EVALUATION OF WOODEN GRAIN SILO

BY

IPINLAIYE OLUWATOYIN
(92/2551)

FEDERAL UNIVERSITY OF TECHNOLOGY
SCHOOL OF ENGINEERING AND
ENGINEERING TECHNOLOGY

DEPARTMENT OF AGRIC-ENGINEERING
MINNA- NIGER STATE

DECEMBER, 1998

EVALUATION OF WOODEN GRAIN SILO

BY

IPINLAIYE OLUWATOYIN
(92/2551)

A PROJECT SUBMITTED TO
TH DEPARTMENT OF AGRICULTURAL ENGINEERING
SHCOOL OF ENGINEERING AND ENGINEERING
TECHNOLOGY

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA
NIGER STATE, NIGERIA.

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG.) DEGREE IN AGRICULTURAL ENGINEERING.

DECEMBER, 1998.

CERTIFICATION

The undersigned certify that they have read and recommend to the engineering and engineering technology for acceptance, a project title "EVALUATION OF GRAIN WOODEN SILO" submitted by IPINLAIYE OLUWATOYIN in partial fulfillment of the requirement for the award of the Bachelor of Engineering degree.

------------------------------	3/2/99
DR AKIN AJISEGIRI	**DATE**
SUPERVISOR	
------------------------------	3/2/99
MR T.A ALABADAN	**DATE**
CO-SUPERVISOR	
------------------------------	26/2/99
DR. M.G YISA	**DATE**
HEAD OF DEPARTMENT	
------------------------------	16/12/98
EXTERNAL EXAMINER	**DATE**
Prof. J.O. Ohu	

DEDICATION

This project is dedicated to the **Almighty God** for he is ever faithful. To my parents **Mr. and Mrs. Ayo A. Ipinlaiye** for their love, care and support.

ACKNOWLEDGEMENT

I thank the **Almighty God** for his faithfulness and love, especially for the grace given to me to study up to this level.

My sincere thanks to my supervisors, **Dr. Akin Ajisegiri** and **Mr. Tope Alabadan** for their thorough supervision and advice.

I wish to express my gratitude to all members of staff and students for their support throughout my stay in their department.

I wish to specially thank my parents **Mr. and Mrs. Ayo A. Ipinlaiye,** they have been an inspiration to my life. If I recorded any achievement in life, it 's a consequence of their encouragement, moral, spiritual and financial support.

Also, I wish to express my appreciation to my brothers and sisters, my friends and to **Akintola Olorunfemi.**

Finally, my special thanks goes to **Folashade Salau**, for sparing her time to type this project work. God bless you all.

IPINLAIYE O.

ABSTRACT

The use of wood products in the consruction of a grain silo istead of alternative materials has become necessary in Nigeria in view of the problem of moisture condensation which is more predominant with silos constructed from steel.

Various construction materials have been tested but no one has proen satisfactory over the other. From the tests which were carried out on a daily basis, it was seen that the problem of moisture condensation which was more prominent with other materials was not experienced using the wooden silo.

From the test carried out, the effect of the environmental factors i.e Relative humidity and temparature on the grains in the wooden silo was determined on a daily basis, it was discovered that the wooden silo can maintain a relatively uniform temperature within for the stored grain. This is due to the low thermal conductividy of the plywood material. There was not much temperature flutuation in the silo compared to the ambient temperature.

It is therefore recommended that a longer period of testing be carried out to determine the suitability of the wooden silo for storage in all the seasos of the year.

TABLE OF CONTENTS

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

CHAPTER ONE

1.0 INTRODUCTION

A major concern of man is the assurance of food supply at all seasons. The concern stems from the critical role of food in the sustenance of human life and the liberation of energies for creative growth.

After harvest, some products may be consumed immediately and some may require a period of storage before being sold or consumed. Some products are stored until a time when the market prices are favourable for sale or are stored waiting for transportation.

Crop storage is therefore a critical part of the farming operation, it involves a means whereby food is made available throughout the year and also to monitor excess harvest in the year.

Much of the damage done on grains is as a result of the effect of environmental factors on the stored grains. These factors include the moisture content of the grains, the Relative Humidity of the surrounding air, the Temperature of the grains, and the infestation on the grains. Each crop has an optimum level of temperature and moisture for best storage. Most grains stored in a cool, dry environment while root crops required cool temperature but higher levels of humidity.

Storage facilities constitute a problem to the local or subsistence farmers, various methods of storing farm product are adopted. Storage maybe in pots, calabashes, baskets or holes in the ground. These methods are very inefficient and may lead to spoilage of food and farm products.

The design and construction of grain storage facilities must suit the purpose which it is to serve. The choice of any material for construction will depend on the availability of the material, the suitability of the material to be used, subsequent maintenance and the relative cost of the material. Steel, Aluminium, Concrete and wood are the most common materials that have been used in silo construction.

There is the need to carry out an evaluation test on the effect of weather on the grain wooden silo and also the effect of moisture, temperature and relative humidity on the stored grains. This is to enable us compare wood as a structural material with all other materials used in the construction of silos.

1.1 STATEMENT OF PROBLEM

The most accepted methods for storing large scale farm produce was the use of the silo, made from different materials. These include aluminium/steel, mud, ferrocement, buty/rubber and wood. Due to the warm humid climatic in Nigeria, the hide daily temperature fluctuations may result in moisture condensation and excessive heating on walls and roofs of the metallic silo. This excessive heating could lead to caking, development of hot spot, mould growth, seed germination and the rapid development of insects. This usually result in the short term storage of grain product. The high cost of materials used in the construction of the silos is also one of the problems faced by the farmer in the storage of their product.

1.2: JUSTIFICATION

Though there are silos constructed of other materials like aluminium, ferrocement, which can be good for storage purpose. The uses of the wooden silo in the storage of grains has been constructed due to it advantages over other types of silos. This advantages includes it low thermal expansion and low thermal conductivity, it ease of working, availability of material and relatively low cost.

This work was initiated to investigate the effect of temperature, relative humidity and moisture content on the grains, and also to determine the effect of the environmental factors on the wooden silo.

1.3 AIMS AND OBJECTIVES.

(1) Determination of the effect of temperature, relative humidity and moisture content on the grains in the wooden silo.

(2) Determination of the effects of environmental factors on the wooden structure

(3) To test for the viability of the grains in the wooden silo.

1.4: SCOPE OF STUDY

This project work is limited to evaluating the effect of temperature, relative humidity and moisture on the grains stored in the wooden silo. Also the effect of this environmental factors on the wooden structure.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. Why storage?

Storage is involved with preserving the quantity and quality of the food and also controlling the intake and release of the food produced. Storage is carried out in order to balance periods of plenty against periods of scarcity. It is also carried out in order to make products available the whole year round. The farmer also wants to store his product at the period of harvest so that when the product is scarce and hence command high financial returns, he can put the product into the market and make maximum profit.

The most obvious requirement for storage is that the product be provided with shelter so that rain, wind and direct sunlight are kept out. In addition, adequate storage facilities must provide crops with protection against rodents, insects and protection against fire, climatic hazards and floods.

2.2 Evaluation of grains Storage Structures and Methods

2.2.1 Low Level grain Storage

This method of storage could also be referred to as the subsistence level storage method, if constitute the most popular aspect of food storage methods. Storage at this level could be before or after threshing. The unthreshed grains and legumes are either hung on trees, on raised platforms or are bundled together and stored in antics of living houses. The threshed grains could be regarded as processed, storage of these are in gourds, calabashes, drums and kerosine tins .

2.2.2 Middle level grain storage.

This is another level of grain storage methods which involves the use of sacks and Rhumbus.

(i) Sacks :- It is a very popular form of storage with marketers and even retailers. shelled produce are stored in the bags which are stacked mostly on raised planks in stores, barns or houses.

(ii) Rhumbus:- There are various physical structures that can be identified with the rhumbus. They could be either roughly cylindrical in shape or flask shaped tapering at one end. The floor of the rhumbus is usually slightly raised from the ground to avoid damages by rain torrent to reduce rodent accessibility and to facilitate the process of unloading the structure which is normally done by gravity at the centre underneath the structure.

2.2.3 Commercial level grain storage

This type of storage is carried out by large scale traders, agro-based and allied companies, exporters, allied companies and Government agencies. The structure for this method of storage are long lasting and permanent. They are mainly silos made from various materials which include concrete, Aluminium and wood. Ware houses are also used for commercial storage.

(Ajisegiri, 1992)

2.3: SILOS.

2.3.1: History and Development of Silos in Nigeria.

The use of silos as grain storage structures in Nigeria dates back to the mid-1950s century. The first silos in Nigeria was a twenty-ton Aluminium type erected at Ilero in Oyo State in 1957 and in 1958, a similar one was erected at Ilaro in Ogun State. (Williams,1971). The grain storage programme of western Nigerian which was coordinated by the extension service division of the Military of agriculture and natural resources of the Western State was responsible to helping the farmers store their grains during the period of low crisis and release them to the market when the prices were more favourable. Initially, silos were supplied in pre-fabricated forms by the United State Agricultural Department, in conjunction with the grains storage programme of Western Nigeria. The silos were made available to the farmers for use free of charge. At a later stage, the Government started to demand for money from the farmers before using the silos, this lead to the reduction of grains that were brought for storage by the farmers. Since most of the silos imported are usually of large capacities they became under utilized. Other problems were also discovered in the use of these imported silos, these include the cost of acquisition and maintenance.

It was therefore discovered the use of the large volume imported silos did not meet the requirement of the small-scale farmers in Nigeria.

The first indigenous silo in Nigeria was a ventilated out-door concrete type designed and erected at the institute of Agricultural research and training, moor plantation, Ibadan in 1965. (**Osobu 1985**) origin of the concrete silo, was to reduce the cost of silos by using our locally available materials. In spite of the recorded success with the use of the concrete silo and the numerous advantages that could be derived from its use, in order to reduce cost of storage, we dim it preferable to use wood as a material for silo construction.

2.3.2 Types of Silos

2.3.2.1 Shallow and Deep Silos- Silos are categorized as deep and shallow types for the purpose of design. When the silo is on the shallow type, the vertical pressure due to the stored grains is completely borne by the floor while the walls bear only the lateral grain pressure.

When the silo is deep, a portion of the vertical pressure due to the grain is carried by the wall and beyond specific height of grain in the silo.

2.3.2.2 Underground storage silo:- In certain areas, grains are stored in underground silos. Uptake of moisture is often the main cause of product deterioration with this method. Experiment conducted showed that underground storage constructed on modified flexible polyolefin being monitored over nine month period remained free to detestable live insects and exhibited fungal growth. It is clamed from reports that insect infestation, fungal growth taste acceptability are well controlled in underground structure.

2.3.2.3 <u>Bunker silo:-</u> This is also known as shallow silo (Gurfinkel, 1979) can be traced back to the early 1950s (Esmay and Brooker, 1955; Esmay et al, 1956). The results of these early investigations and others were summarised and they formed the basis of the design loads that have been used in Canada and United States for Bunker silo for the past 20 years. Bunker silos are prone to cracks initiated by of high negative moment and shear.

2.3.2.4 <u>Concrete silo:-</u> Concrete in various forms have been tested as a possible material for grain silo constructed in Nigeria these include the Mansory silo, Brick silo, Hollow tile cement stare and the Monolithic concrete silo. Concrete has some advantages over the use of steel for the construction of the silos, these includes its poor heat conduction. Since it is a poor conductor of heat, the grain in the silo is insulated from the varying external temperature. It eliminates the problem of caking and development of hotshots. Despite its advantages over the use of steel, it was discovered that moisture condensation was still present even though it took a long time to occur in the Concrete Silos than in Steel Silos.

2.3.2.5 Plastic/Rubber Silo:- The use of plastic silos have been found to be unsuitable for storage. The problem of moisture condensation are as a result of the high tendency of the material to absorb heat, cracks graduating into cuts and holes as a result of intense heat on the plastic material, also result in the unsuitability of the material for the construction of a silo. (Agboola, 1985).

