Sudan University of Science and Technology

College of Graduate Studies

Effect of Different Water Harvesting Techniques on Growth and Yield of Pearl millet (*Pennisetum glaucum*) Intercropped with Cowpea (*Vigina sinensis*) in North Darfur.

أثر تقنيات حصاد المياه المختلفة علي نمو وإنتاجية الدخن (*Pennisetum glaucum*)

عند تحميله مع اللوبيا الأبيض (*Vigina Sinensis*) بولاية شمال دارفور.

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy (Agric) crop production

By

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الآية

قال تعالى:

(قَالَ تَزْرَعُونَ سَبْعَ سِنِينَ دَأَبًا فَمَا حَصَدْتُمْ فَذَرُوهُ فِي سُنْبُلِهِ إِلَّا قَلِيلًا مِمَّا تَأْكُلُونَ)

صدق الله العظيم

سورة يوسف الآية (47)

Dedication

To the soul of my late father and mother

To my family brothers and sisters

To my friends colleagues and Teachers

With and respect

Mohammed.

Acknowledgements

First of all, praise to Allah for giving me heath and patience to accomplish and conduct this work.

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I am greatly indebted to the members of agronomy department who contributed to this work.

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Abstract

Two field experiments were conducted for two consecutive rainy seasons of 2011/12 and 2012/13 at Umhojar Village, Kabkabiya Locality- North Darfur State, Sudan to study the effect of different rainwater harvesting techniques on growth and yield of pearl millet intercropped with cowpea. The area lies on sandy clay loam soil at Latitude 13^{o}. $04^{''}$ N and Longitude $24^{o}.08^{''}$ E,). Split plot design with four replicates was used in which five water harvesting techniques viz.; W1 (Terracing system), W2 (V- shape micro- catchments), W3 (Contour bunds), W4 (Trapezoidal bunds method), W5 (rain fall control) were assigned into the sub plots whereas millet (*Pennisetum glaucum*) intercropped with cowpea (*Vigina sinensis*) were assigned into the main plots in addition to pure millet in monoculture.

The growth parameters measured were plant height, number of leaves/plant, leaf area index, stem- diameter and plant density, taken three times at seedling, flowering and maturity stage in addition to days to 50% flowering, days to maturity and straw yields. Yield parameters measured were; panicle length (cm), yield (kg/ha); and 1000- seed weight (g) of millet. For Cowpea the parameters measured were; number of flowers per raceme, number of pods per flower, number of seed per pod, 100- seeds weight (g) and total yield (kg/ha). In addition, soil moisture content at different growth stages (seedling, flowering and maturity) and at different depths (0-20cm, 20-40cm and 40-60cm) was also measured. Yield quality (nutritive value) in terms of protein content, fiber content and phosphorus content, ash (minerals) for both cowpea and millet were also determined. Results showed that**:** The general trend for soil moisture depletion increased from seedling to flowering stage and decreased at maturity stage, however, water harvesting techniques resulted in great effect on soil moisture content in three stages (seedling, flowering and maturity).All water harvesting techniques applied, increased soil moisture content at different depths (20- 40 and 60 cm) during the three growth stages

compared to rain fall treatment (control).All water harvesting techniques applied; were positively reflected in good crop establishment and improved yield components of both millet and cowpea compared to the control. Trapezoid bunds techniques (W4) significantly increased ($p \leq 0.05$) total yield and final straw yield at both growing seasons compared to other water harvest techniques which showed no significant effect on all parameters (growth and yield attributes).Results also showed that the interaction of intercropping and trapezoid bunds technique relatively gave higher productivity per fadden than other techniques in both seasons. Water harvest techniques had no significant effect on crude protein and different nutritive minerals such as Ca, K, P, Ash and crude fiber for cowpea but significantly ($p \leq 0.05$) increased crude protein, Mg and P percent of millet. Results showed that the interaction of intercropping and water harvest techniques significantly ($p \leq 0.05$) increased crude fiber of cowpea, ash and Ca for millet.

ملخص التجربة

أجريت تجربتان حقليتان لموسمين متتالين(2011-2012 و2012-2013) بقرية أم حجارة محلية كبكابية ولاية شمال دارفور – السودان التي تقع على خط عرض 13.64 درجة شمال و خط طول 24.58 درجة شرق في الاراضي الرملية الطينية اللوميه بهدف دراسة تأثير طرق حصاد مياه الامطار المختلفة علي النمو والانتاجية لمخلوطي الدخن .اللوبيا الأبيض. استخدم تصميم القطع المنشقة ذات أربعة مكررات لتنفيذ التجربة. شملت الدراسة خمس تقنيات لحصاد المياه هي: نظام التروس (W1) ، نظام شكل الحرف V للمساحات الصغيرة (W2) ، نظام نقاط الكنتور (W3) ، طريقة النظام الثلاثي (W4) وطريقة الزراعة العادية بالامطار(W5) كشاهد ، وزعت عشوائيا على الاحواض الثانوية ، بينما تم زراعة محصول الدخن مختلطاً مع محصول اللوبيا الأبيض ، وزعت على الاحواض الرئيسية بالاضافة لزراعة محصول الدخن منفردا (monoculture).

