase in oxygen consumption by 98.6% after 60 minutes and by 92.1% after 120 minutes (Figure 1). At the same time glucose utilization significantly increased by 66.6% within an hour after ischaemia and 97.9% by the end of the experiment (Figure 2).

Discussion

In the present study the effect of enalapril on oxygen and glucose utilization were studied. In the control experiments it was observed that under conditions of autohemoperfusion with a stable volume of blood within 90-120 minutes before brain ischaemia, there

were no significant changes in the main energetic parameters measured. A similar observation has been made by Oksa, *et al* (1992). Rather there was a decrease in oxygen and glucose utilization by (1.0%) and (4.2%) respectively (Table 1). This may be explained by the properties of barbiturates (pentobarbital) to decrease the metabolic rate of oxygen consumption (Frizzell, *et al,* 1993; Messeter, *et al,* 1986; Nara, *et al,* 1998) and glucose utilization (Ableitner, *et al,* 1987) by the brain.

In the postischaemic period the capability of the brain to use oxygen and glucose reduces, despite its availability in the blood and the restoration of blood flow which was reflected by the increased amount of oxygen and glucose content in the venous blood and the development of acidosis which was reflected by the decrease in arterial pH (Table 2). This metabolic depression can normally be observed at all levels of hypoxia in tolerant animals as published by St Pierre *et al* (2000). Thus, the energy level in the brain tissues decreases which probably preceded cell damage and death (Seidi, *et al,* 2000). This may be explained by the destruction of a large number of mitochondria and the enhanced formation of oxygen free radicals during and immediately after brain ischaemia in the brain tissues (Chang, 1990; Oliver and Starke-Reed, 1990; Traystman, *et al,* 1992). The high content of oxygen in the cerebral venous blood in the postischaemic period was caused mainly by the excess perfusion of the cerebral vessels (reactive hyperemia).

Among the violations in cerebral haemodynamics, the postischaemic cerebrovascular phenomena are of a special interest in clinical practice. This is seen especially in hypertensive patients with episodes of cerebral ischaemia and thus necessitates more investigations in the effort to elucidate the role of pharmacotherapeutics in cerebrovascular phenomena.

Conclusion

The results showed that enalapril was capable of significantly reducing the degree of metabolic depression and reversing the decline of oxygen consumption and glucose utilization by the brain during cerebral ischaemia which is life threatening. It is recommended that an extension of this study be done using rat models of hypertension.

Enalapril enhances cerebral oxygen and glucose consumption and reduces the degree of acidosis.

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Levels of Aerosol in Dar es Salaam, Tanzania, Compared to Some Cities

Yusuf I.A. Koleleni

Physics Department, University of Dar es Salaam, P.O. Box 35063 Dar es Salaam, Tanzania

Abstract

The aerosol concentrations in the city of Dar es Salaam were found with aim of investigating pollution levels. The aerosol samples were collected on the sites of Tanzania Oxygen Limited (TOL) which is purely an industrial area, Ocean Road Cancer Research Institute (ORCRI) located along the sea shore at the port exit, and Dar es Salaam International Airport (DIA) far from the city center. The PM10 dichotomous impactor was used for sample collection. The analysis of the samples was conducted with x-ray fluorescence spectrometer. The values obtained for Dar es Salaam aerosol samples are compared to similar samples of aerosol data available for the cities of Kinshasa and Butare in the republic of Congo and Rwanda respectively. The elements found in the aerosol samples include Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Ga, Br, Rb, Sr, Zr, Pb and Se. The variations of the minimum and maximum values of the elemental concentration in the sample for these elements are given for the months between September 1996 and May 1997. The elemental variation was affected by seasonal weather parameters like rain, wind speed and their directions. Temperatures varied between 29 and 32°C; rainfall between 5 and 70 mm while wind speed varied between 5 and 20 m/s.

Key words: Aerosol concentrations, urban pollution level element, season, Dar es Salaam, Butare, Kinshasa, Tanzania

Résumé

Les concentrations d'aérosols dans la ville de Dar es Salaam ont été échantillonnées avec le but d'évaluer le degré de pollution. Les échantillons d'aérosols ont été collectés de l'usine Tanzania Oxygen Limited (TOL) situé dans la zone industrielle, et de Ocean Road Cancer Research Institute (ORCRI) localisé le long de la côte maritime entre l'embouchure du port et l'Aéroport International de Dar es Salaam loin du centre urbain. L'analyse des échantillons a été effectuée au moyen d'un spectromètre fluorescent à Rayons X. Les valeurs obtenues des échantillons des aérosols de Dar es Salaam ont été comparés à celles de Kinshasa en République Démocratique du Congo et à celles de Butare au Rwanda. Les éléments trouvés dans les échantillons d'aérosols incluent Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Ga, Br, Rb, Sr, Zr, Pb et Se. Les variations des valeurs minimales et maximales de concentration de ces éléments dans les échantillons sont données pour les mois entre septembre 1996 et mai 1997. La variation des éléments et leur concentration sont subordonnées aux facteurs régissant les saisons comme la pluie, la vitesse du vent et leurs directions. Les températures variaient entre 29 et 32 oC et la pluviométrie entre 5 et 70 mm tandis que la vitesse du vent oscillait entre 5 et 20 m/s.

Mots clés: concentrations d'aérosols, pollution urbaine, éléments, saison, Dar es Salaam, Butare, Kinshasa, Tanzanie

Introduction

Aerosol sources and their contribution to environmental pollution are well documented elsewhere (Oblad, 1986; Koleleni, 1989; Van Grieken and Labreque, 1985; Dzubay, *et al,.* 1977). The significance of studying aerosol in relation to health hazards makes the subject of pollution attractive to several researchers (Malmqvist, 1981; Oikawa, 1997; Bghard, 1983; Boeker and Van Grondelle, 1995; Markowicz and Abdunabi, 1991). The fine particles when inhaled have a health effects on the respiratory tract and the chemical parts may be absorbed into the blood system and cause several types of diseases. Apart from inhalation of aerosol, particles may be deposited on the skin surface, food, and crops, soils and water that may find ways into human body and may have health effects. Some levels of aerosol are considered tolerable while others excessive and completely toxic especially the heavy elements. The particles may have health effects due to their chemical effects or radioactive properties. The aerosol particles differ in composition from one place to another depending on the source of pollutants. This makes the need of studying these particles, their composition and their effects on health. The understanding of the levels of aerosol is facilitated by both the availability of the sampling equipment (Lodge, 1988) together with accurate, fast, non-destructive, multi-element analyzing spectrometer (Giauque and Jacklevic, 1972; Markowicz and van Grieken, 1993; Jacklevic *et al.*, 1990; Aiginger and Wabrauschek, 1974, Nonomiya *et al.,* 1989; Aiginger and Wabrauschek, 1985). It is certainly important that knowledge on the linkage

between the sampling places, sources and the sample results in relation to the meteorological parameters provides the insight on the interpretation of the data (Van Grieken and Adams, 1976; Oblad and Selin 1986). In many tropical countries, aerosol contributions mainly originate from burning biomass, soil dust, combustion of fuel, industrial and marine activities. In this work aerosol research was performed with the objective of identifying the sources of aerosol pollution and looking at variation of the elemental composition in consideration with the different seasons of the year. Samples were collected between September 1996 and May 1997 in Dar es Salaam at three centers. These are, the Tanzania Oxygen Limited (TOL) purely located at the industrial area, Ocean Road Cancer Research Institute (ORCRI) located at the seashore and port exit, and Dar es Salaam International Airport (DIA) located at the outskirts of the city. The sampling cites reflects the working, residential and the port areas. The average results of the data obtained are given in Table 1 and the comparison has been done with that of Kinshasa and Butare in the Democratic Republic of Congo and Rwanda, respectively. These are neighboring countries with completely different environmental conditions although the results may generate interest in the levels for which the present work was only limited to Dar es Salaam. Some aerosol work going on in other African cities have so far not been available for inclusion in this work.

Methodology

Sample collection

Aerosol sampling was conducted using Sierra Andersen™ PM10 dichotomous impactor with ability to separate two particle sizes of less than 2.5mm as fine particles and greater than 2.5mm as coarse particles which are collected on two different filters. The detailed description of the sampler is given elsewhere (Wesolowski *et al.*, 1985; Lawson, 1980; Gladney, 1974; Paciga and Jervis, 1976; Koleleni, 1990; Loo *et al.*, 1995; Hinds, 1982; IAEA, 1992; IAEA, 1997; Oblad *et al.* 1982; Oblad and Selin, 1985). The vacuum pump sucks in air at the rate of 1 m^3/h and the particles are collected on Millipore TM filters whose pore size is 0.9 μm diameter for 24 hours. The flow rates together with the geometry of the impactor nozzle allow the separation of the two particle sizes according to their aerodynamic diameters. For a flow rate of 1 m^3/h, there are two paths referred as minor and major flow, which share 10% and 90% of the total flow. This means that 0.1 m^3/h deposits the coarse particles while 0.9 m^3/h deposits the fine particles on their respective filters. The sampling stations were Tanzania Oxygen Limited (TOL), Ocean Road Cancer Research Institute (ORCRI), and Dar es Salaam International Airport (DIA). The data available for samples of Kinshasa and Butare were actually not part of this work but were conducted by other authors (Akilimali and Maenhautt, 1990).

Sample Analysis

The aerosol samples collected on filters were placed on a holder system for excitation with x-rays. The x-rays from the Siemens FK60 series tube strike the secondary target to produce monochromatic x-rays, which are, then incident on the sample. The fluorescent x-rays from the sample are detected by the Si (Li) model SL 30180 semiconductor liquid nitrogen cooled detector whose signal is processed via the Canberra ™ model 2008 pre-amplifier, Canberra™ model 2026 amplifier, Canberra™ model 8701 ADC, Canberra™ S-100 multi-channel analyzer. The quantitative analysis was possible after the system calibration (IAEA, 1993; Van Espen *et al.* 1986; Wobrauschek, 1989; Koleleni and Van Grieken, 1991). In EDXRF spectrometer, once the high voltage is applied to the x-ray tube, electron beams are produced and accelerated from the cathode to the anode. The x-ray bremsstrahlung are then produced at the anode. This broad band of energy spectrum is arranged to strike a Mo secondary target so as to get a mono-energetic x-ray photon of Mo, which is in turn used to excite the characteristic radiation from the sample atoms. The characteristic radiation is detected by the Si(Li) semiconductor detector. All the elements in the sample heavier than phosphorous were accurately detected. The concentrations from the sample were evaluated using the relation:

$$I_i = K_i C_i A_i$$

Where I_i is the intensity of the element i, K_i is the sensitivity of the element i, C_i is the concentration of the element i, and A_i is the absorption correction of the element i

The sensitivity of the low Z elements are affected by absorption in the air compared to high Z elements. It is also noted that the sensitivity of elements close to Molybdenum, which was an exciting energy, are slightly diminishing. This is due to these elements being affected by the tailing effect of the Compton scattered peaks. Most of the elements were finally detected when the counting times were prolonged. The errors were mainly due counting statistics. Obviously a lot of work has previously been done on the set-up to lower down the detection limits of many elements and to correct for the absorption.