2.3.2.6 Steel/ Aluminium Silo:- The most common material used for the construction of silos is Steel/ Aluminium. Steel used in this sections, is relatively light in weight. Generally, it must be galvanised or otherwise coated to minimised deterioration from moisture and oxidation. One of the main problem with steel is its extreme low resistance of heat transfer, also fluctuation in the temperatures also result in moisture condensation. They are predominantly imported materials hence attracting higher cost for silo construction.

2.3.2.7 Wooden Silo:- Wood products in general include any item that is obtained from the conversion and processing of timber, but here the term is limited to plywood and swan solid wood (planks). Wood as a construction material for silos is not generally as common as steel, aluminium and concrete in Nigeria. A major problem is that many farm storage have been installed on very short notice owning to excessively large yields or overfilled commercial storage. Some of the advantages of using wooden in the construction of the silo includes:

(i) The low thermal expansion coefficient and low thermal conductivity which is quite small compared to that of concrete and aluminium.

(ii) The availability of the material.

(iii) It has good ease of workability

(iv) The labour requirement to work the wooden material and erect the silo can be met locally.

Some problems encountered with the use of wood for construction of the silo include

(i) The difficulty in making the surface of many wood species smooth, cracks and splits may also develop and so insects herbinate there by making fumigation difficult.

(ii) Several wood species can rot leading to mould growth which lead to deterioration of the stored grains.

(iii) Panel joints are difficult to be made water proof.

The use of plywood as a construction material for the silo has overcome many of the disadvantages of wood with respect to strength characteristics and gives the possibility of pre-fabrication in large sections.

2.5 Meteorology and grain storage.

The losses of food grains by damage, during storage are often sufficient to wipe out the grains which are by improved varieties and cultural methods.

Meteorology plays an important role in understanding the causes of this damages and the protective measures that must be applied.

Much of the damages done on grains is as a result of the effects of environmental factors on the stored grains. These factors include the moisture content of the grains, the relative humidity of the surrounding air, the temperature of the grains, the effects of insect mites and micro-organisms and rodents.

(i) **Temperature:-** Storage at temperature is preferable in order to reduce biological and biochemical deterioration. The temperature of stored product may rise considerable usually due to the combined respiratory activities of products, insects, mites and micro-organisms.

(ii) **Moisture content/ Relative humidity:-** Micro-organisms need a certain level of moisture for good growth. Below this level they will grow very slowly or not at all. Grain product normally should not be stored in a moisture content higher than that which would be in equilibrium with a relative humidity of 70%, otherwise micro-organism will developed. This is referred to as the maximum permissible moisture content for safe storage. The maximum permissible moisture content for safe storage for maize is 13.5% (Muckle and Sterling, 1971).

(iii) **Insects and Mites:-** There are about 30 important storage pests. Development take place at temperatures between 17^{o}c and 35^{o}c at almost any moisture content. Mites develop on product with a high moisture content while pests develop completely inside the cereals. Some pests could also be found to develop outside the product.

(iv) **Micro-organisms:-** Development of most species takes place between $5^{o}c$ and $30^{o}c$. Some however have their optimum growth at $50^{o}c$ -$60^{o}c$ while others still develop below $5^{o}c$.

(v) **Rodents:-** In general, rodents cause greater damage to the standing crop than to the crop in storage. Losses are caused by direct consumption by the rodents.

CHAPTER THREE

3.0 METHODOLOGY.

3.1 Project Environment.

The project is being carried out at the Federal University of Technology Minna, Niger State.

It is necessary to consider the temperature, relative humidity and rainfall of the environment where the silo is being used for these factors will influence the quality of the stored grains and the material (wood) used in the construction of the silo, since the silo is being considered for use under the warm humid climate of Niger State. A five years records (1993-1997) of rainfall, temperature, and relative humidity for this location are presented in tables.

3.1.1 Relative Humidity.

From the tables it is observed that the relative humidity is higher for the wet months (April-October) than the dry months (November- March). Storage period therefore coincide with period of high relative humidity.

3.1.2 Rainfall

From the tables, we can also see that there are two seasons, the wet and dry season. The wet season lasts from April - October while the dry season lasts from November- March. It is observed from the tables that from 1993-1995 the maximum rainfall was in August, whereas in1996 and 1997, the maximum rainfall was in July and May respectively.

3.1.3 Temperature.

From the tables we can also observe that the temperature is lowest between July and August. The temperature then begins to increase steadily from August till March and steady increase starts from the month of April.

Table 1

WEATHER RECORD FOR 1993

	TEMPERATURE			RAINFALL	RELATIVE
MONTH	maximum 9h to 9h next day	minimum previous day to 9h same day	Grass minimum 9h	Total (mm)	Humidity 09h 15h 21h
JANUARY	33.5	19.8	17.5		33,27,37
FEBRUARY	36.8	22.6	21.2		40,28,37
MARCH	36.6	24.2	23.6	13.5	53,36,51
APRIL	37.6	25.4	24.9	8.6	63,42,56
MAY	34.9	23.9	33.1	174.4	72,51,77

Table 1 WEATHER RECORD FOR 1993

JUNE	31.3	22.4	22.3	170.5	80,85,84
JULY	29.7	21.7	21.9	189.7	86,71,91
AUGUST	29.4	21.7	21.9	271.1	86,70,89
SEPTEMBER	30.7	21.3	21.5	178.3	81,65,88
OCTOBER	32.5	22.0	21.9	63	71,60,86
NOVEMBER	3.37	-	-	-	-
DECEMBER	-	-	-	-	44,37,47

Table 2

WEATHER RECORD FOR 1994

	TEMPERATURE			RAINFALL	RELATIVE
MONTH	maximum 9h to 9h next day	minimum previous day to 9h same day	Grass minimum 9h	Total (mm)	Humidity 09h 15h 21h
JANUARY	34.3	20.2	29.1	-	40,28,40
FEBRUARY	37.1	22.7	21.6	-	25,20,28
MARCH	39.2	25.2	24.5	7.3	55,29,41
APRIL	36.1	24.9	25.1	72.5	63,47,59

Table 2 WEATHER RECORD FOR 1994

MAY	33.6	23.3	23.2	114.4	74,57,79
JUNE	31.3	22.0	22.1	289.0	80,65,85
JULY	30.1	22.0	21.9	142.5	84,69,68
AUGUST	29.8	21.8	22.2	367.2	87,75,90
SEPTEMBER	29.8	21.8	22.2	261.3	85,74,90
OCTOBER	31.2	21.2	21.0	208.1	76,67,89
NOVEMBER	34.5	18.9	18.0	-	45,33,63
DECEMBER	34.2	18.7	16.8	-	30,26,41

Table 3 **WEATHER RECORD FOR 1995**

	TEMPERATURE			RAINFALL	RELATIVE
MONTH	maximum 9h to 9h next day	minimum previous day to 9h same day	Grass minimum 9h	Total (mm)	Humidity 09h 15h 21h
JANUARY	34.2	19.3	18.2	-	34,27,39
FEBRUARY	37.0	21.8	20.5	-	27,20,28
MARCH	38.9	25.0	24.0	-	48,28,38
APRIL	37.2	25.4	24.9	100.5	62,43,62

Table 3 WEATHER RECORD FOR 1995

MAY	**33.6**	**23.2**	**22.8**	**123.2**	**72,56,78**
JUNE	**31.9**	**22.3**	**22.1**	**144.5**	**77,59,78**
JULY	**30.3**	**21.9**	**21.6**	**153.7**	**81,68,82**
AUGUST	**29.0**	**21.8**	**21.6**	**409.0**	**86,73,86**
SEPTEMBER	**30.6**	**21.6**	**21.4**	**189.1**	**80,65,85**
OCTOBER	**32.0**	**21.9**	**21.2**	**135.7**	**73,61,84**
NOVEMBER	**34.4**	**19.9**	**18.1**	**-23.6**	**39,34,56**
DECEMBER	**34.7**	**18.8**	**16.9**	**-**	**34,27,47**

Table 4 **WEATHER RECORD FOR 1996**

	TEMPERATURE			RAINFALL	RELATIVE
MONTH	maximum 9h to 9h next day	minimum previous day to 9h same day	Grass minimum 9h	Total (mm)	Humidity 09h 15h 21h
JANUARY	36.2	19.3	17.0	-	33,26,40
FEBRUARY	37.6	22.9	20.5	-	42,29,37
MARCH	38.3	24.9	24.2	-	57,32,46
APRIL	37.6	25.0	24.9	48.6	63,37,55

Table 4 WEATHER RECORD FOR 1996

MAY	33.4	22.7	22.8	164.7	73,55,77
JUNE	30.5	21.5	21.9	225	81,68,83
JULY	29.2	21.3	21.1	259.7	87,71,89
AUGUST	28.5	20.9	21.4	257.0	88,76,91
SEPTEMBER	29.9	21.0	21.7	191.1	84,72,89
OCTOBER	31.5	20.4	21.2	127.9	74,60,85
NOVEMBER	35.0	17.5	29.9	-	32,27,51
DECEMBER	35.8	17.6	15.3	-	31,26,46

Table 5 **WEATHER RECORD FOR 1997**

	TEMPERATURE			RAINFALL	RELATIVE
MONTH	maximum 9h to 9h next day	minimum previous day to 9h same day	Grass minimum 9h	Total (mm)	Humidity 09h 15h 21h
JANUARY	35.8	20.6	18.6	-	31,21,32
FEBRUARY	35.3	21.4	19.7	-	18,15,22
MARCH	37.1	24.6	23.7	3.6	46,30,45
APRIL	35.4	24.6	23.9	80.6	64,43,58

Table 5 WEATHER RECORD FOR 1997

MAY	**32.2**	**22.8**	**22.8**	**238.4**	**78,61,82**
JUNE	**30.8**	**22.4**	**22.3**	**233.0**	**82,66,85**
JULY	**29.6**	**22.1**	**21.6**	**172.4**	**85,71,87**
AUGUST	**30.2**	**22.4**	**22.1**	**192.7**	**85,69,85**
SEPTEMBER	**30.8**	**21.6**	**21.3**	**203.3**	**82,68,88**
OCTOBER	**31.7**	**22.0**	**21.9**	**115.0**	**78,65,87**
NOVEMBER	**34.9**	**19.5**	**18.4**	**6.1**	**45,29,53**
DECEMBER	**35.0**	**18.8**	**15.9**	**-**	**28,24,41**

3.1.4 Initial condition of the grains

3.1.4.1 Moisture Content.

In stored grains, changes occur in the fat acidity enzymes, colour, vitamins e.t.c. These changes are influenced greatly by the moisture content and temperature which are often used as a means of indicating the quality of the stored products.

The initial moisture content of the grains was determined using the Grain Master 2000 moisture meter.

3.1.4.2 Colour

There is the need to determine the initial colour of the grains before storage, this is done in order to be able to determine if there is any change in colour during the storage period. The initial colour of the grain was noted before storage.

3.1.4.3 Viability

The viability of the grains was determined by carrying out the germination test on the grains. Fifteen seeds were taken from the grains and planted around the location of the silo.

3.1.4.4 Contamination

The shaft, the dead organic materials make up the impurities in the grains. the percentage of impurities was determined by carrying out a grading test on the grains. A sample of grains was separated into different categories which included the impurities. The weight of these impurities was determined by using the electric weighing balance. The percentage of impurities was later determined by calculation.

3.1.4.5 Infestation

The source of infestation for the stored commodity may be from the field crop itself which is carried along with the grain. The detection of this infestation is a must for safe storage. Before storage, the grains were properly checked to make sure that they were not infested from the market.

3.1.5 Initial condition of the silo

3.1.5.1 Size

The silo was designed to a capacity of $1.87m^3$, an equivalent of 1 ton for shelled corn. (Danjuma and Tolufase, 1998).

3.1.5.2 Shape

The wooden silo is hexagonal in shape with an inner diameter of 16.2M and each side measures 0.81M while the height is 1.10M. (Danjuma and Tolufase, 1998).

3.1.5.3 Mounting.

There are six columns of 1400mm long which serve as a foundation. This helps to transmit the dead and live load into the foundation. These columns hold the wall panels in place.

3.1.5.4 <u>Materials.</u>

The materials used in the construction of the wooden silo is plywood which is made up of 4 plies. Plywood is a processed lumber and as overcome many of the disadvantages of the ordinary wood with respect to strength characteristics and gives the possibility pre-fabricating in large section.

Advantages of plywood over ordinary wood.

(1) It has a greater dimensional stability than natural wood.

(2) Plywood cannot be split by nails

(3) Plywood has a minimum warping

(4) Large width can be made from plywood

(5) Thin Veneer can be bent

(6) Plywood increase lateral strength as a result of cross plies which reinforce each other.

3.2 <u>Silo Evaluation</u>

3.2.1 Effect of weather on silo

3.2.1.1 Peeling

A daily observation of the silo revealed that certain changes had started to occur on the body of the wooden structure.

3.2.1.2 Colour

A daily observation on the silo also showed that there had been a change in the colour of the silo compared to its initial colour before storage.

3.2.1.3 Expansion

A daily observation of the silo also showed that there was expansion of the wooden material to some extent. This expansion was basically along the joints.

3.2.1.4 Dimensional Changes

Dimensional changes is as a result of mechanical stress on the material as well as moisture fluctuations within the wooden materials. This changes caused by shrinkage and swelling may result in change in shape, checking or warping. A daily observation on the silo was also carried out to determine if there was any changes on the material.

3.2.2 Effects of Biological activities in the silo

3.2.2.1 Micro-organisms

3.2.2.1.1 Fungi

The smaller fungi of microscopic size are called micro fungi and include yeasts, moulds, rusts and smuts. The fungus body is composed of threadlike hyphae interwoven in a mycelium. Fungi inject food is store and cause infection of wood. Daily observation showed that at a particular period of high rainfall water found its way through the joints of the silo which led to the effect of fungi on the silo.

3.2.2.1.2 Bacteria

Bacteria are pathogenic parasites that causes diseases on both plant and animal. Bacteria are cultured on moist nutrient media containing organic food material at a temperature of $38^{o}c$-$40^{o}c$. From daily observation, no effect of bacteria was noticed on the grains.

3.2.2.2 Macro-organisms

3.2.2.2.1 Termite

Termite is a type of insect also known as White ant and of the order Isoptera. Termites are destructive insects that feed upon and destroy wooden structures. Before the storage of grains, it was observed that termites attacked the wooden structure. Daily observation during the storage period showed that there was no termite attack on the silo.

3.2.2.2.2 Weevil

Weevil also known as snout beetle is another type of insect that could easily be identified by the snout like projection or proboscis from the head. From daily observation, it was seen that as the temperature of the grain in the silo was increasing the action of the weevil on the grain was noticed.

3.2.2.2.3 Rodents.

Rodents are a potential source of damage to the silo structure and its contents. Since the content of the structure is grains, the rodents would make all efforts to get at it. From daily observation, there was no attack on the grains and the silo.

3.2.3 Effect of Loading

The test parameters and procedures carried out to determine the effect of loading includes

(i) Loading Test

The loading was done manually through the door

Test observations include

(a) Behaviour of joints

(b) Sinking of structure

(ii) Unloading test.

This involves discharging the grain out from the silo through the discharge chute

Test observations include

(a) Behaviour of joints

(b) Sinking of structure

3.3 Grains Evaluation

3.3.1 Shape and Size

Shape and size are inseparable in a physical object. The chartered standards method is used in determining the shape of the grain, this is done by visual comparison of the shape of the object with chartered standards. From the visual view the grain is truncate in shape.

3.3.2 Colour

Daily observation of the colour of the grains compared to the initial colour of the grain before storage showed that there was no change in colour.

3.3.3 Infestation

It was observed that during the periods of heavy rainfall and the effect of heavy wind blow on the silo, water found its way through the joints of the wooden material. The effect of moisture in the walls of the silo led to the formation of moulds and discolouration of the grains which was mainly along the joints were the micro-organism acted.

3.3.4 Temperature

It was considered necessary to monitor the variation of temperatures within and outside the silo since comparison between the ambient temperature and that within the silo provides information on the rate of heat movement into and out of the structure. Three thermometers were placed in the wooden silo. One was placed by the wall of the silo, another placed at the top, while the third was within the grains of the centre. Two thermometers, the dry and wet bulb thermometers were placed outside of the wooden silo to take the ambient temperature. Temperatures were read from the thermometers three times a day, 9.a.m in the morning,12p.m at noon and 5p.m in the evening.

3.3.5 Moisture Content.

The moisture content of the grains within the silo structure is an indication of the amount of moisture present.

Moisture content measurement is very necessary because it provides a fairly reliable estimate of grains suitability for safe storage and even during storage.

The measurement of the moisture content of the grains, Grain master 2000 moisture meter was used to determine the moisture content of the grains. This was determined once in a week.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

Tables 1 to 4 in the appendices shows a daily record of the relative Humidity, Temperature and Moisture contents of grains. Two temperature reading were taken, the ambient temperature which was taken in the Morning, Afternoon and Evening. The temperature of the silo was also taken. The temperature at the interphase of the wall and grain, and the temperature of the air space above the grains. The moisture contents of the grains was also determined on a weekly basis.

4.11 Ambient and Silo Temperature

Figure 1 (a) - (d) which is the graph of the ambient temperatures recorded from the month of July to the month of October shows a typical daily temperature variation for Morning, Afternoon and Evening periods.

Figure 2 (a) - (b) which is the graph of the silo (Room) temperature record from the month of July to the month of October shows a typical average daily temperature variation for Morning, Afternoon and Evening periods.

From Figures 1(a) - (c) and 2(a) it is observed that the ambient temperature record for the month of July and August can be compared to the silo temperature record for the same month. From the graph it is observed that in the morning the ambient temperatures were lower as compared to the wooden silo. It was also observed that the ambient temperatures were higher in the afternoon than in the wooden silo. From the graph it was observed that the temperature within the wooden silo was still high in the evenings, this was as a result of the heat conducted during the day which is held within the silo. This results in the build up of heat within the silo which leads to a corresponding increase in temperature.

From Figures 1(d) - (e) and 2(b) it was observed that there was an increase in the ambient temperature in the month of October, this increase was also observed in the wooden silo which was as a result of the gradual change in seasons i.e wet to dry season associated with increase temperature.

4.12 Moisture Movement in the Silo

Figure 3(a) and 3(b) is the graph of the moisture contents of the grains from July to October recorded on a weekly basis.

From Figures 3(a) and 2(a) it is observed that an increase in the room temperature led to a decrease in the moisture content of the grains. It was also observed that a fall in temperature led to a rise in the moisture content of the grains.

From Figure 3(b) it was observed that there was an increase in the moisture content of the grains in the month of October, this was as a result of the high rate of rainfall within the first thre weeks of the month.

4 .13 **Relative Humidity**

Figure 4(a) and (b) is the graph of relative humidity of the silo environment. From the graph it was observed that the relative humidity for the month of August was predominantly high. Comparing the ambient temperatures from July to August in Figure 1(a) - (c) it was observed that a rise in the relative humidity led to a decrease in the ambient temperature. A fall in the relative humidity therefore led to a rise in the ambient temperature.

4.14 **Termite attack on the Silo**

It was observed that there was termite attack on the wooden silo before loading. Solignum chemical was applied within the silo to stop the action of the insects. In order to totally eradicate the termite on the silo, the foundation of the silo was filled with concrete and the piles were installed.

4.15 **Delamination of Joints**

It was observed that there was expansion of the wooden structure, this led to the delamination of joints on the structure. The body filler was used in covering the delaminated joints to prevent water from passing through the joints into the silo.

4.16 **Deflection of Floor**

$$\delta = -\frac{0.01304\ WD^3}{EI} \quad \text{.......eqn 1}$$

(Jensen A & Chenoweth)

Where W = Weight of load = 300kg

E = Modulus of elasticity of wood (Iroko) at minimum value = 4480/mm^2 - Jensen, A. & Chenoweth

I = Moment of inertial of a hexagonaal section (mm^4) $\Pi D^4/64$

Where D = actual diameter of silo floor

D = 1620 mm

$$I = \frac{3.142 * (1620)^4}{64}$$

$$= 3.38 * 10^{11}\ mm^4$$

W = 300 * 9.81 = 2943N

Substituting into equation 1

$$\delta = -\frac{0.01304\ 2943N * (1620)^3\ mm^3}{4480N/mm^2 * 3.38 * 10^{11} mm^4}$$

$$= \frac{-1.63 * 10^{11}}{1.514 * 10^{15}} = -1.077*10^{-4} mm.$$

This shows that deflection of floor is negligible hence it will withstand the material.

4.17 Sinking of Structure

The height of the column from the base of the soil to the floor of the silo was determined before loading to be 1400mm. After loading it was determined to be 1400mm, there therefore was no sinking.

4.18 Wood Deterioration

From daily observation there was no appreciable deterioration of the wooden structure. It was observed that there was a change in colour and peeling of the painting on the wooden structure, which was as a result of the effect of the sun and rain on the wooden structure.

4.19 Moisture Condensation

Moisture condensation was noy experienced in the silo through out the period of the test. This is as a result of the low thermal conductivity of the wooden material.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

From the test carried out, it was observed that the problem of moisture condensation which is predominant with storage structures made of steel was not experienced using the wooden silo. The results from the test confirms the uniform variation in temperatures which is as a result of the low thermal conductivity of the wooden sructure. This therefore made it possible for the grains to be well stored during the period of test.

5.2 RECOMMENDATIONS

It is necessary that the wooden silo be subjected to the environmental conditions for a much longer duration, this is to enable the test cover all the seasons in the year.

The tests which will cover a longer duration will cost much and so Government and Research Institutes should take interest and make funds available for further work on the project.

A cordinated production system whereby the silo components are factory produced with proper seasoning and treatment is there recommended.

REFERENCES

1. AJISEGIRI, A. and Osunde, Z.D. (1992). Storage and processing of grains: "The choice is yours" paper presented at the Annual conference of the Agricultural Society of Nigeria, F.U.T., Minna.

2. Danjuma and Tolufase (1998); Design and construction of a wooden Grain Silo B.Eng project, Department of Agric. Eng. F.U.T., Minna.

3. Elsevier (1989); Agricultural Compedium for Rural Development in the Tropics and subtropics.

4. Gurfinkel, G (1979); Reinforced Concrete Bunkers and Silos in in structural Handbook. Edited by E.H. Gay Lord and C.N Gay Lord. Mc graw-Hill book company, New York. 2nd Edition.

5. Jensen A. and Chenoweth, H. (1975) Static and Strength of Materials. Mcgraw-Hill Book Company Tokyo. 3rd Edition.

6. Mc Graw-Hill concise Encyclopedia of science and Technology. Second Edition (1989). Editor in Chief, Sybil P. Parker

7. Mijinyawa Y, (1989); The use of wood products in the design and construction of a grain silo for Humid Tropics. Unpublished Ph.D Thesis Dept. of Agric. Engineering University of Ibadan, Ibadan.