Results and Discussion

The results presented in this section are those, which were analysed for the Dar es Salaam sampling sites. However, the results quoted in this section for samples obtained from Kinshasa and Butare were from the literature (Maenhaut and Akilimali, 1985) just for comparison purposes in terms of the levels though the sampling times, places and conditions were completely different from Dar es Salaam. All the results presented in Table 1 for three stations of Dar es Salaam namely TOL, ORCRI, DIA are range of values (minimum to maximum) and those of the cities of Kinshasa (Democratic Republic of Congo) and Butare (Rwanda) are average elemental concentrations in ng/m^3. In our discussions it may be found to be incorrect to compare soil elements for Kinshasa, Butare and that of Dar es salaam since the land formations and industries of these three places are completely different. It can further be pointed out that the wind directions which may very much determine where the aerosol were picked were only available for Dar es Salaam and not the rest in the other cities mentioned. However, the inclusion of the data from the other cities is important for readers to grasp the idea of what levels they should expect from other cities in addition to Dar es Salaam.

Table 1: The average atmospheric concentration in Dar es Salaam (TOL, ORCRI, DIA) compared to the average values of Kinshasa and Butare in (ng/m^3)

	Democratic Republic of Congo and Rwanda		Dar es Salaam		
Element	Kinshasa	Butare	TOL	ORCRI	DIA
Si	2800	141	-	-	-
P	34	4.4	-	-	-
S	370	36	73	105	354
Cl	49	-	58	30	232
K	410	87	132	91	166
Ca	410	30	182	312	304
Ti	110	7.7	29	14	8
V	2.6	-	-	-	-
Cr	2.3	-	9	7	1.5
Mn	15.0	1.80	115	102	100
Fe	770	70	248	178	136
Ni	0.69	-	-	-	-
Cu	1.48	0.19	122	72	52
Zn	7.1	1.06	116	37	21
Ga	0.56	-	-	-	-
Br	4.1	8.2	33	24	11
Rb	1.54	0.56	-	-	-
Sr	3.3	0.29	11	15	5
Zr	3.1	0.42	10	6	4
Pb	13.8	14.7	170	60	370
Se	-	-	6	9	5

The S values in aerosol are higher in Kinshasa than in Butare (Table 1) in the republic of Congo as outlined by Maenhaut and Akilimali (1987) and Maenhautt and Akilimali (1985). When these values are compared to those obtained in this work, they stand between the TOL and DIA values in content. The average values for DIA and ORCRI are much higher for the reasons of its location between the ocean coast exposed directly to sea marine activities and sea vessels, the places where S originates. The same applies to Cl values(58-232 ng/m^3 for which Dar es Salaam International Airport (DIA) has higher values. The Soil elements of K, Ca, and Ti in Dar es Salaam have higher values of Ca because some industries use raw materials rich in Ca. The comparison of elemental concentration between Dar es Salaam and Kinshasa provides an insight of environmental aerosol levels in these two cities in countries, which are neighbors despite the incorrectness of the comparison due different factors, which are not co-existing in the two cities.

The elements such as Fe, Cu, Zn and Mn in Dar es Salaam are contributions from industrial and soil activities. The levels of these elements depend on how much soil was covered by vegetation as well as the wind direction for which the values depend very much on the month of collection, which have weather variations. The combustion elements of Pb and Br for the Dar es Salaam stations depend very much on the sampling sites and time. For example, the high levels of Pb originating from combustion are mainly during the daytime when you have high traffic intensity.

In all, it must be appreciated that Kinshasa, Butare and Dar es Salaam are cities with several sources of pollution which are not comparable. The cities have different types of industries, and land formation, different seasons and other different environmental factors. Nevertheless, the table of the three cities provides an insight on the apparent levels observed at different places.

Monthly variations of elemental concentrations in the aerosol samples

The high concentrations of Ca, Fe, and Cu in Dar es Salaam are due to local air pollution from soil and industrial effluents passing over the sampling sites, whereas some levels appear to be added apparently due to transport over long distances. Here we refer to short transport as that from localized source and a long-range transport as from a long distance air mass movement regional (East Africa), and occasionally intercontinental (outside East Africa) . The continuous changing of wind directions result into mixing of aerosol from different parts and therefore continuously affecting their concentrations. Hids (1982) report on the chemical composition of the coarse particle mostly

Al, Si, Ca and Fe originating from soil and the finer particles containing mostly, sulfur and lead from combustion source, similar to those suggested by Lawson (1980), Gladney *et al.* (1974), Paciga and Jervis (1976), Koleleni (1990) and Loo *et al.* (1995). Figures 1 to 9 show monthly fluctuations for the minimum and maximum elemental composition for all aerosol collection months from August 1996 to May 1997.The fluctuations are due to a number of reasons. These are partly due meteorological monthly changes such as wind movements at different speeds and in different directions. It could also be due to the differences in sampling locations for which the levels are changing with the surrounding environment. It is also due to influences of variations of distances from the polluting sources. The wind also pass over the polluting sources and picks the particles and deposit them in other places and thus contributing to the increase in levels.

Figure 1: The minimum and maximum elemental concentrations in August 1996

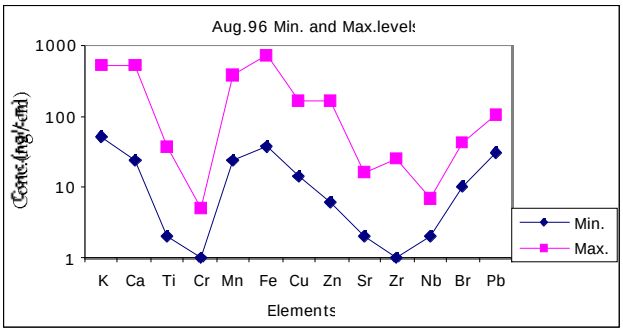
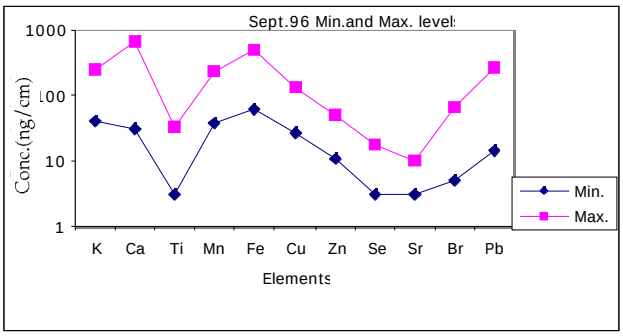


Figure 2: The minimum and maximum elemental concentrations in September 1996



The high maximum values are observed for elements like K, Ca, Mn, Fe, Cu, Zn and Pb and low minimum values of Ti, Cr, Sr and Zr in August 1996 and September 1996. The values of the same elements are much lower in October 1996 and December 1996. The reason was due to variations in wind speeds fluctuating between 10 and 20 m/s and directions changing from North Easterlies to South Easterlies. The months of March 1997 and April 1997 have undetected Ti, Cr and Mn levels in the air. Sr, Br and Pb for these two months are also low. This was due to rainy season whereby some aerosol particles coagulate with raindrops and fall down because of gravity. In April 1997, rainfall was between 5 mm and 22 mm, May 1997 rainfall amounted to 5 mm on 3rd day, 5 mm on 4th day and 2 mm on 13th day, 32 mm on 17th day, 30 mm on 18th day and between 5 and 15 mm on 23-30th day.