8. Mohsenin N.N. (1978); Physical properties of plant and Animal Material. Gordon and Breach Science Publishers, London.

9. Smith C.V.(1969); Meteorology and Grain Storage

10. The Longman Encyclopedia 3rd Edition (1990) Editor in Chief: Asa Briggs.

Daily Temperature Record

TABLE 6

JULY

	AMBIENT TEMPERATURE (°C)			ROOM TEMPERATURE (°C)			
DAY /TIME	DRY BULB	WET BULB	RELATIVE HUMIDITY (%)	TOP	CENTRE	WALL	MOISTURE CONTENT OF GRAINS (%)
1 M	26.2	26.0	97.0	27.0	27.0	27.0	
N	28.2	28.0	98.0	31.0	27.0	30.0	
E	28.2	28.0	98.0	31.2	28.5	30	12.0
2 M	25.0	25.0	100	27.2	27.3	27.0	
N	29.6	28.4	92.0	33.5	27.5	28.0	
E	28.5	28.2	96.0	32.0	29.8	32.0	
3 M	26.9	26.9	100	27.0	26.0	27.0	
N	30.0	28.5	86.0	35.0	28.0	34.0	
E	29.3	28.0	86.0	23.8	22.0	24.5	
4 M	22.2	22.5	79.0	25.8	26.0	26.2	
N	24.0	24.9	100	30.2	27.0	29.0	
E	24.4	24.4	100	30.6	27.0	30.0	
5 M	26.5	26.5	100	27.0	26.0	27.0	
N	25.8	25.0	93.0	33.0	27.0	32.0	
E	26.5	26.5	100	32.0	29.0	31.0	
6 M	26.0	24.0	84.0	25.0	25.0	24.5	
N	28.0	27.5	92.0	27.0	26.0 27.0	25.0	
E	27.5	27.5	100	23.0		24.5	
7 M	25.0	23.5	87.0	26.0	25.4	26.2	
N	25.0	25.0	100	28.5	26.0	27.0	
E	23.0	23.0	100	30.0	28.0	30.0	
8 M	25.0	24.5	97.0	27.0	27.0	27.0	12.9
N	29.8	28.3	89.0	34.0	30.0	33.0	
E	30.0	20.0	37.0	34.0	31.0	32.0	
9 M	30.0	20.0	37.0	26	25.0	26.0	
N	30.0	25.0	65.0	28.5	26.0	27.0	
E	31.0	25.0	61.0	30.0	28.0	30.0	
10 M	27.4	27.0	96.0	25.0	27.0	25.5	
N	32.0	25.0	55.0	31.0	27.0	30.0	
E	27.0	27.0	100	31.0	28.5	30.0	
11 M	26.0	25.0	92.0	26.0	25.4	26.0	
N	27.0	26.8	97.0	28.0	25.0	26.0	
E	30.0	25.0	65.0	30.0	27.0	30.0	
12 M	26.0	26.0	100	26.0	26.0	27.0	
N	27.0	26.0	96.0	28.5	27.0	27.0	
E	28.5	26.0	81.0	30.0	28.0	30.0	
13 M	27.0	26.5	96.0	23.8	22.0	24.5	
N	22.5	21.8	92.0	25.0	23.0	25.0	
E	28.4	28.0	96.0	23.0	27.5	24.5	
14 M	23.5	23.2	98.0	25.0	24.8	25.0	
N	29.3	26.4	92.0	27.2	25.0 30.0	26.5	
E	31.4	27.0	70.0	30.5		29.2	

Table 6

JULY

15 M N E	25.0 27.0 30.0	24.9 26.0 27.0	99.0 92.0 78.0	26.0 27.2 30.0	25.4 25.0 28.0	26.0 25.0 30.8	12.8
16 M N E	25.0 27.0 29.0	24.0 26.4 26.0	92.0 92.0 79.0	26.0 28.5 30.0	25.0 26.0 28.0	26.0 27.8 31.0	
17 M N E	27.0 29.2 30.0	26.5 27.5 26.0	96.0 84.0 67.0	25.0 28.0 28.0	26.0 27.0 26.0	26.0 27.0 26.0	
18 M N E	25.8 29.0 27.0	25.2 26.0 27.0	94.0 79.0 100	27.0 28.0 29.0	26.0 27.0 36.0	27.0 27.0 30.0	
19 M N E	26.0 28.0 29.9	25.5 27.0 26.0	93.0 91.0 73.0	26.0 28.5 30.0	25.4 26.0 28.0	26.2 27.8 30.0	
20 M N E	29.2 27.0 28.0	25.8 26.0 28.0	75.0 91.0 100	25.0 25.0 26.2	26.0 26.0 26.0	25.8 26.0 26.0	
21 M N E	26.5 27.0 28.5	26.0 26.0 26.0	96.0 92.0 81.0	27.2 33.5 32.0	26.5 27.5 29.8	27.8 28.0 32.0	
22 M N E	25.0 27.0 30.0	24.9 26.0 27.0	99.0 92.0 78.0	23.8 25.0 23.0	22.0 23.0 27.5	24.5 25.0 24.5	
23 M N E	26.8 29,8 32.5	26.0 25.0 27.0	94.0 66.0 64,0	26.0 28.5 30.0	25.4 26.0 28.0	26.2 27.8 30.4	12.7
24 M N E	26.8 30,0 31.4	26.4 26.4 27.0	92.0 92.0 70.0	27.0 35.0 33.0	27.0 28.0 30.0	27.5 34.0 33.0	
25 M N E	25.0 30,0 28,5	25.0 27.0 27,0	100 79.0 84.0	25.0 31.0 31.2	27.0 27.0 28.5	25.5 30.0 30,0	
26 M N E	27.0 31.5 30.0	26.5 27.0 27.0	96.0 69.0 78.0	27.2 33.5 32.0	26.5 27.5 29.8	27.8 28.0 32.0	
27 M N E	26.8 32.0 31.8	26.4 26.0 27.0	96.0 61.0 68.0	27.0 35.0 34.8	27.0 28.0 30.2	27.8 34.0 33.0	
28 M N E	23.5 22.5 27.0	23.2 21.8 26.8	98.0 92.0 98.0	23.8 25.0 23.0	22.0 23.0 27.5	24.5 25.0 24.5	
29 M N E	25.0 26.8 28.4	24.0 25.6 28.0	98.0 91.0 96.0	25.0 27.2 30.5	24.8 25.0 27.0	25.0 26.5 29.2	
30 M N E	25.8 26.8 30.0	25.0 26.0 24.8	93.0 93,0 69.0	26.0 28.5 30.0	25.4 26.0 28.0	26.2 27.8 30.8	
31 M N E	30.2 25.0 24.8	26.1 25.0 24.8	70.0 100 100	25.2 25.0 26.2	26.0 26.0 26.0	25.8 26.0 26.0	

Daily Temperature Record

TABLE 7

AUGUST

	AMBIENT TEMPERATURE (°C)			ROOM TEMPERATURE (°C)			
DAY /TIME	DRY BULB	WET BULB	RELATIVE HUMIDITY (%)	TOP	CENTRE	WALL	MOISTURE CONTENT OF GRAINS (%)
1 M	26.2	26.0	97.0	25.0	26.0	26.2	13.7
N	28.2	28.0	98.0	30.2	25.0	28.8	
E	28.2	28.0	98.0	30.6	27.6	30.0	
2 M	25.0	25.0	100	25.1	25.4	25.0	
N	29.6	28.4	92.0	32.0	26.2	30.1	
E	28.5	28.2	96.0	30.4	28.0	30.1	
3 M	26.9	26.9	100	27.2	26.0	27.8	
N	30,0	28.0	86.0	33.2	27.0	32.0	
E	30.0	28.0	86.0	32.0	29.0	31.5	
4 M	25.0	22.5	79.0	23.2	20.5	24.0	
N	24.9	24.9	100	26.5	25.5	26.0	
E	24.4	24.4	100	28.4	26.6	28.0	
5 M	26.5	26.5	100	25.0	25.2	25.0	
N	25.8	25.0	93.0	27.0	25.2	27.0	
E	26.5	26.5	100	28.5	26.5	28.0	
6 M	26.0	24.0	84.0	25.0	25.1	25.0	
N	28.6	27.5	92.0	31.0	25.4	29.8	
E	27.5	27.5	100	29.8	27.5	29.5	
7 M	25.0	23.5	87.0	24.0	25.3	24.1	
N	25.0	25.0	100	27.0	25.5	26.0	
E	23.0	23.0	100	24.8	25.5	24.8	
8 M	25.0	24.5	97.0	22.8	25.5	25.0	13.9
N	29.8	28.2	89.0	30.8	25.0	30.0	
E	30.0	20.0	37.0	32.5	26.8	30,0	
9 M	30.0	20.0	37.0	31.2	25.2	29.0	
N	31.0	31.0	100	35.2	26.0	34.5	
E	29.4	27.0	96.0	34.0	27.0	32.0	
10 M	27.4	27.0	96.0	28.0	27.0	27.0	
N	32.8	31.0	92.0	36.0	27.5	34.5	
E	27.0	27.0	100	30.0	26.0	30.0	
11 M	26.0	26.0	100	25.5	26.5	25.2	
N	27.0	26.8	98.0	29.4	27.0	28.0	
E	30.8	30.0	96.0	33.0	28.0	31.0	
12 M	26.0	26.0	100	26.5	26.8	26.5	
N	28.4	28.0	96.0	31.4	27.0	30.0	
E	30.7	30.0	61.0	34.0	29.0	32.0	
13 M	22.4	22.0	91.0	23.0	22.0	23.0	
N	23.9	23.8	99.0	24.8	26.8	25.0	
E	25.5	25.2	97.0	26.0	26.8	26.4	
14 M	24.5	24.0	95.0	23.4	25.0	24.0	
N	28.0	27.0	92.0	30.0	25.0	29.0	
E	28.0	28.0	100	31.0	27.0	30.0	

Table 7 AUGUST

15 M N E	24.2 26.0 26.5	24.0 25.0 26.5	97.0 91.0 100	24.0 26.4 29.0	25.6 26.0 27.0	24.5 26.5 28.8	13.7
16 M N E	26.0 26.5 25.0	25.2 25.8 25.0	93.0 94.0 100	27.0 28.8 25.6	25.2 25.8 26.8	26.7 27.8 26.7	
17 M N E	27.5 30.2 30.8	25.4 25.0 30.0	83.0 63.0 68.0	26.8 35.0 32.4	25.0 26.2 29.0	26.0 33.0 32.0	
18 M N E	24.9 27.1 28.2	24.0 24.1 27.2	93.0 77.0 98.0	25.0 31.0 30.4	25.4 26.0 28.4	25.5 30.0 30.2	
19 M N E	24.2 27.0 28.6	24.0 26.0 27.5	98.0 92.0 93.0	25.0 29.0 31.0	26.8 25.4 28.0	25.2 28.0 30.0	
20 M N E	29.0 27.8 27.2	28.6 27.0 27.0	97.0 97.0 98.0	29.2 30.0 29.8	26.5 26.8 28.0	30.0 29.0 30.0	
21 M N E	26.0 28.0 30.0	25.0 28.0 29.2	92.0 100 94.0	25.5 30.0 32.0	26.0 27.0 28.8	26.0 29.0 31.0	
22 M N E	25.0 24.0 20.5	25.0 24.0 20.0	100 100 95.0	25.0 24.0 21.0	27.0 27.0 25.5	25.5 25.0 23.0	
23 M N E	24.0 26.2 28.0	24.0 26.0 28.0	100 98.0 100	24.0 28.2 31.0	24.0 24.0 25.5	24.0 27.5 29.0	13.8
24 M N E	24.8 28.2 28.1	23.8 27.0 28.0	95.0 91.0 99.0	23.2 30.8 31.0	25.1 25.0 27.0	24.0 29.0 30.0	
25 M N E	24.8 28.0 29.0	24.0 27.0 28.0	93.0 92.0 92.0	24.8 29.0 31.0	26.0 25.9 27.8	25.0 28.0 30.0	
26 M N E	27.0 30.0 30.5	26.5 25.0 25.5	93.0 65.0 54.0	28.0 37.0 33.5	26.0 27.8 24.0	27.0 32.8 32.0	
27 M N E	27.0 33.5 31.0	26.5 26.0 27.0	96.0 53.0 73.0	26.0 36.0 34.0	27.0 27.0 30.0	27.0 34.0 33.0	
28 M N E	29.0 32.5 30.0	26.0 27.0 27.0	78.0 64.0 78.0	28.0 36.0 33.0	28.0 29.0 31.0	29.0 34.8 33.0	
29 M N E	25.8 28.0 30.0	25.0 27.2 27.0	93.0 93.0 78.0	26.0 31.8 32.0	27.0 28.6 29.0	26.0 30.0 31.0	
30 M N E	26.0 29.0 26.0	25.0 27.0 20.0	92.0 85.0 100	26.0 32.0 33.0	27.0 29.0 29.0	26.0 30.0 32.0	