Figure 3: The minimum and maximum elemental concentrations in October 1996

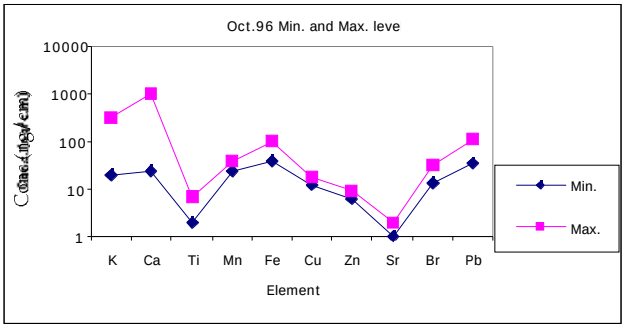


Figure 4: The minimum and maximum elemental concentrations in December 1996

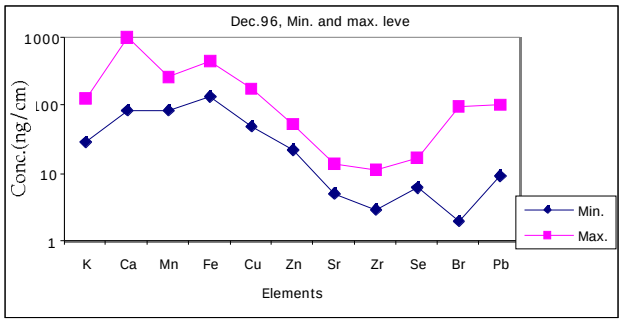


Figure 5: The minimum and maximum elemental concentrations in January 1997

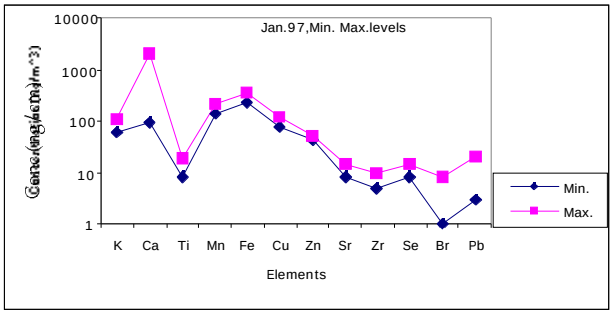


Figure 6: The minimum and maximum elemental concentrations in February 1997

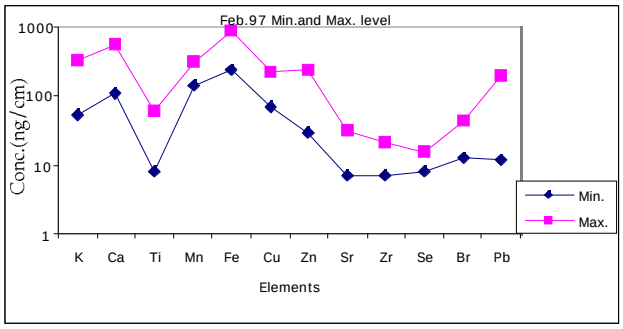


Figure 7: The minimum and maximum elemental concentrations in March 1997

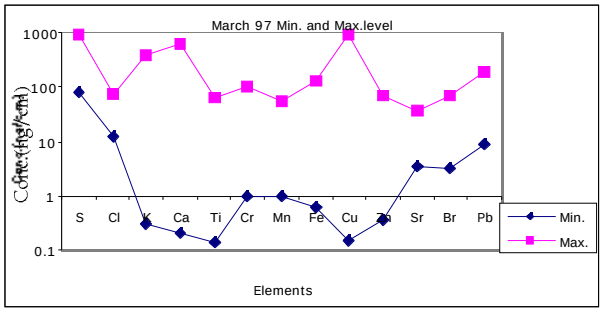


Figure 8: The minimum and maximum elemental concentrations in April 1997

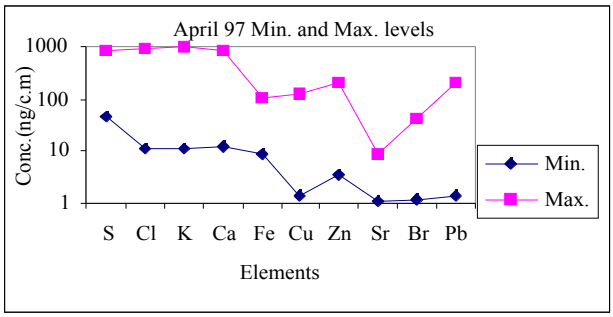


Figure 9: The minimum and maximum elemental concentrations in May 1997

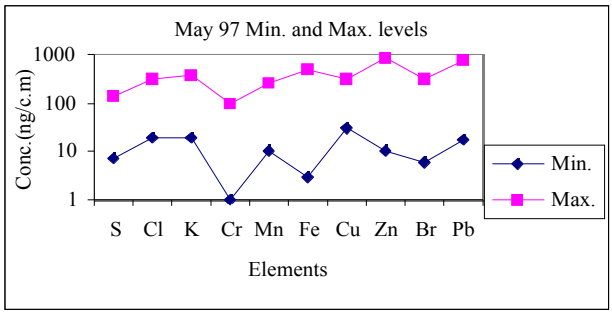
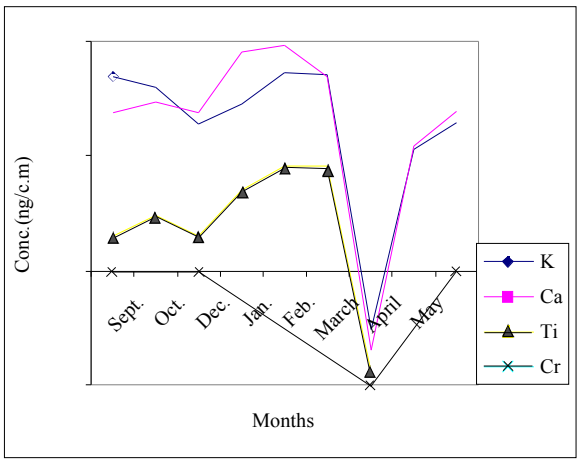


Figure 10: The monthly minimum elemental concentrations of K, Ca, Ti and Cr



The concentrations of elements like K, Ca, Ti and Cr have their monthly minimum shown in Figure 10 and maximum shown in Figure 11. The minimum concentrations of K, Ca and Ti are varying in the same way (Figure 10), which indicate variation of polluting sources purely affected by the sampling areas.

The elemental monthly maximum concentrations for Ca, K, Ti and Cr are shown in Figure 11. Except for K and Ca, elements like Ti, Cr and Mn were absent in April 1997. These elements could have been cleared from the atmosphere by rainwater. Some elements like Ca peaks up at the months of August 1996, February 1997 and May 1997 simply because of the influence of the sampling position of TOL. Ca is abundant as industrial raw material used in the factory.

The minimum levels of Mn, Fe, Cu, Zn, Sr and Zr are shown in Figure 12. These elements vary in the same way between August 1996 and February 1997. In March 1997, there was a sudden drop of minimum levels of these elements because of influence of rain and vegetation. The monthly maximum levels for these elements are shown in Figure 13.

Figure 11: The monthly fluctuation of K, Ca. Ti, Cr and Mn maximum levels

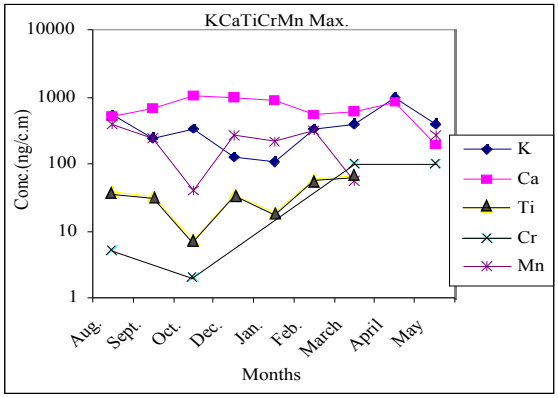


Figure 12: The monthly fluctuation of Mn, Fe, Cu, Zn, Sr and Zr minimum levels

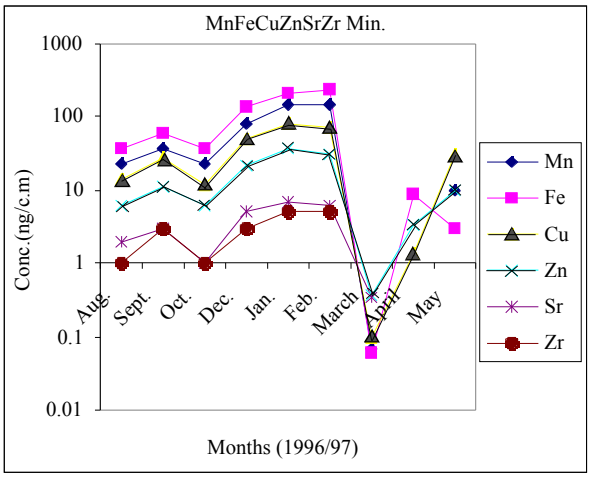
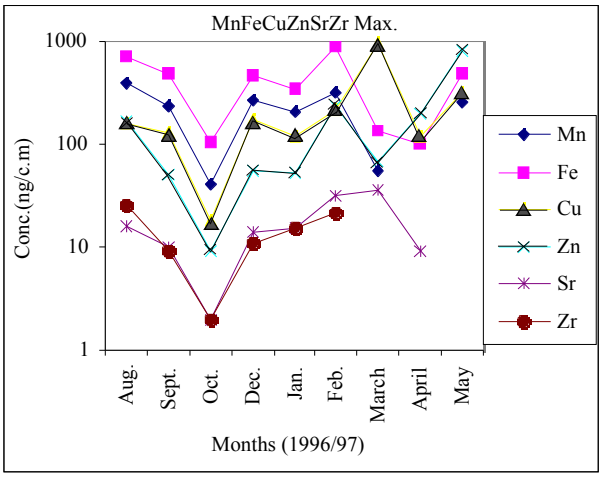


Figure 13: The monthly fluctuation of Mn, Fe, Cu, Zn, Sr and Zr maximum levels



These elements are sometimes originating from more than one source of pollution such as industries, eroded soil and marine activities. Air movements may transfer some pollutants from one area to another (Oblad, 1986; Koleleni, 1977; Oblad and Selin, 1985; Larsson and Oblad, 1984). The low concentration values are observed for elements such as Mn, Fe, Cu, Zn, Sr and Zr in the month of October 1996 and April 1997 (Figure 13) at ORCRI, which is slightly far from the industrial areas but close to the port entry. The drop in concentration may be a result of differences in the sampling times where each sample was collected for a period of 24 hours, monthly changes of sampling stations rotated from TOL, DIA and ORCRI as well as variation in meteorological conditions. A high maximum concentration levels of Mn, Fe and Cu (Figure 13) are observed in TOL, the sampling station close to industrial area where sampling took place in August 1996, February 1997 and May 1997.

Figure 1 and Figure 2 show that K and Ca in August 1996 and September 1996 have similar trends. The concentration of Ti was lower in August 1996 compared to September 1996 while the concentration of Mn, Fe, Cu, Br, Pb and Sr show similar trends for the two months. However, small amounts of Cr appear in August 1996 and May 1997 and not in any other month. The months of October and December 1996 show similar trends as those of August and September 1996 with only the difference that in the latter, the values go down by 10%. January 1997 had a similar pattern as February 1997 with former months values down by 10% that of latter. March and April 1997 look similar in pattern. However, elements like S, Cl, K, Ca, have higher values of order of 10% that of April 1997 while minimum levels of Br and Pb are lower by the factor of 10% that of April 1997. Values of March and May 1997 for Sr, Br and Pb are very close. The variation is due to differences in collection seasons and sampling sites.

The presence of sulphur, bromine and lead are result of fuel combustion and are examined by their correlation. Apart from Br and Pb, fuels often contain vanadium and nickel (Hansson, 1983). The concentrations of V and Ni vary somewhat depending on the origin of the oil. The sulphur emissions are mainly in the form of sulphur dioxide gas which is gradually converted to sulphates at a rate dependent on the pollution level, and typically in the range of 0.1 to 10% per hour (Bouland *et al.*, 1978; Calvert *et al.*, 1978; Harrison *et al.*, 1983 and Lannerfors *et al.*, 1983).

El-Shabokshy *et al.* (1990) provides values of elemental concentrations for S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Br and Pb for the City of Riyadh. Oblad and Selin (1986) presents concentrations of the same elements for two cities of Sweden and Maenhaut *et al.* (1981) for the Atlantic Ocean. The general trend appears to show that Riyadh has higher values of concentration than the rest of the cities for all the elements. This may be due to high elemental contents of rocks and sands in the desert with strong wind influences. In the Oblad and Selin (1986) presentation, the two cities within same countries one has relatively higher values compared to the other but both very low compared to Riyadh. Scheff and Valiozis (1990) measured the same elemental values for Athens, Greece and provided values, which are by factor of 10 less than that of Riyadh, Saudi Arabia. In general, the values obtained by other authors compared to this work in Dar es Salaam for TOL, DIA and ORCRI show that pollution levels in Dar es Salaam is between that of Saudi Arabia and that of the City of Athens. The Athens values are relatively higher than what is recorded by Maenhaut *et al.* (1981) for Atlantic

Ocean. However, the comparisons are very superficial since the meteorological and environmental conditions of these countries are completely different.

Samples collected from DIA, TOL and ORCRI show significant amounts of S, Cl, K and Ca higher in ORCRI than other places due to sea spray (Morales *et al.* 1990; Weisel *et al.* 1984). Coarse particles can easily settle on the ground due to their mass while fine particles may be blown up to very far distance for the same reason. The concentrations of coarse particles may be higher than that of fine particles for the localised particles. The concentrations of fine particles may for that matter be higher as it may be a combination of localised and distant sources.

The first and last five days of December 1996, rain amounted to between 1 and 5 mm. The aerosol samples were collected from Dar es Salaam International Airport (DIA) and the temperature registered ranged between 25°C early in the morning and about 32°C in the afternoon.

There was rain in January 1997 on the ninth day amounting to 1.7 mm while the temperature averaged to 26°C in the morning and 32°C in the afternoon. Sampling during the month of January was at Ocean Road Cancer Research Institute (ORCRI).

There was no rainfall in February 1997 except on the eighth day which amounting to 0.3 mm^3 and the temperature averaged to 24°C in the morning and 32°C in the afternoon. At the Tanzania Oxygen Limited (TOL) sampling center Ca is among the raw material used in the factory and therefore influences the aerosol content of this element. For the same station, Fe and Mn which are associated as natural composition of soil and are introduced to the atmosphere by soil erosion and human activities (Parekh and Husain, 1981). The aerosol amounts in DIA could mainly originate from vegetation, aeroplanes and vehicles. The elements of Cu, Zn, Pb and Br are mainly related to fine particles emitted by anthropogenic activities. These originated from industrial activities and transport (Pb and Br are common in all and are result of fuel effluents) and their contributions to the atmosphere seem to be higher than that produced by natural sources (Nriagu, 1979; Pacyna, 1986). Although many times the amount of the fine particles depends very much on the wind direction, the traffic intensity and how close the sampling site is from the bare soil.