Daily Temperature Record

TABLE 18

SEPTEMBER

	AMBIENT TEMPERATURE (°C)			ROOM TEMPERATURE (°C)			
DAY /TIME	DRY BULB	WET BULB	RELATIVE HUMIDITY (%)	TOP	CENTRE	WALL	MOISTURE CONTENT OF GRAINS (%)
1 M	25.0	24.5	96.0	25.0	25.6	26.0	
N	28.2	27.4	94.0	31.2	26.0	29.0	13.9
E	27.6	27.1	96.0	29.0	27.2	29.0	
2 M	25.0	24.2	93.0	25.0	27.0	26.0	
N	30.8	29.5	90.0	34.0	28.6	30.0	
E	27.8	27.8	100	33.0	30.0	31.0	
3 M	27.8	27.1	94.0	25.0	25.0	24.0	
N	26.4	25.4	94.0	30.0	27.0	28.4	
E	26.0	25.2	96.0	31.0	29.0	29.0	
4 M	25.2	27.1	97.0	26.2	25.1	26.0	
N	28.4	25.4	94.0	34.8	28.0	32.0	
E	26.0	25.2	96.0	32.2	28.0	31.2	
5 M	24.8	27.1	93.0	27.0	27.0	28.0	
N	26.4	25.4	96.0	39.5	27.5	34.0	
E	28.2	25.2	90.0	33.2	29.0	33.0	
6 M	25.2	24.5	96.0	25.0	25.6	26.0	
N	25.3	27.4	91.0	31.2	26.0	29.0	
E	27.4	27.1	96.0	29.0	27.2	29.0	
7 M	25.0	25.0	100	25.8	26.5	20.0	
N	25.0	25.0	100	26..5	25.0	26.0	
E	26.0	26.0	100	26.2	25.1	26.0	
8 M	27.0	25.0	84.0	26.2	25.1	26.0	
N	30.0	27.0	78.0	34.8	28.0	32.0	
E	28.2	29.6	76.0	32.2	28.0	31.2	
9 M	27.0	26.0	92.0	27.0	27.0	28.0	
N	33.0	31.0	86.0	39.5	27.5	34.0	13.7
E	30.8	30.0	98.0	33.2	29.0	33.0	
10 M	25.6	25.4	74.0	26.4	28.0	27.0	
N	30.4	28.0	83.0	34.8	29.0	32.0	
E	29.0	26.8	72.0	32.0	29.0	31.0	
11 M	29.2	27.8	85.0	30.0	27.2	29.0	
N	31.2	29.2	86.0	29.6	27.6	33.0	
E	29.0	27.6	87.0	31.0	29.0	31.4	
12 M	27.0	26.0	92.0	28.0	28.0	28.0	
N	32.0	29.2	81.0	31.0	28.0	32.6	
E	33.0	30.4	83.0	31.8	30.0	34.0	
13 M	24.0	24.0	100	29.0	27.0	27.0	
N	27.8	27.0	94.0	30.8	27.6	29.0	
E	28.6	28.0	96.0	31.0	28.4	30.8	
14 M	26.8	25.0	86.0	27.0	27.0	27.0	
N	30.6	28.0	81.0	34.0	27.0	31.2	
E	30.4	28.0	83.0	33.0	28.2	32.0	

Table 8

SEPTEMBER

15 M N E	26.0 29.2 30.2	25.0 28.0 29.0	87.0 91.0 91.0	27.0 32.2 35.0	27.0 27.0 29.0	27.0 30.0 32.0	
16 M N E	28.0 34.0 31.0	26.0 31.0 29.4	85.0 80.0 88.0	27.0 39.0 35.0	27.0 27.0 30.0	27.0 34.0 33.2	
17 M N E	26.7 30.0 31.0	26.0 28.0 30.0	90.0 86.0 93.0	27.6 32.0 34.0	28.0 28.0 29.0	27.4 31.4 33.0	
18 M N E	24.0 29.2 28.4	23.0 27.0 26.4	72.2 72.2 75.3	25.0 30.2 30.0	27.0 27.0 27.0	25.0 28.0 29.0	
19 M N E	26.0 27.0 29.0	23.5 26.0 27.8	80.1 75.7 74.3	25.2 28.6 32.0	26.0 26.0 27.0	25.2 28.0 29.0	
20 M N E	29.0 32.0 31.0	27.0 30.0 27.0	73.89 73.8 71.6	27.0 36.0 34.0	27.0 27.0 29.0	26.0 38.0 33.0	
21 M N E	27.8 29.7 29.1	24.0 27.2 27.0	71.6 72.2 72.4	25.0 39.6 32.0	26.2 26.2 28.0	25.0 31.0 31.0	
22 M N E	27.0 28.9 24.8	25.0 28.0 24.4	82.0 94.0 96.0	26.4 32.0 26.2	27.0 28.0 30.0	27.0 30.2 27.2	
23 M N E	26.4 27.0 30.0	24.8 26.4 29.0	77.9 92.0 90.0	26.0 30.0 35.0	26.0 26.0 27.0	26.0 28.4 31.0	
24 M N E	25.0 29.7 26.5	24.6 29.0 25.0	88.0 92.0 74.0	25.8 27.0 29.0	27.0 27.4 28.0	27.0 31.0 28.0	
25 M N E	26.8 33.0 31.4	25.0 30.0 31.0	74.0 73.5 96.0	25.0 32.0 36.0	26.0 27.0 29.0	27.0 37.0 33.0	13.0
26 M N E	26.6 28.6 30.6	24.0 28.0 29.8	76.0 66.4 71.6	29.4 33.0 31.0	27.2 27.6 30.0	29.0 31.0 33.0	
27 M N E	26.8 28.6 30.0	25.0 27.2 30.0	70.0 72.7 100	26.0 35.0 35.2	26.0 27.0 28.8	26.0 31.2 32.0	
28 M N E	28.4 33.0 24.2	25.0 30.0 23.0	76.4 73.5 83.4	28.0 33.0 27.0	28.0 28.0 30.0	28.0 34.0 29.0	
29 M N E	27.0 31.4 32.0	26.0 30.0 30.2	93.0 92.0 86.0	27.0 33.4 32.0	27.0 28.0 30.0	26.0 31.0 34.0	
30 M N E	27.0 33.0 31.0	21.0 30.0 30.0	79.1 73.5 90.0	27.0 33.8 32.0	27.0 27.2 29.0	27.0 31.0 33.0	
31 M N E							

Daily Temperature Record

TABLE9

OCTOBER

	AMBIENT TEMPERATURE (°C)			ROOM TEMPERATURE (°C)			
DAY /TIME	DRY BULB	WET BULB	RELATIVE HUMIDITY (%)	TOP	CENTRE	WALL	MOISTURE CONTENT GRAINS (%)
1 M	26.5	24.5	85.0	26.0	24.0	26.0	
N	29.0	28.0	78.5	27.8	27.0	31.2	
E	25.0	25.0	100	26.0	27.0	33.0	13.0
2 M	27.0	25.0	75.7	26.8	24.0	26.8	
N	33.0	31.0	72.5	36.0	27.0	30.0	
E	31.0	30.0	75.9	29.0	27.0	29.0	
3 M	27.0	25.0	71.0	26.0	28.0	27.5	
N	34.0	31.0	67.1	37.0	28.0	32.0	
E	33.0	32.0	66.4	38.0	30.0	35.0	
4 M	29.0	27.0	73.3	30.0	29.0	30.0	
N	32.0	31.0	70.8	37.0	29.0	33.0	
E	32.0	31.0	63.7	36.0	30.5	35.0	
5 M	26.3	26.6	89.1	39.0	29.4	29.0	
N	32.2	31.6	78.2	36.0	29.2	34.0	
E	33.0	31.0	36.0	27.0	32.0	35.0	
6 M	29.6	21.0	69.6	27.0	28.8	27.5	
N	31.4	28.6	63.0	33.0	29.0	32.0	
E	33.0	29.8	69.6	37.0	31.3	35.0	
7 M	25.2	24.8	79.8	26.0	28.0	27.0	
N	30.1	27.8	71.3	36.0	28.0	21.1	
E	32.2	31.6	78.0	27.0	30.5	35.0	
8 M	28.4	28.0	96	28.6	27.0	25.0	
N	29.8	27.2	73.3	28.0	29.0	29.2	
E	31.0	29.0	75.3	31.2	29.0	33.0	13.6
9 M	25.1	24.9	86.6	26.2	27.8	30.0	
N	29.2	28.4	82.8	32.2	27.8	30.4	
E	30.2	29.4	70.9	36.2	29.0	33.8	
10 M	26.0	25.0	77.7	26.9	27.5	28.6	
N	32.0	29.8	69.4	37.5	27.0	32.0	
E	31.0	30.0	80.0	38.0	29.0	34.0	
11 M	26.0	25.0	82.1	27.0	28.0	26.8	
N	31.8	29.5	75.1	35.0	28.0	31.0	
E	25.0	23.8	79.0	28.0	28.0	29.4	
12 M	26.0	25.2	82.0	37.0	30.0	26.8	
N	29.0	28.2	75.5	32.8	30.0	31.0	
E	30.1	29.0	75.8	35.4	30.0	32.2	
13 M	25.0	24.8	83.2	26.7	28.0	26.5	
N	30.2	28.0	73.5	35.1	28.0	31.4	
E	30.4	29.8	61.8	37.0	31.0	32.8	
14 M	29.0	27.5	81.0	27.0	28.0	27.0	
N	35.0	31.0	69.8	38.0	29.0	32.0	
E	31.4	31.8	68.2	38.0	32.0	34.4	

Table 9

OCTOBER

15 M	26.8	25.0	72.6	26.2	28.6	26.4	
N	32.0	30.0	66.6	37.0	29.0	31.0	
E	32.0	30.0	80.0	26.0	32.0	33.0	13.4
16 M	27.8	26.0	79.8	27.0	30.0	27.6	
N	34.0	31.0	74.3	38.8	30.1	33.0	
E	33.0	32.0	63.8	38.0	32.0	35.0	
17 M	26.8	25.0	82.0	27.0	27.0	27.0	
N	30.0	28.0	79.8	33.2	30.1	30.8	
E	32.0	30.0	70.2	34.0	32.0	33.0	
18 M	29.0	27.5	81.0	27.0	28.0	27.0	
N	35.0	31.0	69.8	37.0	29.0	31.0	
E	31.4	31.8	68.2	38.0	31.0	29.4	
19 M	27.2	26.0	69.8	27.0	28.0	27.0	
N	31.0	30.0	77.1	37.0	29.0	32.0	
E	30.0	29.6	75.1	34.8	31.0	32.0	
20 M	27.2	25.8	77.6	28.0	29.2	28.0	
N	32.7	29.0	65.7	31.6	30.0	32.0	
E	30.0	29.9	79.1	35.0	31.0	33.0	
21 M	26.2	25.0	65.4	27.0	29.0	27.0	
N	32.4	29.0	69.6	31.0	29.8	31.6	
E	25.6	25.0	82.4	29.4	31.0	31.0	
22 M	27.5	25.0	74.9	27.0	28.0	27.0	
N	30.7	29.0	72.4	35.0	29.0	33.0	
E	24.6	26.0	77.4	30.0	30.0	30.0	
23 M	26.1	25.2	77.4	27.0	28.0	27.0	
N	30.2	29.0	72.1	36.0	28.2	32.0	
E	32.0	30.0	68.7	37.0	33.0	33.6	13.2
24 M	24.8	26.0	65.8	26.0	28.0	26.0	
N	30.0	29.0	73.0	35.0	25.0	33.0	
E	31.0	30.0	72.5	36.0	28.8	35.0	
25 M	26.4	25.4	73.6	27.0	28.0	27.0	
N	32.0	30.0	68.7	37.0	35.0	32.4	
E	33.2	30.0	68.0	41.2	31.0	35.0	
26 M	29.0	27.0	63.8	30.0	28.0	29.0	
N	33.4	31.6	73.2	41.0	35.0	34.0	
E	33.8	32.0	53.4	41.0	32.0	36.0	
27 M	29.6	27.4	75.5	29.0	30.0	28.0	
N	35.0	31.9	73.5	41.2	28.0	35.0	
E	33.6	31.1	63.7	39.0	32.2	31.0	
28 M	28.0	26.0	74.3	27.0	30.0	27.0	
N	36.5	32.0	52.2	44.0	30.0	35.5	
E	34.0	31.0	68.5	41.0	32.0	36.0	
29 M	28.0	25.0	76.7	27.0	30.0	27.0	
N	35.0	30.0	70.9	42.2	30.0	35.0	
E	32.0	30.0	83.0	40.5	32.2	36.0	
30 M	29.0	27.0	67.5	28.0	30.0	27.0	
N	35.0	31.0	55.5	40.0	30.0	34.0	
E	33.0	29.0	51.5	37.0	32.0	35.0	
31 M	28.0	24.2	48.7	27.4	29.0	27.0	
N	35.0	30.0	35.2	41.2	30.0	35.0	
E	32.0	28.4	52.0	40.0	30.0	34.0	