The measured concentrations of heavy metals were implicated to road, air and sea traffic. The leaded gasoline is the main cause of Pb and Br (Nriagu, 1990, Metternich *et al.*1981; TIPPER, 1999). On the question of levels of other elements (Li and Winchester, 1990; Thurston and Spengler, 1985; Infante *et al.* 1990; Parekh, 1990; Maenhaut *et al.* 1981; El-Shobokshy *et al.* 1990; Abu-Hilal and Badran 1990; Lee, 1990; Leland *et al.* 1987) did aerosol research and their conclusions were based on the temporal evolution of the anthropogenic components in the atmosphere and found abundance in elements such as Si, S, Cl, K, and Ca. Measures for planting trees and grasses to cover the soil as well as using irrigation to water the soil may change the aerosol contents especially that result from natural emissions such as erosions and drying vegetation. This is so because the analysis showed a good linear correlation between Mn and Fe, indicating that anthropogenic Mn and Fe were coming from the soil rich in the two elements. Sweeping the tarmac roads may reduce elements such as Ca, K, Fe and Mn, which show high levels of inhalable fine particles that could easily be picked by moving wind and introduced to the atmosphere.

In future when a number of impactors together with their meteorological facilities are simultaneously placed in different stations, air mass trajectories would be used to interpret the observed aerosol concentration in terms of atmospheric transport regionally or internationally. A striking resemblance is seen in many of the features of the time variability patterns at different sampling stations in all periods between August 1996 and September 1996 and December 1997 to May 1997. The different sites show concentrations, which are initially low and later peak up to higher values. This is due to air mass trajectories originating from certain parts with high concentration sources. The Br and Pb elements resulting from burning fuel are shown in Figure 14 and Figure 15 for minimum and maximum levels. The Br and Pb form a similar pattern with values of Pb being higher than that of Br and therefore making the ratio of the two constant.

Figure 14: Variation of the minimum Br and Pb levels between August 1996 and May 1997

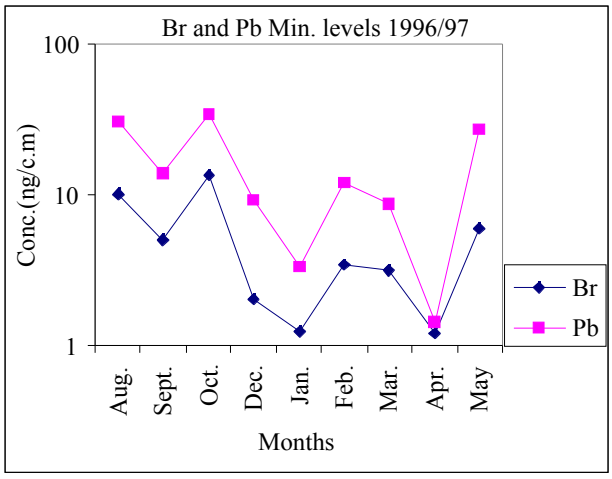
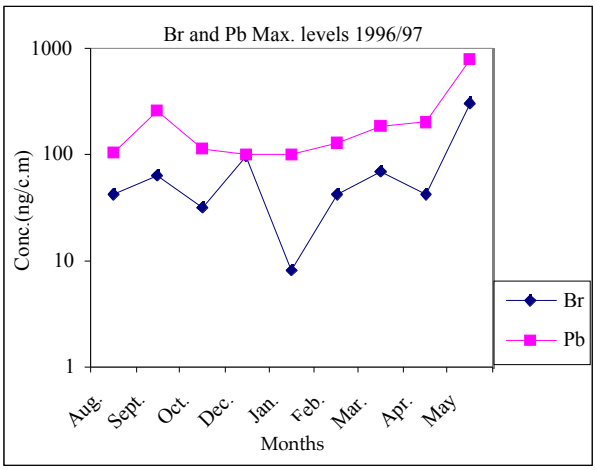


Figure 15: Variation of the Maximum Br and Pb levels between August 1996 and May 1997



The Br and Pb composition normally originate from the addition of the lead bromide compound to the automotive fuel to facilitate the ignition of the engine. This constitutes to what is known as the ethyl ratio of Br: Pb concentration. The ratio which has a fixed value of 0.386 from the added compound (Oblad, 1986; Oblad and Selin, 1985; Harrison and Sturges 1983; El_Shobokshy *et al.,* 1990; Parekh and Hussein, 1981) and therefore confirmation of the source when the ratio is checked. When individual values for different stations are compared, roughness and the meteorological conditions sometimes affect this ratio. In our case, the ratio varied between 0.200 and 0.400. According to earlier established results (Oblad 1986; El-Shobokshy *et al.,*1990; Koleleni, 1998; Alves *et al.,* 1998) for the road cases lead airborne emissions agglomerate rapidly into heavier particles and most tend to settle near their point of emissions, usually along highways and streets. It is also noted that except for TOL and DIA stations, ORCRI has values of Br slightly higher than the rest of stations at lower levels. The ORCRI is right at the beach of Indian Ocean and therefore influence of the sea bromide salts could be another contributing factor.

Conclusion

The combination of the dichotomous impactor for sample collection and the EDXRF technique for sample analysis has made the aerosol studies possible for determination of daily values of K, Ca, Ti, Mn, Fe, Cu, Zn, Se, Sr, Br and Pb. The data obtained have been compared to the minimum and maximum values of these elements for months of August, September, October and December 1996, January, February, March and May 1997. The values obtained in Dar es Salaam were campared with literature values for Kinshasa and Butare. It's absolutely incomparable because of the different conditions of the environments of the three cities but still it gives a picture of the levels one can expect from the different cities. The variation in composition is affected by seasons as well as change of polluting sources like human activities on dry soil and vegetation, which constitute to high aerosol contents. In the month of December 1996 there were light rain showers, which contributed to both settling down of the aerosol from the atmosphere to the ground. The rain also facilitated the growth of vegetation, which in a way reduces aerosol from the topsoil.

Acknowledgement

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Influence of Irrigation and Fertilisation on Early Growth of *Eucalyptus grandis*

Janine M. Campion[1] and Mary C. Scholes

School of Animal, Plant and Environmental Sciences, University of Witwatersrand, P Bag 3, Wits, 2050, South Africa

[1] Current address of author for correspondence: janine@icfr.unp.ac.za

Abstract

A field experiment was initiated in the Natal midlands to determine the influence of irrigation and fertilisation on the growth of *Eucalyptus grandis*. The experimental design consisted of an untreated control, irrigation, fertilisation, and irrigation and fertilisation treatments. Foliar nutrient dynamics were used to optimise fertilisation practices. Treatment effects were apparent in the measured growth parameters. The irrigated and fertilised treatment exhibited the greatest height, diameter (at ground line and at breast height), and canopy volume in seventeen-month-old trees. The same treatment ranking was observed in the height and ground line diameter values, in the order which yielded the greatest response: irrigated and fertilised, control, fertilised, and irrigated. Poor early growth may have resulted from intense weed competition or severe damage by animals. As consistent increases in the growth parameters occurred in all treatments over time, and it is anticipated that these responses will be maintained as the canopy develops.

Key words: Fertilisation, irrigation, foliar nutrient dynamics, *eucalyptus grandis*

Résumé

Une expérience en milieu réel a été entamée dans les Midlands (région de moyenne altitude du Natal, Afrique du Sud) afin de déterminer l'influence de l'irrigation et de la fertilisation sur la croissance des *Eucalyptus grandis*. Les traitements appliqués étaient: l'irrigation, la fertilisation seule, l'irrigation plus fertilisation de même qu'un témoin. La dynamique nutritive foliaire a été employée afin d'optimiser les procédés de fertilisation. Les effets des traitements étaient évidents pour les paramètres de croissance étudiés. Le traitement irrigation plus fertilisation a montré des meilleures valeurs de la taille, le diamètre au collet, le diamètre à la hauteur de la poitrine et le volume du feuillage au sein des arbres âgés de dix-sept de mois. On a observé les mêmes effets pour le diamètre au collet et la taille au sein des autres traitements. Ainsi, par ordre décroissant, la plus grande réponse a été observée pour le traitement irrigation plus fertilisation, témoin, fertilisation seule et enfin irrigation seule. La faible croissance observée au début de mise en place des essais pourrait être attribué à la concurrence intense des jeunes plants avec des mauvaises herbes ou aux dégâts graves provoqués par des animaux. Étant donné qu'une augmentation uniforme des paramètres étudiés de croissance a été remarquée au sein de tous les traitements tout le long de la période d'observation, on peut s'attendre à ce que ces réponses seront maintenues au cours du développement ultérieur du couvert forestier.

Mots clés: Fertilisation, irrigation, dynamique nutritive foliaire, *eucalyptus grandis*

Introduction

South Africa has a plantation area of 1.4 million hectares, which represents 1.1% of the land area (DWAF, 2003). A total volume of 16.6 million cubic metres of roundwood was produced from these plantations over the period 2001/2002 (DWAF, 2003). The projected consumption for 2020, however, is calculated to approximate 37.1 million cubic metres. Utilising more land for wood production would increase supply (Brown and Hillis, 1984) but this expansion may be limited by many restrictions such as permits, availability of suitable land and water issues (Dye, 1999). Improving the productivity of new and re-established plantations can partially compensate for the deficit in new afforestation (Schönau, 1983). Fertiliser application is one of the most cost-effective methods of economically improving and maintaining the productivity of commercial plantations (Schönau, 1983; Herbert and Schönau, 1989).

Eucalyptus grandis Hill ex Maiden, which is indigenous to Australia (Grut, 1965), is the most widely planted hardwood in South Africa and accounts for approximately 21% of the total plantation area (DWAF, 2003). The harvested tree stump of *E. grandis* coppices to form second and more crops, which are normally harvested between seven and ten years (The South African Forest Owners Association, 1997). Schönau (1983), Schönau and Herbert (1989) and Herbert and Schönau (1989, 1990) have extensively reviewed the development of fertiliser research applied to trees at planting in southern Africa. These studies indicated that *E. grandis* responded mainly to phosphorus (P) during the first 18 months after fertiliser application. An additive response was evident when nitrogen (N) was combined with P (Schönau and Herbert, 1989).

Response to fertilisers included rapid colonisation of the soil by the roots, improved survival, rapid canopy closure and suppression of weeds, a more homogeneous stand and increased yields at harvesting (Herbert, 1985).

Available moisture and nutrients strongly influence plantation forest growth, as these are the most common factors which limit productivity (Brown *et al*., 1997). Generally, nutrient limitations are overridden by climatic restrictions, as even trees in a very fertile soil will not grow under limited water supply or when temperature is unfavourable (Landsberg and Waring, 1997). Soil moisture, nutrients, organic matter, effective rooting depth, quality of seed and nursery material, site preparation and vegetation control are deemed by Schönau and Herbert (1989) to be the main components influencing stand development of *Eucalyptus* plantations. Of these, soil moisture and nutrients are regarded as being the most important (Schönau and Herbert, 1989).

As extreme nutritional disorders are uncommon, fertiliser is applied to optimise conditions for growth (Herbert, 1996). Nutrient optimisation involves the repeated additions of nutrient elements relative to N. Nitrogen regulates the development of foliage, which controls the amount of plant production and therefore the extent of wood increment (Schönau and Herbert, 1989). Many long-term studies have aimed to determine the effects of 'near-optimal' nutrient and water availability on the growth of trees such as *Pinus radiata* in Australia (Linder *et al.*, 1987), *Eucalyptus globulus* in Portugal (Pereira *et al.*, 1989; 1992), *Pinus taeda* in North Carolina, USA (Albaugh *et al.*, 1998) and *Picea abies* in Sweden (Bergh *et al.*, 1999). These types of experiments enable a relationship to be established between tree nutrition and forest yield (Linder, 1995). In all experiments, the greatest volume yields and best growth in terms of height and diameter values were obtained from trees where the availability of nutrients and water was optimised.