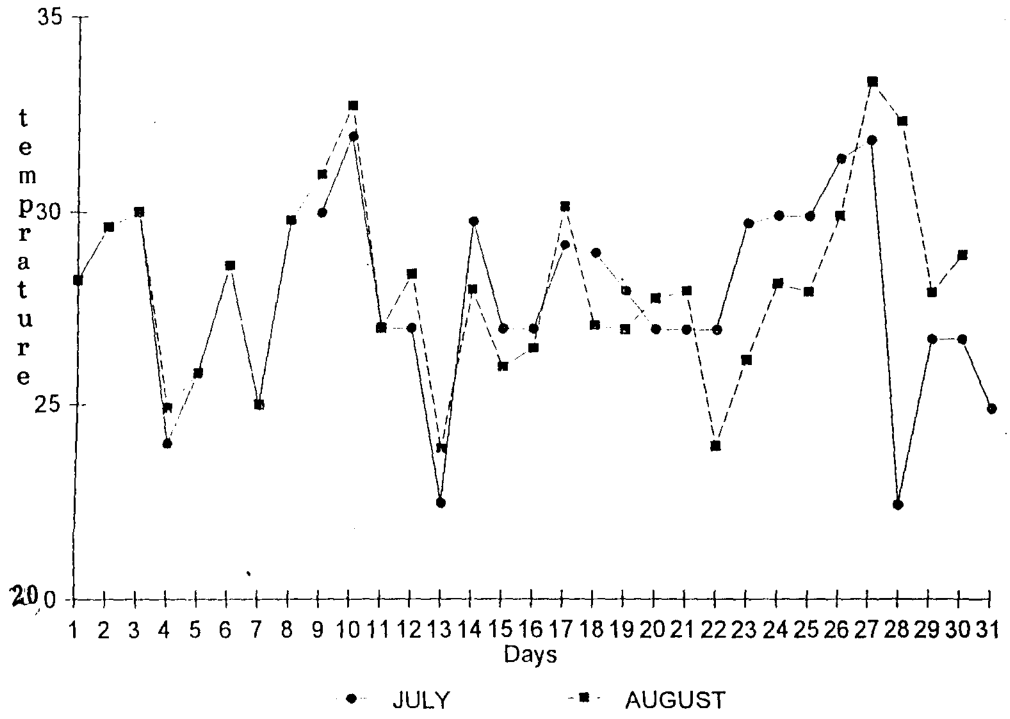

Fig. 1(b) AMBIENT TEMPERATURE (Degree Centegrade)
Afternoon

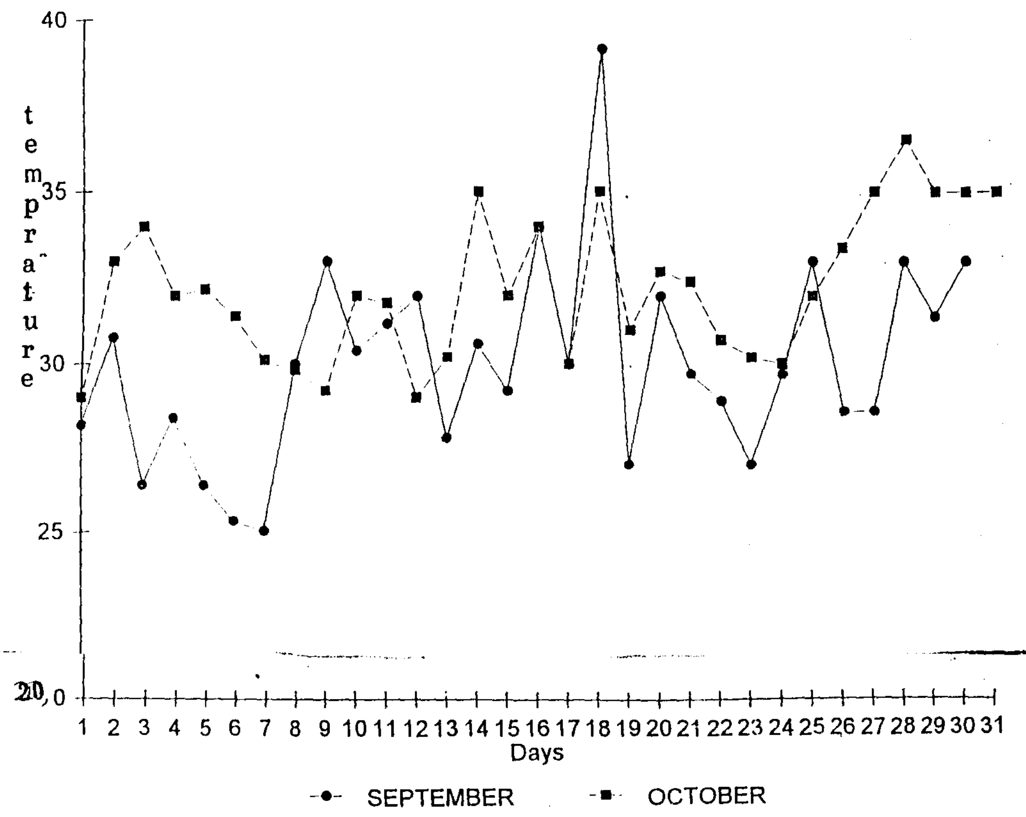

Fig. 1(e) AMBIENT TEMPERATURE (Degree Centegrade)
Afternoon

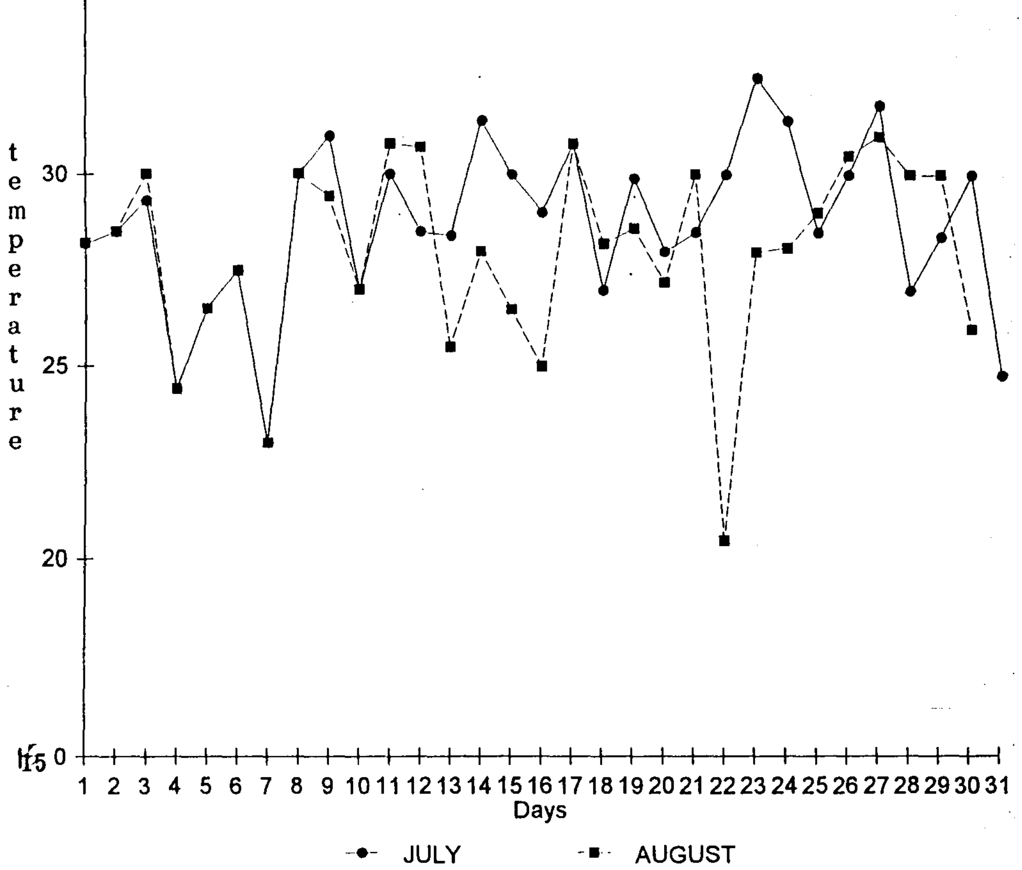

Fig. 1(c) AMBIENT TEMPERATURE (Degree Centegrade)
Evening

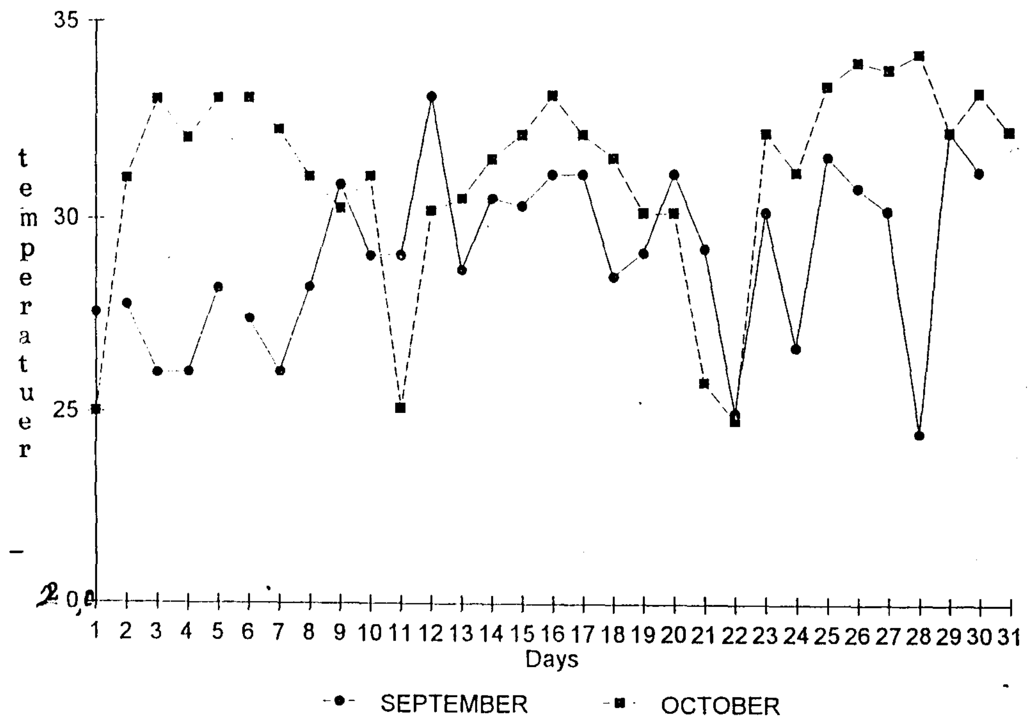

Fig. 1(f) AMBIENT TEMPERATURE (Degree Centegrade)
Evening

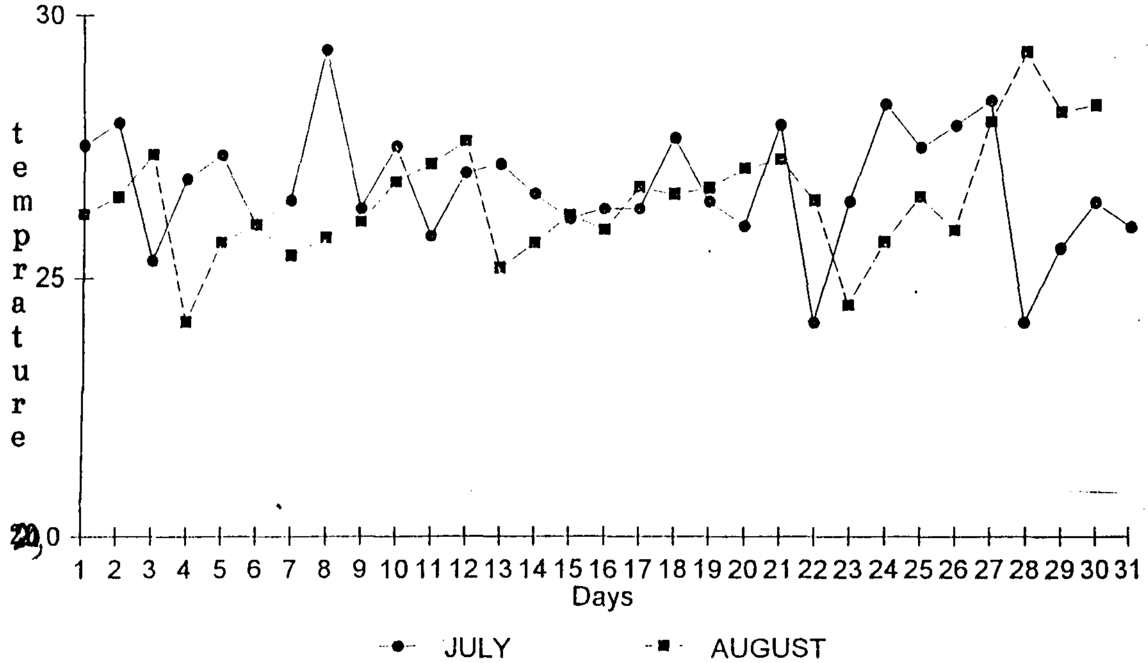

Fig. 2(a) **SILO** TEMPERATURE (Degree Centegrade)
Average Per Day

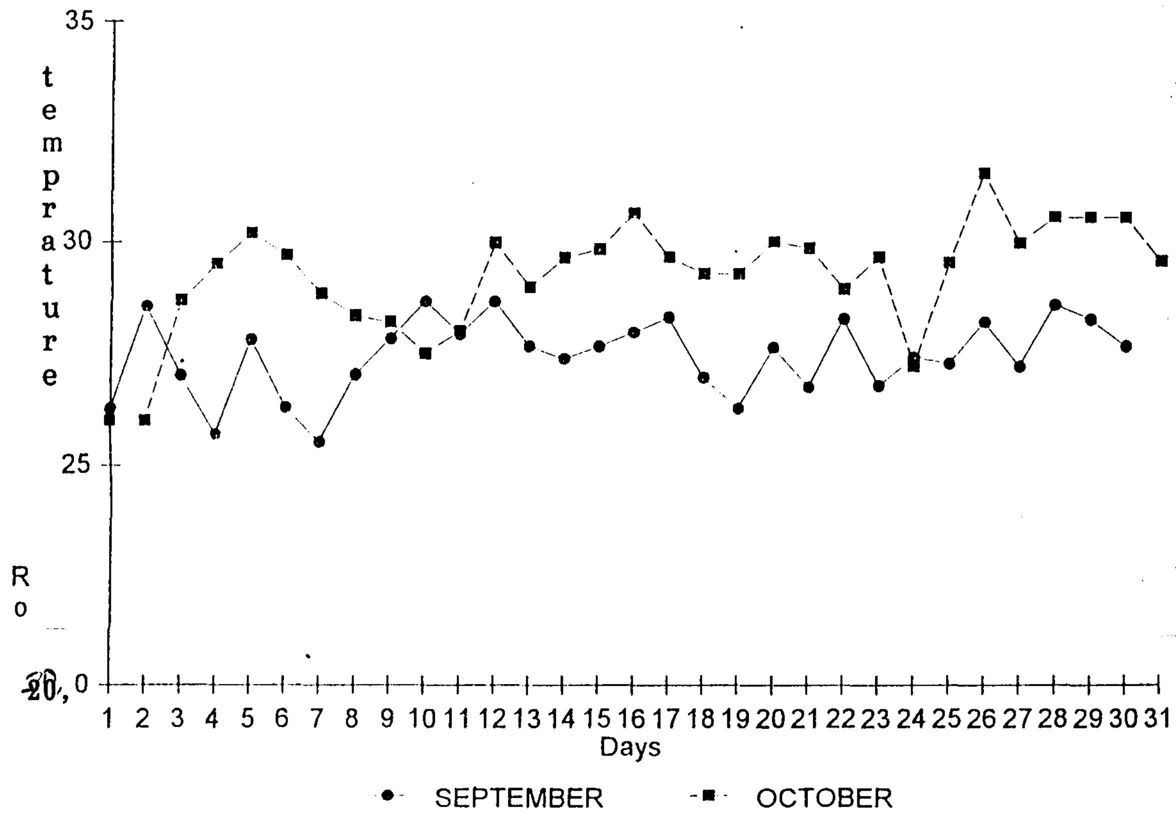

Fig. 2(b) **SILO** TEMPERATURE (Degree Centegrade)