A similar type of field trial was set up near New Hanover, KwaZulu-Natal, South Africa. The project aimed to determine the influence of irrigation and fertiliser application on the growth of *E. grandis*. Two hypotheses were formulated. (1) As a result of climatic limitations outweighing nutrient deficiencies, growth would be high on the irrigated treatment, but because of a synergistic effect, maximum growth would be attained on the irrigated and fertilised treatment. (2) By diagnostic foliar analyses, the proportions of elements relative to N could be manipulated and improved.

The purpose of acquiring these results was to demonstrate potential forest yields by adjusting nutrient and water supply to uptake requirements.

Materials and Methods

Site Description and Experimental Design

The experiment was conducted at Came Farm, near New Hanover, KwaZulu-Natal. Site description and stand characteristics are as presented in Table 1. The previous *Eragrostis curvula* pasture was removed and in November 1998, the site was sprayed with Roundup (4 R ha^{-1}) and the land was ripped to a depth of 400 mm. Thereafter the site was rotavated (1200 mm wide) and pitted with a 500 x 250 mm standard pit on a centre ripline. Two-month-old *Eucalyptus grandis* seedlings were planted in March 1999 at a 3.0 x 2.0 m espacement. All trees were manually ring cleaned and weed growth was slashed in April and October 1999, when the site was re-sprayed with Roundup (4 R ha^{-1}). The experiment covered a total area of 6.5 ha and consisted of sixteen 54 x 75 m plots each containing 675 trees and an internal measurement plot containing 30 trees. At least three blanking procedures took place within the internal measurement plots, and all blanked trees were eliminated from further analyses.

Treatments

The experimental design consisted of an untreated control (C), irrigation (I), fertilisation (F) and irrigation and fertilisation (IF) treatments, each replicated four times. These treatments aimed to eliminate both water (I and IF), and nutrients (F and IF) as growth-limiting factors. The plots were laid out in four non-randomised but balanced blocks. The irrigated treatments, initiated in April 1999, were irrigated to 70% of the field capacity, and fertiliser treatments were applied according to recommendations as a result of foliar analyses. Nitrogen was applied to F and IF trees in the form of limestone ammonium nitrate (LAN) in July 1999 and April 2000, at rates of 17 and 50 kg ha^{-1} respectively.

Growth Measurements

Tree height, diameter and canopy volume were measured monthly. Diameter was measured both at 5 cm, ground line diameter (gld) and at 1.3 m, diameter at breast height (dbh). The latter measurements commenced in March 2000, when the average tree height of the internal plots measured approximately 2.7 m. Canopy volume was calculated using the formula of a spherical cylinder:

Volume = $\pi r^2 h$, where $\pi = 3.14$, r^2 = (canopy radius squared), and h = canopy height.

Canopy height was measured from the lowest live branch on the stem to the shoot apex. Canopy radius was calculated from the canopy diameter (distance measured from the centre of the stem to the two furthest leaves on each side of the stem).

Foliar Nutrient Concentrations

For the first nine months following planting, foliar samples were obtained by bulking all stripped leaves from six harvested trees per plot, as sufficient foliar material was required for nutrient analysis. From January 2000, approximately thirty of the most recent fully-formed undamaged leaves were collected at random from all sides of the top third of the crown of each of six trees per plot. The foliar material was placed in paper bags and packed in cool boxes for transportion to the laboratory. Foliar material was oven-dried at 60°C and the bulked samples from each plot were sent to the ICFR (Pietermaritzburg, KwaZulu-Natal) for foliar nutrient analysis. Total N was determined by Kjeldahl digestion and titration (Donkin *et al.*, 1993). Following ashing, samples were analysed for phosphorus (P) and boron (B) (segmented flow autoanalyser), calcium (Ca), magnesium (Mg), manganese (Mn), iron (Fe), zinc (Zn) and copper (Cu) (atomic absorption spectroscopy), and potassium (K) and sodium (Na) (flame emission spectroscopy) (Donkin *et al.*, 1993).

Statistical Analyses

All data was subjected to a 2 x 2 factorial analysis of variance (ANOVA), using the Statistical (Statsoft, 2000) package to test for any significant ($p < 0.05$) treatment effects. Post-ANOVA testing was carried out by means of a Tukey HSD test.

Results

Stand characteristics

The experiment was carried out on a highly weathered acid mineral soil ($p^H(KCl) = 4.1$) with a silty clay loam texture (Table 1). The soil contained a relatively high percentage of organic carbon and total N (4.2% and 0.3% respectively), and the available P concentration was also high (11.5 mg kg^{-1}). The exchangeable cations (cmol (+) kg^{-1}) were present in similar concentrations measured for soils in the same region as the New Hanover trial. The Ca (2.40) and K (0.12) contents fell within the reported ranges of 1.40 - 4.80 and 0.03 - 0.88, respectively (Schönau, 1981). A lower Mg concentration (0.60) was measured in this experiment in comparison to values of 1.00 - 3.60, whereas higher levels of Na (0.13) were quantified, relative to concentrations ranging from 0.00 - 0.05. A silty clay loam textured soil allows excellent retention of nutrients and water (White, 1979). It was expected that this well-structured soil will not only drain adequately, but will also hold sufficient nutrients and water for plant growth.

Table 1: Site description and stand characteristics, with physical and chemical properties of the surface soil (0 - 20 cm).

		Site description	
Location		Came Farm, New Hanover, KwaZulu-Natal	
Latitude/longitude		29°14′ S / 30°33′ E	
Altitude		1260 m above sea level	
Previous vegetation		*Eragrostis curvula*	
Planting date		March 1999	
Stocking (stems ha^{-1})		1667	
		Soil properties	
Field capacity (%)[a]	37.6	Available P (mg kg^{-1})[f]	11.5
pH(KCl)[b]	4.1	Na (cmol (+) kg^{-1})[g]	0.13
Particle size	35/49/16	K (cmol (+) kg^{-1})[g]	0.12
(% clay/silt/sand)[c]	Silty clay loam	Ca (cmol (+) kg^{-1})[g]	2.4
Organic C (%)[d]	4.2	Mg (cmol (+) kg^{-1})[g]	0.6
Total N (%)[e]	0.3		

a Estimated in situ (Anderson and Ingram, 1993)
b 1:2.5 suspension of soil in extractant
c Hydrometer
d Walkley Black
e Digestion
f P-Bray 1
g Ammonium acetate

b-g Soil samples analysed by the Institute for Soil, Climate and Water (Pretoria) following the Handbook of Standard Soil Testing Methods (1990).

Climatic data

Climatic data relevant to the site are presented in Table 2.

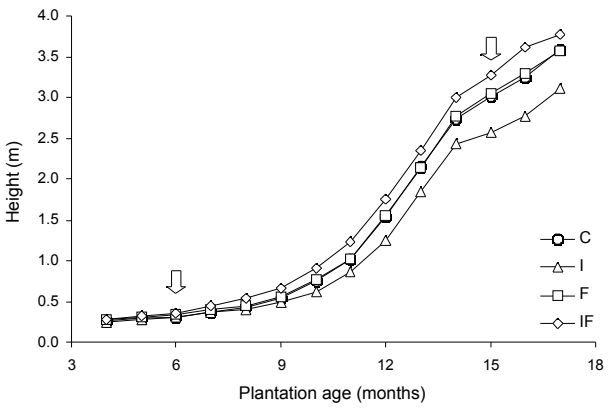
Table 2: Monthly climatic data obtained from a meteorological station situated at 29° 36′ S, 30° 26′ E, for the period 1961 - 1990

Months	Mean min. temp (°C)	Mean max. temp (°C)	Mean rainfall (mm)
January	17.5	28.2	141
February	17.4	28.2	117
March	16.3	27.8	113
April	12.4	26.1	48
May	7.3	24.2	24
June	2.9	22.3	13
July	3.1	22.7	11
August	6.2	23.7	31
September	10.4	25.0	60
October	12.6	25.2	74
November	14.7	25.8	104
December	16.4	27.0	108
Total	11.4	25.6	844

The hottest months are January and February, with maximum temperatures approaching 30°C, compared to the coolest months (May through August), where minimum temperatures drop well below 10°C. Seasonal summer rainfall occurs in this region, as indicated by the average monthly figures where the wettest months occur from November to March, compared to the drier winter months of June and July. An average rainfall of 844mm yr^{-1} was recorded for this area over the period 1961 - 1990, but South Africa as a whole receives only 560mm per year and as such, there is intense competition for this limited resource (Olbrich *et al.*, 1993).

Stem height

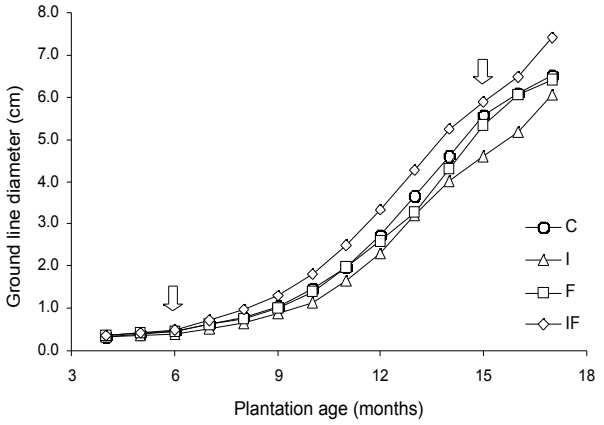
Figure 1: Cumulative height growth of *Eucalyptus grandis* under various treatment regimes, C = control, I = irrigation, F = fertilisation, and IF = irrigation and fertilisation. Values presented represent the mean height in each treatment, which is the average of the four blocks. Arrows indicate fertilisation events.



The increase in stem height of *E. grandis* from time of planting until 17 months of age is depicted in Figure 1. The heights measured at this time were 3.6 (C), 3.1 (I), 3.6 (F), and 3.8 m (IF). Treatment effects were not significant.

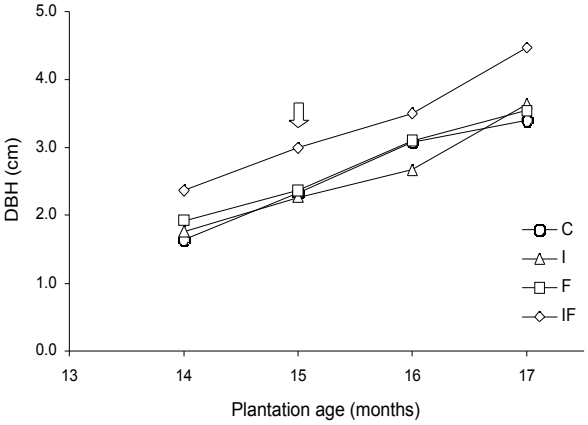
Stem diameter

Figure 2: Accumulative stem diameter at ground line of *Eucalyptus grandis* subjected to different treatments. Values presented represent the mean diameter in each treatment, which is the average of the four blocks. Arrows and abbreviations as for Figure 1



Stem diameter at ground line increased continuously until 17 months of age, where respective values of 6.5, 6.0, 6.4, and 7.4 cm for the C, I, F and IF treatments respectively were measured (Figure 2).