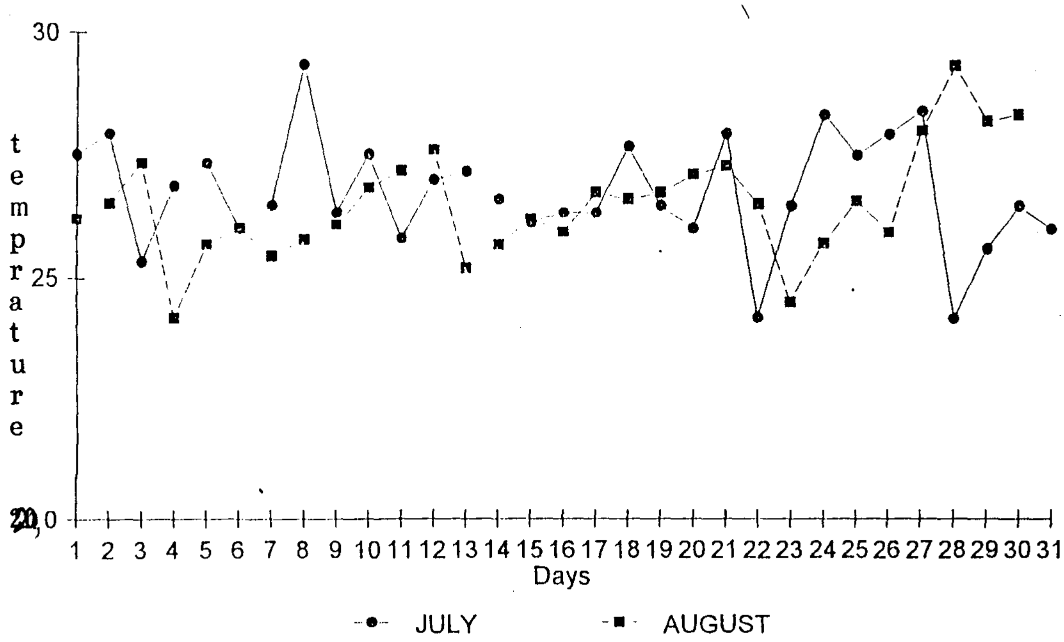

Fig. 2(a) SILO TEMPERATURE (Degrée Centegrade)
Average Per Day

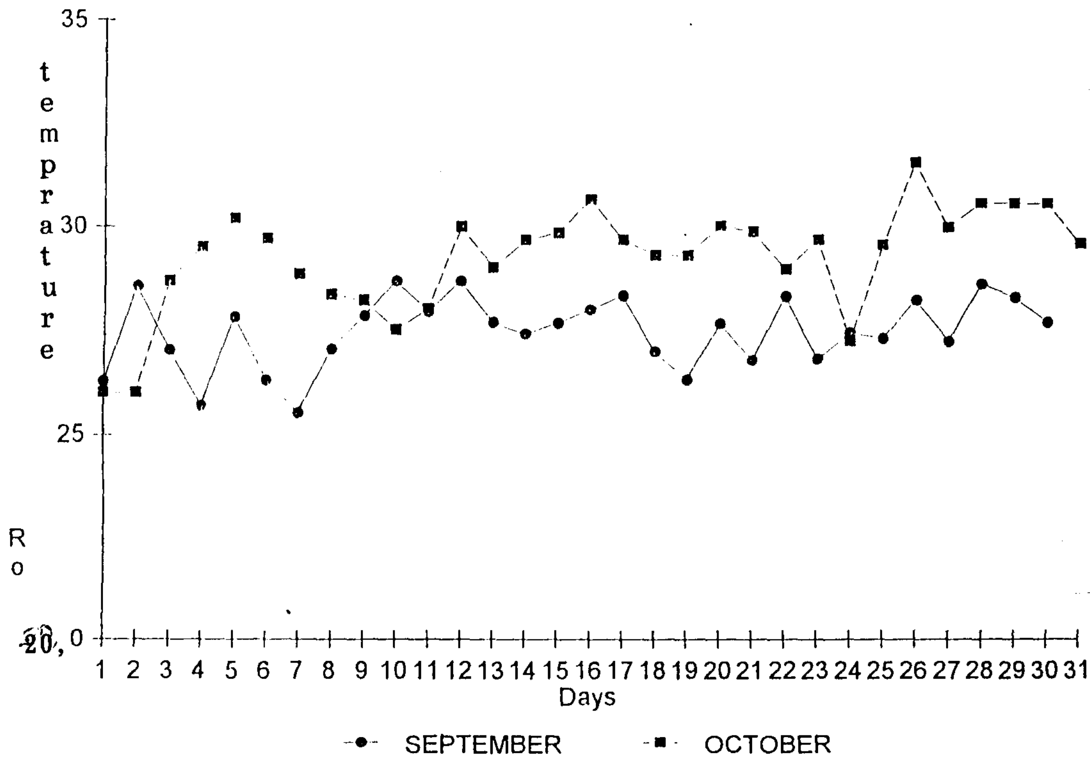

Fig. 2(b) SILO TEMPERATURE (Degrée Centegrade)
Average Per Day

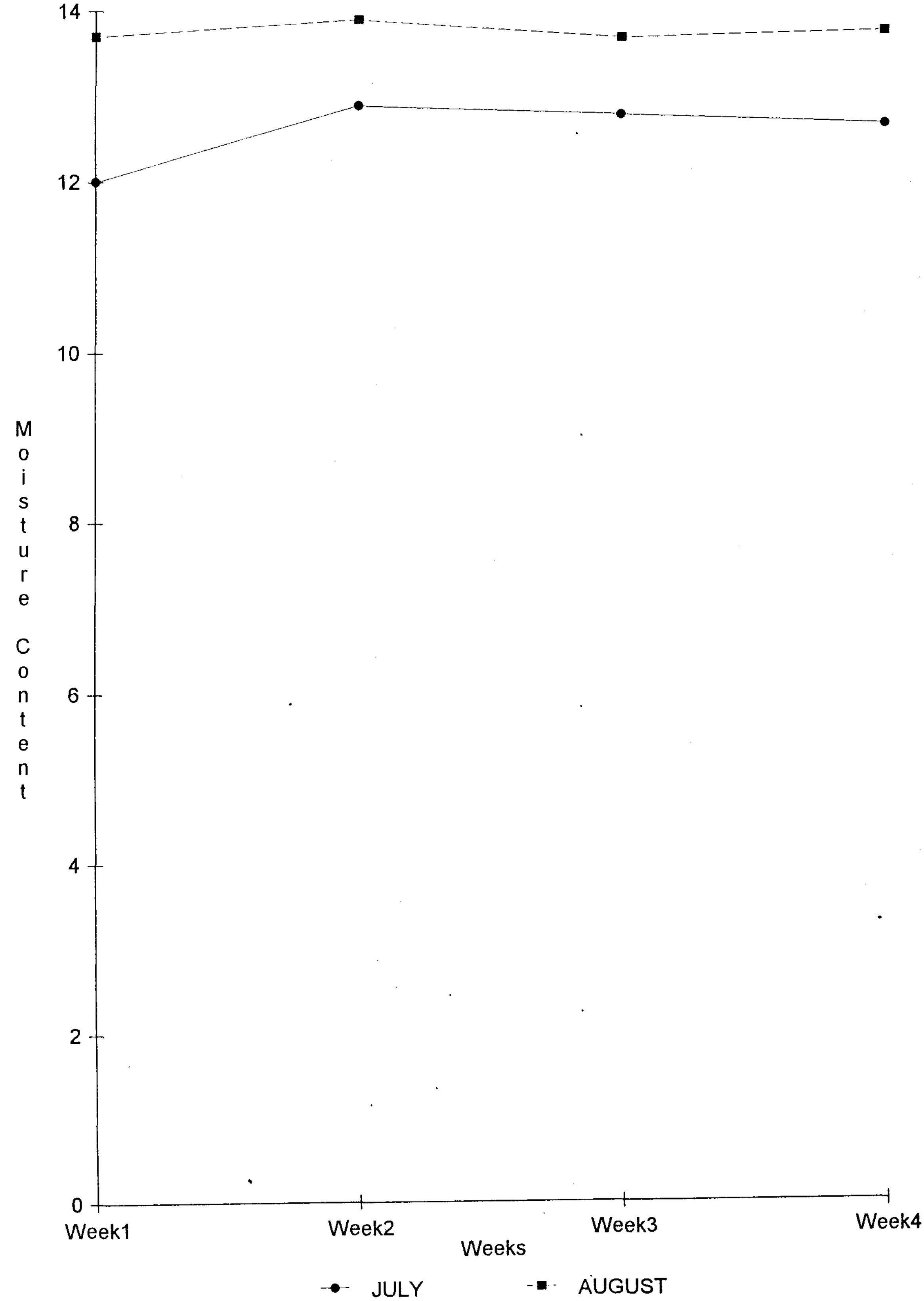

Fig. 3(a) MOISTURE CONTENT OF GRAINS (Percentage) Weekly