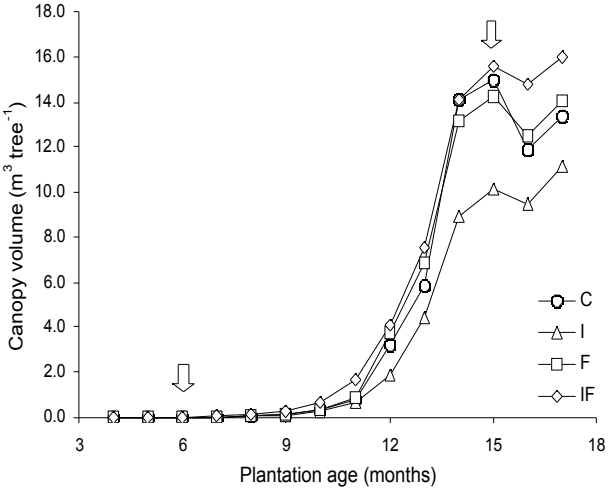
Figure 3: Increase in *Eucalyptus grandis* stem diameter at dbh, aged 14 to 17 months. Values presented represent the mean dbh in each treatment, which is the average of the four blocks. Arrows and abbreviations as for Figure 1.



The dbh of 17-month-old *E. grandis* trees was 3.4, 3.6, 3.5, and 4.5 cm for the C, I, F, and IF treatments, respectively (Figure 3). No significant treatment effects were observed in either the gld or the dbh values.

Canopy volume

Figure 4: Cumulative canopy expansion of *Eucalyptus grandis* subjected to various treatments. Values presented represent the mean volume in each treatment, which is the average of the four blocks. Arrows and abbreviations as for Figure 1.



There was a steady increase in the canopy volume in all treatments until 15 months of age (Figure 4). At this time, values of 15.0, 10.1, 14.2, and 15.6m^3 tree^{-1} were measured for the C, I, F, and IF treatments, respectively. A decrease in the canopy volume across all treatments occurred over the period 15 to 16 months: 15.0 - 11.9 (C), 10.1 - 9.5 (I), 14.2 - 12.5 (F), and 15.6 - 14.8m^3 tree^{-1} (IF), but were observed to increase again thereafter. Treatment effects were not significant.

The foliar nutrient concentrations and their ratios of one-year-old trees, presented in Table 3, were within the encountered ranges documented by Herbert (1996). The Mn concentration in the I treatment was significantly lower (p=0.005) than that measured in the control. The N:P, N:K, P:K and Ca:Mg ratios in all treatments were found to approach the optimum. In comparison with Linder (1995) however, the P and K concentrations were in limited supply. This author defines an optimal N status in the foliage, and then defines target values for each nutrient element relative to N (Table 4).

Foliar data

Table 3: Foliar nutrient concentrations and some of their ratios (mean and standard deviation) for one-year-old *E. grandis*, together with their optimum values and encountered ranges in South Africa. The different treatments are control (C), irrigation (I), fertilisation (F), and irrigation and fertilisation (IF).

Foliar Nutrient or Ratio	Units	KwaZulu-Natal Study				Comparative values (Herbert, 1996)		
		C	*I*	*F*	*IF*	*Opt*	*Min*	*Max*
N	%	3.45 (0.14)	3.51 (0.13)	3.45 (0.13)	3.42 (0.12)	2.8	1.25	3.35
P	%	0.20 (0.01)	0.21 (0.01)	0.19 (0.03)	0.21 (0.01)	0.15	0.10	0.35
K	%	0.99 (0.09)	0.78 (0.11)	0.85 (0.06)	0.90 (0.18)	0.75	0.36	1.19
Ca	%	1.01 (0.11)	0.96 (0.06)	1.06 (0.08)	0.99 (0.14)	>1.0	0.56	1.82
Mg	%	0.22 (0.02)	0.24 (0.02)	0.23 (0.02)	0.23 (0.02)	0.35	0.21	0.62
Na	%	0.25 (0.00)	0.29 (0.04)	0.23 (0.05)	0.28 (0.09)	0.32	0.11	0.46
Mn	ppm	807.25 (150.07)	556.25 (106.29)	699.50 (91.90)	591.00 (40.98)	600	129	6005
Fe	ppm	78.00 (9.70)	71.50 (4.43)	71.00 (8.83)	71.75 (1.26)	110	52	1021
Zn	ppm	35.25 (7.14)	35.25 (3.40)	37.25 (10.72)	33.75 (3.69)	18	8	32
Cu	ppm	12.75 (1.71)	13.50 (1.91)	11.00 (0.82)	12.25 (0.96)	12	2	26
B	ppm	21.50 (3.00)	20.25 (1.71)	22.25 (2.06)	19.00 (1.41)	32	15	47
N:P		17.56 (1.75)	16.98 (1.67)	18.66 (2.57)	16.11 (0.79)	18	3.0	28.6
N:K		3.51 (0.38)	4.58 (0.60)	4.09 (0.30)	3.91 (0.67)	3.5	1.0	5.4
P:K		0.20 (0.03)	0.27 (0.05)	0.22 (0.03)	0.24 (0.05)	0.2	0.093	0.620
Ca:Mg		4.71 (0.71)	3.95 (0.21)	4.54.40 (0.08)	(0.32)	>3.3	1.24	7.28

Table 4: Foliar nutrient concentrations and ratios of one-year-old *E. grandis*, compared to target values used as optimal in one-year-old Norway spruce (Linder, 1995). Nitrogen [N] is presented as mg g^{-1}, and other nutrient elements as per cent of nitrogen. Abbreviations as for Table 3

Nutrient	Target	C	I	F	IF
N (mg g^{-1})	[28]	34.5	35.1	34.5	34.2
P (% of N)	10	5.7	5.9	5.4	6.2
K (% of N)	35	28.7	22.1	24.5	26.2
Ca (% of N)	2.5	29.1	27.2	30.8	29.0
Mg (% of N)	4	6.2	6.9	6.7	6.6
Mn (% of N)	0.05	2.34	1.59	2.03	1.73
Fe (% of N)	0.2	0.23	0.20	0.21	0.21
Zn (% of N)	0.05	0.10	0.10	0.11	0.10
Cu (% of N)	0.02	0.04	0.04	0.03	0.04
B (% of N)	0.05	0.06	0.06	0.06	0.06

The N concentration in all treatments in the KwaZulu-Natal trial was greater than the target value of 28 mgg^{-1} (Table 4). The P and K concentrations were interpreted as limiting, as the levels of these elements relative to N were lower than the target values of 10 and 35, respectively. The other nutrients were considered as being in adequate supply, as these ratios exceeded the target levels recommended by Linder (1995).

Discussion

In an optimisation study of *Eucalyptus globulus*, the combined irrigation and fertilisation treatment resulted in the greatest rate of height growth, compared to irrigation or fertilisation, which alone also improved growth relative to the control, but irrigation produced a larger response than fertilisation (Pereira *et al.*, 1989). Similar treatment effects were not observed in the height growth of *E. grandis*, but were evident in dbh values, as discussed below.

Fertiliser applied in factorial combination to four seedlots of *E. grandis* for three years resulted in a significant increase in the growth of mean height, compared to irrigation, where no response was evident, and no interaction between irrigation and fertilisation occurred (Cromer *et al.*, 1993). Similar results were obtained in this trial. The height of one-year-old *E. globulus* trees measured 2.1, 3.1, 2.6, and 3.5 m for the C, I, F, and IF treatments, respectively (Pereira *et al.*, 1989), compared to the notably lower values of 1.5, 1.3, 1.6, and 1.8 m for similar aged trees in this trial. The control treatment of 14-month-old *E. globulus* had mean heights ranging from 1.1 - 2.1 m, and from 1.4 - 2.4 m for the fertilised treatment (Judd *et al.*, 1996). Larger tree heights of 2.7 and 2.8 m were observed in similar aged *E. grandis* in the control and fertilised treatments, respectively. In a study assessing the effects of nutrient applications made to *E. grandis* at planting, performed by Carlson *et al.* (1998), ground line diameter measured in one-year-old control plots was 3.2cm, compared to 3.1cm in fertilised plots. In the KwaZulu-Natal trial, one-year-old C and F trees had gld values of 2.7 and 2.6cm, respectively. The trend observed in the height ranking was also displayed in the ground line diameter values. The dbh (cm) of 14-month-old *E. globulus* under 'near optimal' conditions was 2.0, 3.3, 2.7, and 4.0 for C, I, F, and IF, respectively (Pereira *et al.*, 1989). A similar treatment ranking was evident, but only in 17-month-old *E. grandis* trees.

The decrease in canopy volume resulted from a large number of trees dropping their lower branches. This phenomenon occurred at random throughout all the treatments, but was observed mainly in the taller trees. Dropping of branches was observed by Herbert (*pers. comm.*) in previous experiments with *E. grandis* during spates of rapid growth. Boron and Cu, important components of branching and lignification, could not be correlated with this phenomenon.

Herbert (1996) stated that a decrease in nutrient concentration does not necessarily result in poorer growth, as an increase in nutrient uptake does not always signify better growth. Rather, an overall balance of nutrients, i.e. where nutrient ratios approach their optimum levels, results in the best growth. Foliar analyses indicated a limitation of P and K when compared to the target values of Linder (1995). It is anticipated that the nutrient status of the trees can be further improved with the application of fertiliser following these diagnoses.

The height and diameter of the *E. grandis* trees were found to lie within the range quoted in other comparable studies. In some instances, however, these values were considerably lower than those cited in the literature. The many problems experienced at the site may have contributed to the poor performance of the trees thus far. Fertiliser was applied late, and heavy trampling from cows and browsing by small antelopes caused extensive damage to some areas. The presence of weeds created a problem throughout 1999, causing a marked competition in the establishment of the seedlings. If the maximum benefit from fertilising is to be reached, weed control should be sustained for nine to twelve months following fertilising, as *Eucalyptus* trees may show little or no response if post-fertiliser weeding is not effectively carried out (Herbert, 1985).

It was hypothesised that as a result of climatic limitations outweighing nutrient deficiencies, growth would be high on the irrigated treatments, but because of a synergistic effect, maximum growth

would be attained by trees that were both irrigated and fertilised. Maximum height, diameter (at ground line and at breast height), and canopy volume growth were attained in the IF treatment. The I treatment, however, exhibited very poor growth in comparison. As the foliar analyses did not reveal any major nutritional limitations, this may be attributed to a greater disturbance from animals, or to a higher presence of weeds.

Optimum responses to fertiliser application will only be attained if healthy nursery material is used, fertiliser is correctly positioned and weeds are properly controlled (Herbert, 1996). If this is ensured, the annual increase as a response to fertilising may not only be maintained until clear felling, but may increase over time (Herbert, 1985). Despite the early setbacks in the trial, it is envisaged that if the foliar nutrient concentrations (particularly P and K) relative to N can reach, and be maintained at their optimum levels, the trees will continue to grow at a rapid rate under conditions of increased water and nutrient availability.

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An Evaluation of Powder Obtained from Natural Sponge (*Luffa aegyptica* Mill) as a Disintegrant in Lactose Tablets

G. Alebiowu

Department of Pharmaceutics, Faculty of Pharmacy, Obafemi Awolowo University, Ile-Ife, Nigeria
E-mail:galebiowu@yahoo.co.uk

Abstract

The powder prepared from natural sponge *Luffa aegyptica* Mill family *Cucurbitaceae* was studied for its disintegrant activity with corn starch BP (CS) as the standard. The natural sponge powder (NSP) showed promising results considering the parameters used in evaluation i.e. weight uniformity, friability, tensile strength and disintegration time of tablets prepared for evaluation.