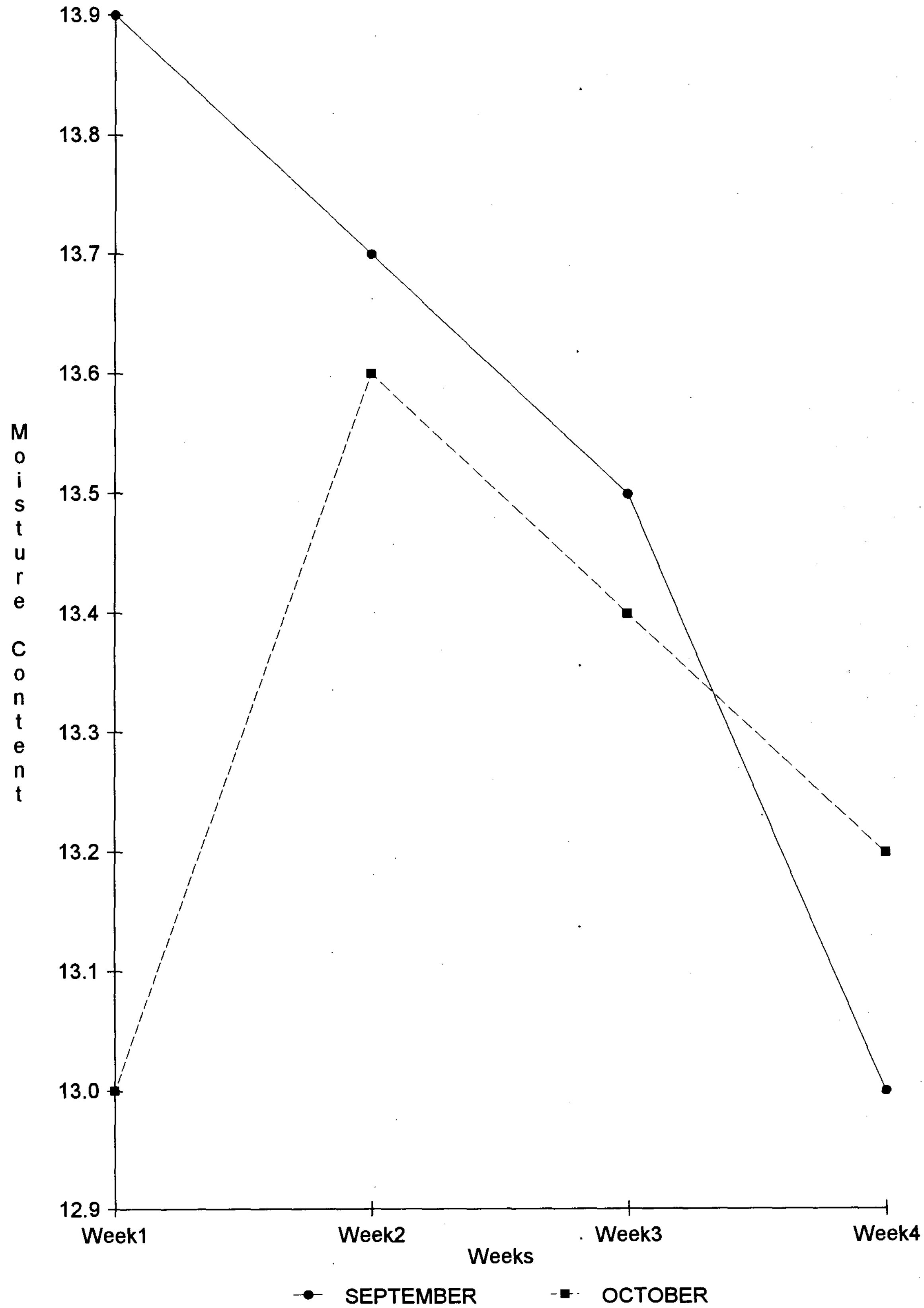

Fig. 3(b) MOISTURE CONTENT OF GRAINS (Percentage) Weekly

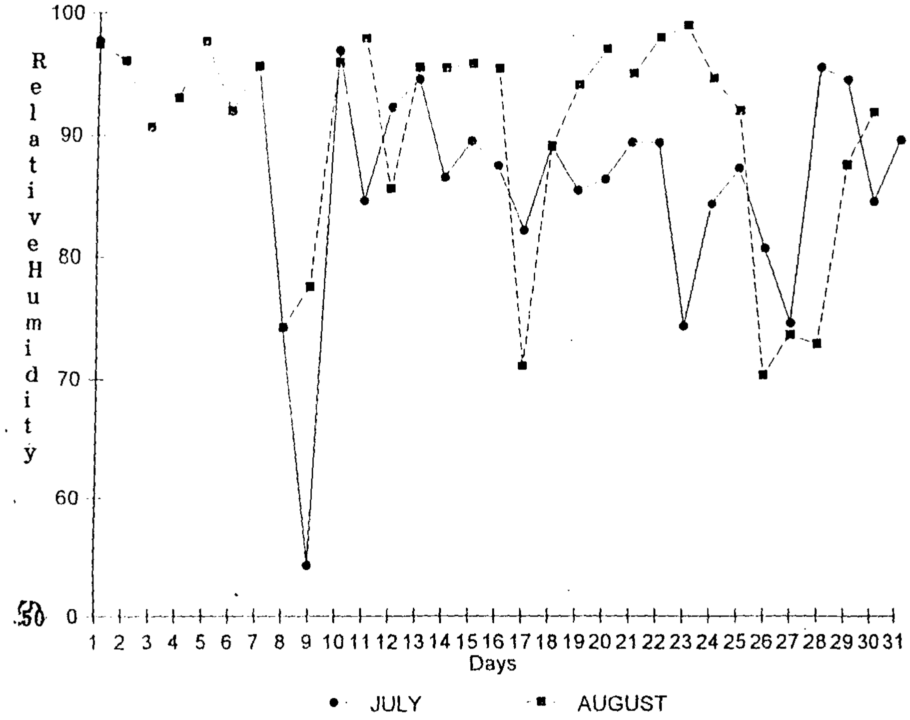

Fig. 4(a) RELATIVE HUMIDITY (Percentage)
Average Per Day

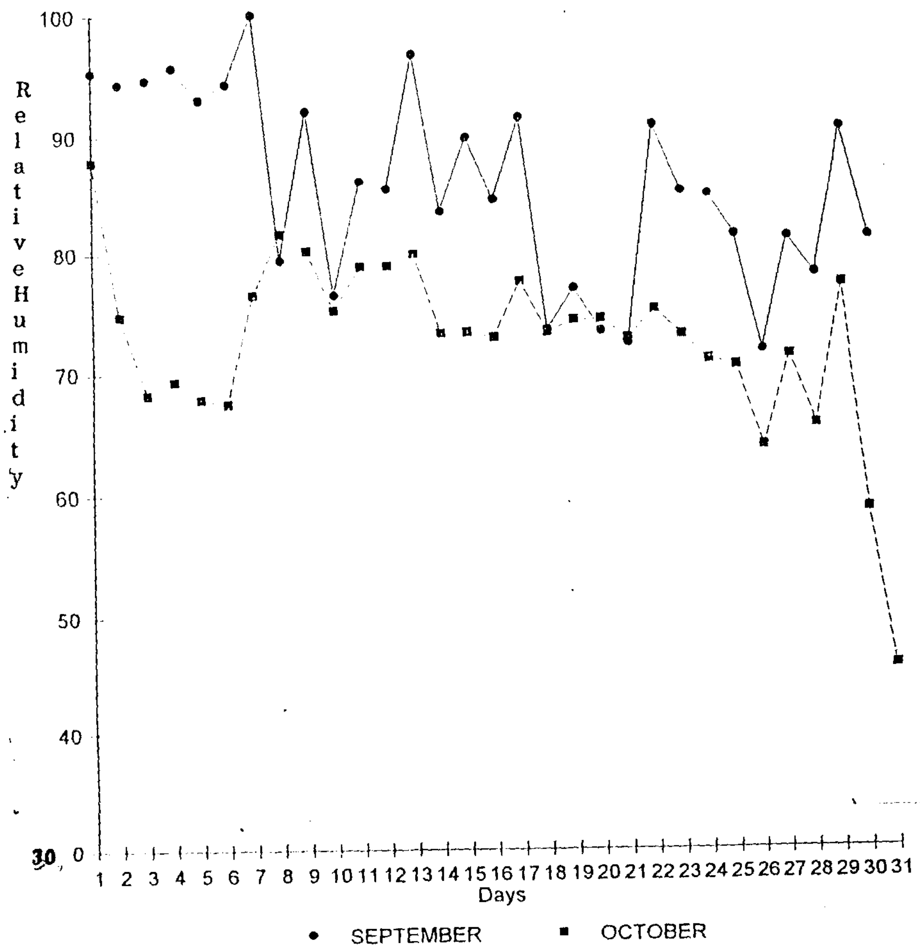

Fig. 4(b) RELATIVE HUMIDITY (Percentage)
Average Per Day