Key words: Luffa aegyptica, natural sponge powder, corn starch, lactose, disintegrant

Résumé

La poudre préparée à partir de l'éponge naturelle Luffa a*egyptica,* famille *Curcubitaceae* a été étudiée pour son pouvoir de désagréger l'amidon du blé BP, afin de l'utiliser comme matériel de référence. La poudre de l'éponge naturelle a montré des résultats prometteurs tenant compte des paramètres utilisés dans l'évaluation c'est-à-dire, l'uniformité du poids, la friabilité, l'élasticité et le temps de décomposition des comprimés préparés pour cette évaluation.

Mots clés: Luffa aegyptica, poudre de l'éponge naturelle, amidon de blé, lactose, matière désagrégeante

Introduction

Disintegrants constitute a category of excipients that usually must be incorporated in conventional tablets and starch is one of the most popular disintegrants (e.g. corn and rice starches). However, with the worsening food supply situation in most tropical developing nations and the attendant increase in the cost of staple foods, there is an urgent need to find substitutes for starch as a disintegrant in tabletting technology. Hence, the decision to undertake investigation on the effects of natural sponge as a disintegrant in tabletting using lactose as the base material and corn starch BP (CS) as standard disintegrant.

Natural sponge (*Luffa aegyptica* Mill), an agricultural weed of cultivated crops and a fibre is used in Nigeria for bathing and washing of cooking utensils. It is an annual herb, rough to touch, climbing by means of branched tendrils and reproducing from seeds. It is cultivated for its spongy endocarp (Akobundu and Agyakwa, 1987). The fibre consists mainly of cellulose (see test on cellulose below).

Materials and Methods

Materials

The materials used were lactose (A.B. knight and Co. London), corn starch BP, gelatin and magnesium stearate (Hopkin and Williams, England), talc (BDH Chemicals Ltd, Poole, UK) and natural sponge powder (NSP) (prepared in the laboratory).

The natural sponge (*Luffa aegyptica* Mill) powder (NSP) was prepared as follows. The mature but unripe pods of the natural sponge were plucked early in the morning at the back of Faculty of Pharmacy, Obafemi Awolowo University, Ile-Ife, Nigeria and authenticated at the Botany Department of the University. The outer layer and the seeds embedded inside the sponges were removed with a knife and washed in a detergent solution. The washed sponges were soaked in a 3.5% solution of sodium hypochlorite (Reckitt and Colman Nig. Ltd., Agbara, Ogun State, Nigeria) for 24 hours to allow for bleaching. The bleached sponges were then rinsed severally with distilled water. The sponges were then dried at 60°C in a Galllenhamp hot air oven Model OV- 335 (Vindon Scientific Ltd. Diggle, Oldham, Lancaster, UK) until they became dried and crisp. The dried sponges were milled (Christy Milling Machine, 8" Lab-Mill, Christy and Norris, Ltd., Chelmsford, UK) at 8000 rpm and sieved to obtain the desried particle size (i.e. < 180 μm> 90 μm) using Endecotts test sieves on a Pascal Verner P 14 mechanical shaker (Pascal Engineering Co. Ltd., Crawley, UK).

Test for Cellulose

This was carried out using the method of Pharmaceutical Codex (1979). Phosphoric acid (5 ml) was added to 5 mg of the NSP and heated on a water bath (Type 1083, Gesellaschaft fur Labotechnik mbH, D 3006, Burgwedei, Germany) for 30 minutes. A 0.2% solution of catechol in phosphoric acid (20 ml) was then added and heated further for 30 minutes. A red colour was produced indicating presence of cellulose.

Swelling Capacity Test

This was carried out using the method of Bowen and Vadino (1984). Five grammes of NSP was placed in a 100 ml measuring cylinder and the bulk volume (Vx) noted. Eighty-five millilitres of distilled water was added and the measuring cylinder agitated to disperse the NSP. The volume of the suspension was made up to 100 mlL with more distilled water. The dispersion was allowed to stand for 24 hours after which the volume of the sediment (Vy) was noted. The swelling capacity was computed as Vy/Vx. The determination was carried out in quadruplicate. This procedure was carried out for corn starch BP.

Water Retention Capacity

This was determined according to the method of Ring (1985). Fifteen millilitres of a fresh suspension prepared as described for the determination of the swelling capacity was centrifuged for 25 minutes at 5000rpm (0ptima Centrifuge, Type BHG 500, Germany) and the weight of the residue (Wx) determined . The residue was dried to constant weight (Wy) at 80°C in a Gallenhamp hot air oven (model 0V-335 Vindon Scientific Ltd., Diggle, Oldham, Lancaster, UK). The water retention capacity was computed as $\frac{Wy}{Wx} \times 100$. The determination was carried out in quadruplicate. This procedure was followed for both corn starch and natural sponge powders.

Preparation of Granules

Granules were prepared from either lactose (22μ *; 1.548 cm^{-3}+) alone or mixtures of lactose and disintegrant (natural sponge powder or corn starch (14.6μ * ; 1.571+); ……*microscopy method; plus liquid pycnometry, method. The wet granulation method was employed. Batches (400g each) of a mixture of disintegrant and lactose were prepared with each batch containing the disintegrant added as either internal, external or internal-external disintegrant. The internal distintegrant granules were prepared by dry mixing the required quantities of lactose and disintegrant for five minutes in a Hobart planetary mixer (model N-50, Hobart Manufacturing Co., Ltd., London) and then moistening with appropriate amount of 5 % gelatin binder solution for four minutes. The resulting wet mass was granulated by passing it through a 16 mesh (1000mm) screen using an oscillating granulator (Erweka T.A. Germany). The wet granules were dried at 50°C for 60 minutes in a Gallenhamp hot air oven (model OV- 335, Vindon Scientific Ltd, Diggle, Oldham, Lancaster, UK). The dry granulation was screened through the same mesh 16 (1000mm). Finely sifted magnesium stearate and talc were weighed, added and intimately mixed with the granules retained on mesh 30 (500μm). This mixture was then stored in amber coloured screw capped bottles.

The external disintegrant granules were prepared by moistening the required amount of lactose with appropriate amount of 5% gelatin binder solution. The resulting wet mass was granulated as for internal disintegrant granules. The required amount of disintegrant was then added as external disintegrant by mixing in a bottle. The internal-external disintegrant granules were prepared by dry mixing the required quantities of lactose and half the amount of disintegrant and then moistened with appropriate amount of 5 % gelatin binder solution. The resulting wet mass was then granulated as before. The remaining 50 % of disintegrant was then added as external disintegrant by mixing in a cylindrical bottle.

Preparation of Tablets

Tablets were prepared from 0.5 g of granules retained on mesh 30 (500 μm) using a hydraulic press (Model C, Carver Laboratory Press Inc. USA) at 2.0 metric tonne load with 12 mm flat faced punches in all cases. The tablets were held at the load level for 30s before release and then stored in screw-capped amber coloured bottles for 24 hours to allow for elastic recovery and hardening before evaluation.

Evaluation of Tablet Properties

Weight uniformity test was carried out by weighing ten tablets of each batch separately on a Mettler H8 analytical balance (Metter Instrument AG,CH-8606, Greifensee – Zurich, Switzerland) and the coefficient of weight variation (CV) calculated. The friability was determined by causing ten randomly picked tablets to cascade in a Roche friabilator (model TA3R, Erweka T.A., Germany) rotated at 25 rpm for four minutes. The percentage loss in weight was computed as the friability of the compacts. The crushing strength was measured using a Monsanto crushing strength tester. The average of five determinations was taken as the crushing strength of the batch. The tensile strength (Ts) was computed using the Fell and Newton (1970) equation i.e.

$$Ts = \frac{2F}{dT}$$

Where F is the crushing strength; Ts is the tensile strength; d is the tablet diameter and T the tablet thickness.

The disintegration time of tablets in distilled water was measured in a Manesty disintegration test unit (Manesty Machines Ltd., Liverpool, UK) using the British Pharmacopoeia, BP (1988) method with the result expressed as an average of two determinations. Statistical analysis (standard error of the mean for Tables 1 and 2 at 5 % confidence level) of the results revealed that the variability within the results obtained was at a minimum level. The obtained values were then subjected to one-way analysis of variance (one-way ANOVA) at 5% probability level and found to be significantly different from zero.

Table 1: Swelling and water retention capacities of the disintegrant powders

Disintegrant	Swelling Capacity	Water Retention Capacity
NSP	3.05 - 0.16*	2.12 – 0.23
CS	1.57 – 0.18	3.43 – 0.19
NSP + CS	4.35 – 0.23	2.03 – 0.31

* Standard error of the mean

Table 2: Properties of lactose tablets prepared with NSP and CS

Batch	Weight uniformity (g)	Coefficient of weight variation (CV)(%)	Friability (%)	Tensile strength (MN m^{-2})	Disintegration time (min)
NSP(I)	0.488 (± 0.003)*	0.56	0.92 ± 0.04	0.852	2.09 (± 0.05)*
CS(I)	0.501 (± 0.004)	0.72	0.95 ±	0.07 0.918	2.38 (± 0.04)
NSP (E)	0.513 (± 0.004)	0.87	0.85 ± 0.03	1.108	10.68 (± 0.01)
CS (E)	0.508 (± 0.004)	0.88	0.71 ± 0.06	1.184	7.56 (± 0.02)
NSP (I + E)	0.499 (± 0.001)	0.20	0.90 ± 0.06	0.894	5.71 (± 0.01)
CS (I + E)	0.500 (± 0.004)	0.83	0.48 ± 0.01	0.978	1.54 (± 0.11)
NSP + CS	0.494 (± 0.008)	1.72	1.00 ± 0.11	0.833	4.05 (± 0.04)
LAC	0.496 (± 0.008)	1.70	1.76 ± 0.09	1.005	19.14 (± 0.00)

I = Intragranular; E= Extragranular; I + E = Intragranular + Extragranular
LAC = Tablets without disintegrant ; * = Standard Error of the Mean

Results and Discussion

In normal tablet production, a high CV indicates a poorly flowing granulation while low values signify a highly reproducible flow rate. From the results (Table 2), the CV of the batches with the exception of NSP + CS and LAC indicates good flowing granulation since the CV is minimally low. The friability values for the batches except LAC were observed to conform with what is adequate i.e. 0.8 – 1.0 % (Banker and Anderson, 1986).

From the tensile strength results (Table 2), it can be seen that tablets with external disintegrants had higher tensile strength. This could be due to deformation of the granules which will give rise to breaking and formation of new bonds between the particles. This will lead to more particle-particle contact points and hence increase in strength of tablets formed (Bi *et al*, 1999). The more the new bonds formed, the stronger the tablets resulting from the compression (Hancock *et al*, 2001; Alebiowu & Itiola, 2002).

It is also generally known that particles of similar size and nature (e.g. lactose-lactose; NSP-NSP) have cohesive forces in between them which allows for their coming together hence, formation of a strong bond between them while particles of different sizes and nature have adhesive forces between them which does not allow for too strong a bond (Cooper and Gunn, 1983; Alebiowu and Femi Oyewo, 1998). In the case of tablets with externally added disintegrants, the externally added disintegrants are of the same type and size of particles, the lactose granules are also of the same particles and size. These will lead to stronger bonds hence, stronger tablets than tablets with internally added disintegrant.

During the disintegration process, a number of mechanisms could occur (Lowenthal, 1973; Kanig and Rudnic, 1984; Ferrari *et al*., 1996). These include capillary action, swelling and particle-particle repulsion force. However, since uptake of liquid must precede distingeration (Caramella *et al*., 1986; Van Kamp *et al*., 1986), the rate and extent of liquid uptake are of vital importance in the disintegration process. From Table 1, it is seen that the effectiveness of NSP lies in its ability to absorb liquids as shown in its swelling capacity. The mechanism through which NSP absorbs liquid may be attributed to a combination of adhesion and capillarity. First due to adhesion, there is a wetting of the entire surface of the sponge creating an enormous liquid surface, the capillarity forces now enable the movement of the liquid into myriads of minute interstitial spaces and capillaries of the sponge powder. This causes the sponge particles to swell to a wet volume much greater than their dry volume resulting in an effective disintegrant action.

The results in Table 2 for NSP (I) and CS (I) indicate that the NSP disintegrates better than CS when both were used as internal disintegrants. This could be due to the fact that NSP's swelling capacity is higher than that of CS hence facilitating more penetration of fluid into the tablet mass since the disintegrant was intimately mixed throughout the tablet granules necessitating intragranular absorption of the liquid media into the tablet. The higher swelling capacity of NSP would lead to the generation of higher swelling force (Guyot-Herman, 1992). This force would initiate the active mechanism of disintegration at a faster rate than for tablets containing CS as the disintegrant hence a shorter disintegration time of the tablets with NSP, more so, when there is no amylopectin present in NSP. Amylopectin is the major component for most starches (about 70-80 %) and is responsible for the binding activity of starches (Herman *et al*., 1989). The disintegration time of NSP(E) is longer than that of CS(E). As external disintegrants, they were not intimately mixed throughout the tablet granules but only a peripheral mixing which may not be sufficient to effect intragranular absorption of the liquid media into the tablet mass. The longer time observed in the case of NSP(E) could be attributed to the low water retention capacity of NSP which may not allow for exertion of sufficient hydrostatic pressure which disrupts the tablets mass by the disintegrating fluid (Ingram and Lowenthal, 1968; Ferrari *et al*., 1996).

The NSP(I + E) batch was found to have a longer disintegration time than CS (I + E). This could also be due to the water retention capacity of NSP which is lower than that of CS. In NSP(I + E), it was not all the NSP that will facilitate effective breaking of the tablet since the amount of NSP added extragranularly may not be able to achieve total penetration of fluid into the tablet mass. However, for CS(I + E) the part added extragranularly would assist in reducing the time required for the tablet mass to disintegrate because of the amylopectin which forms a network in starches that prevents water loss or gain into the starch structure (Shangraw *et al*., 1980; Herman *et al*., 1989). This may prevent disintegration fluid loss of the tablet, hence, leading to a build up of hydrostatic pressure on the tablet mass and subsequent breakage of the tablet.

The disintegration time of a mixture of NSP and CS was higher than those of NSP (I), CS (I), NSP, (I + E) and CS (I + E). This may be due to a combination of the effects of swelling capacity and water retention capacity of the mixture. The swelling capacity index of 4.35 would lead to excessive swelling of the tablets while the water retention capacity index of 2.03 would also lead to high retention of water in the tablet core.

On contact with distilled water (disintegrating fluid) the tablet became a sticky gelatinous which did not easily break up.

Conclusion

The results obtained from this work indicate that NSP can act as a disintegrant. With more research on natural sponge especially with the quantification of the amount of celluloses present in the plant (cellulose is the major constituent of the plant) natural sponge may be a more useful material for sourcing celluloses which will act as disintegrants in tablets.

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Book Review

Samuel, O. Akatch

Director, Housing and Building Research Institute, University of Nairobi, P.O. Box 30197 Nairobi, Kenya.
Email: soakatch@uonbi.ac.ke

Book Title:	Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa
Editor:	André Bationo, Ph.D
Year of Publication:	February 2004
Pages:	608 pp

Introduction

This book is presently being published by the Academy Science Publishers (ASP) of the African Academy of Sciences (AAS), Karen, Nairobi on behalf of the Tropical Soil Biology and Fertility (TSBF) Institute of CIAT (International Centre for Tropical Agriculture) at ICRAF, Gigiri, Nairobi. The book is edited by Dr. André Bationo and is dedicated to Professor Mike Swift, a long time Director of the TSBF Institute and founder of AfNet as the single most important implementing agent of the TSBF Institute.

The Tropical Soil Biology and Fertility (TSBF) Institute of CIAT is a research programme whose main aim is to contribute to human welfare and environmental conservation in the tropics by developing adoptable and suitable soil management practices that integrate biological, chemical and socio-economic processes that regulate soil fertility and optimise the use of organic and inorganic resources available to the land users. TSBF research basically targets the empowerment of farmers so as to effectively (i) manage nutrient cycles (ii) manage below ground biodiversity and (iii) manage ecosystem services, so as to achieve the necessary sustainable agro-ecosystem management.

The African Network for Soil Biology and Fertility (AfNet) is the single most important implementing agency of TSBF in Africa. Its main goal is to strengthen and sustain stakeholder capacity to generate, share and apply soil fertility and biology management knowledge and skills to contribute to the welfare of farming communities. It is a mechanism to facilitate and promote collaboration in research and development among scientists in Africa for the purpose of developing innovative and practical resources management interventions for sustainable food production. AfNet has membership from National Agricultural Research and Extension Services (NARES) and universities from various disciplines mainly in soil science, social science, agronomy and technology exchange.

Research

Enormous research has been done within the African continent in various areas including soil organic matter, soil biota, synchrony and resource integration. All this research is geared towards gaining more understanding on soil processes which have direct or indirect influence on soil fertility and land productivity as a whole.

The Tropical Soil Biology and Fertility Institute of CIAT is a research programme whose main aim is to contribute to human welfare and environmental conservation in the tropics by developing adoptable and suitable soil management practices that integrate the biological, chemical and socio-economic processes that regulate soil fertility and optimise the use of organic and inorganic resources available to the land-users. The African Network for Soil Biology and Fertility being a network of scientists in Africa is the single most important implementing agency of TSBF in Africa. AfNet's main goal is to strengthen and sustain stakeholder capacity to generate, share and apply soil fertility management knowledge and skills to contribute to the welfare of farming communities. It is a mechanism to facilitate and promote collaboration in research and development among scientists in Africa for the purpose of developing innovative and practicable resource management practices for sustainable food production in the African continent.

AfNet's overall target outputs are to:

1) Exchange information and combine collective experience of professionals in the same field;

2) Achieve economies of scale and efficiency by concentrating scarce human, financial and other resources on key national and regional problems;
3) Carry out collaborative research through network experiments;
4) Minimise duplication;
5) Provide increased bargaining power with external partners; and
6) Undertake joint capacity building.

In order to enhance these objectives of collaborative research, the network members were offered the opportunity to participate in a conference that brought together all partners and stakeholders to share ideas and experiences. The result of this conference is the publication of this book under review.

Soil Fertility Degradation

Soil fertility degradation still remains the single most important constraint to food production in sub-Saharan Africa. An efficient cycling of nutrients among crops, animals and soil is crucial to the sustained productivity of the farming systems. Emerging evidence indicate that there is considerable consensus on guiding principles for Integrated Soil Fertility Management (ISFM) as the more pragmatic and feasible approach to overcome the limitations of past research approaches. As a holistic approach to research on soil fertility, ISFM embraces responses to the full range of driving factors and consequences namely biological, physical, chemical, social, economic and political aspects of soil fertility decline. The approach encompasses nutrient deficiencies, inappropriate germplasm and cropping system design, pest-disease interaction with soil fertility, linkage between land degradation and poverty and global policies, incentives as well as institutional failures. Such long-term soil fertility management strategy requires an evolutionary, knowledge intensive process, participatory research and development focus rather than a purely technical focus.

Synopsis of the Book

This book, like its predecessor "*Soil Fertility Management in Africa: A Regional Perspective*" by AfNet members is a synthesis of results from AfNet and other sources and presents the views of African scientists on the critical issue of managing nutrient cycles in order to sustain the much needed soil fertility that is crucial for the sustenance of life in the African sub-continent. The book incorporates both thematic and agro-ecological reviews.

Chapter one of the book highlights the challenges and opportunities for the African Network for Soil Biology and Fertility and in effect gives the gateway to the enormous research networking of the sub-African countries. Integrated Soil Fertility Management is covered in the first part of the book which runs from chapter two to twenty eight with various contributions on the topic.

Below ground biodiversity is exhaustively dealt with in the second part of the book which runs from chapter twenty nine to thirty four. This section also has varied contributions on the subject matter.

The third and final part of the book consists of chapters thirty five to forty two and deals with the all important aspect of participatory research. This section is very exhaustive and wide ranging and scales up the various soil fertility restoration technologies.

This book has the advantage in that it carefully incorporates an empirical approach to nutrient cycle management in order to confront the dynamics and heterogeneity of the African environment. The empirical case studies are also regional in perspective and are preceded with an expose of the works of the African Network for Soil Biology and Fertility Institute.

With over 600 pages, this book provides a milestone foundation of documented research work from Africa which is crucial source material for university students, researchers, policy makers and even politicians who would be keen to scale the landscape of managing nutrient cycles to sustain soil fertility and hence poverty reduction in sub-Saharan Africa. This book is therefore, an essential reader to all those interested in alleviating poverty in Africa and in indeed the world!

ANNOUNCEMENT

4th International Symposium Agroenviron – 2004 Role of Multi-purpose Agriculture in Sustaining Global Environment

20-24 October 2004, Udine University, Udine (Italy)

The University of Agriculture of Faisalabad (Pakistan) organized in 1998 the first Agroenviron Symposium. It proved to be an important plate form to share ideas, exchange knowledge and develop international links between organizations involved in agro-environmental issues. The second symposium was hosted at Trakya University, Tekirdag (Turkey) in 2000 and the third by National Authority for Remote Sensing and Space Sciences (NARSS), Cairo (Egypt) in 2002.

The University of Udine (Italy) will organize the fourth symposium of this series in October 2004. The organizers of this event are hopeful that the series will continue in future and prove as an instrument to involve more and more scientists, engineers, planners, institutions and countries on agro-environmental issues for sustaining the environment of this globe. The symposium will certainly provide an in-sight for the scientists in today burning issues related to agriculture and should help in setting the right directions for the future in sustainable agriculture in this millennium.

The proposed topics for presentation in Udine includes: Land, water, air pollution in agricultural areas; Precision agriculture and yield forecasting, Landscape ecology; forestry, and range land management, Climate changes and global agricultural environment; Biotechnology and agricultural biodiversity; Desertification and land degradation control; Agricultural waste reuse and field management; Wetland and coastal ecology in humid environment; RS/GIS techniques in agriculture; Current Advances in Restoration of rural areas for sustainability.

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The Editor appreciates the following referees who kindly assisted in the peer review process of manuscripts that appeared in this issue. We hope that they will continue to help us in the future in our efforts to make *Discovery and Innovation* a coherent forum for Africa's wide ranging and scattered research and a true vehicle for science-led development in the continent and the Third World.

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Cover Photograph: Ganoderma mushroom growing on dead bamboo stem. The Ganoderma mushroom is a woody, robust mushroom which need strong physical support and normally grows on trunks of woody trees and shrubs. Cover photographs by Keto E. Mshigeni; Cover design by John Rittmann and Keto E. Mshigeni

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