المعايير التي درست شملت : معايير النمو طول النبات ، عدد الاوراق/ النبات ، دليل مساحة الورقة ،قطر الساق، والكثافة النباتية اخذت ثلاث مرات حسب مراحل النمو المختلفة (مرحله الانبات ، مرحله الازهار و مرحله النضج) بالأضافة الي نسبه 50% ازهار،عدد الايام للوصول الي النضج ووزن انتاجية القصب.

. اما بخصوص معايير الانتاجية فقد شملت: طول السنبلة، الانتاجية لوحدة المساحه (طن /هكتار) ، وزن ال 1000حبه لمحصول الدخن ، اما بالنسبه لمحصول اللوبيا فقد تم ايجاد ؛ عدد الأزهار بالنورة ، وعدد القرون بالنبات، وعدد البذور بالقرن الواحد ، وزن ال 100 حبه ووزن البذور الكلي لوحدة المساحه (طن\ هكتار).

جمعت بيانات عن المحتوى الرطوبى للتربة على أعماق مختلفة (0-20،20-40 ،40- 60سم) مع مراحل النمو المختلفة (مرحلة البادرات والإزهار ومرحلة النضج) .

تم تحليل القيمه الغذائيه لمحصولي الدخن واللوبيا فيما تتعلق بنسبه البروتين , والالياف ونسبه المعادن (الكالسيوم ، البوتاسيوم و الفسفور). عموما إزداد معدل الأختلافات في الرطوبة من مرحلة الانبات وحتي الازهار ولكنها نقصت عند مرحله النضج، عليه أن الطرق المختلفة لحصاد المياه قد ادت الي تأثير واضح في المحتوي الرطوبي للتربة في مراحل النمو الثلاث (الانبات ،الازهار والنضج).

كل التقنيات المستخدمة في حصاد المياه؛ أدت الي زيادة معنوية ($p \le 0.05$) في المحتوي الرطوبي للتربه في كل الأعماق التي رصدت وفي المراحل الثلاث مقارنة مع للشاهد. تقنية النقاط الثلاثي

(W4) له تأثير معنوي ($p \leq 0.05$) **على الانتاجية والانتاجية النهائية للقصب** خلال الموسمين الزراعيين مقارنة مع التقنيات الأخرى ، كان اكثر هذه الانظمه تأثيراً علي الانتاجية الكلية **والانتاجية النهائية** للعشب في خلال الموسمين ، بينما **الانظمة الاخري لم** تكن لها أثر معنوي علي كل المعايير التي قيست . **أوضحت النتائج أن تفاعل** الزراعه المختلطه بين اللوبيا والدخن واستعمال طريقه حصاد المياه شكل V **اعطت اعلي** انتاجية للفدان مقارنة مع الانظمه الاخري في خلال الموسمين الزراعيين.

تقنيات حصاد المياه المختلفه ليس لها تأثير **معنوي** علي محتوي البروتين **الخام ومحتوي العناصر الغذائيه** المختلفه مثل الكالسيوم **و** البوتاسيوم **والرماد ونسبة** عنصر الفسفور وخام الالياف لمحصول اللوبيا ولكن لها تأثير معنوي($p \leq 0.05$) علي البروتين الخام والماغنيزيوم و**الفسفور للدخن**.

أوضحت النتائج ان تفاعل الزراعه المختلطه وتقنيات حصاد المياه المختلفة لها تأثير معنوي ($p \leq 0.05$) علي خام الالياف للوبيا ونسبه الرماد والكالسيوم لمحصول **الدخن** .

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CHAPTER ONE

INTRODUCTION

In Sudan Pearl millet (*Pennisetum glaucum*) is grown under rain fed conditions as the staple food for most of the inhabitants in Darfur and Kordofan states. Other important producing states include Blue Nile, White Nile, Sinnar and Gadarif.(Elgailani *et al*, 2013). However, pearl millet comes second to sorghum in terms of area of production, while low productivity is caused by many constraints that limit production in Sudan, among there is low rainfall as the crop is grown mainly under traditional rainfall farming method (Abu Elgasim 1989) .The valuable agricultural lands are being degraded by poor management and absence of crop rotations. The high crop productivity and heavy rains that have characterized the area before and during the sixties and seventies have markedly started to decline. In the semi arid zones of Darfur, rainfall is concentrated over short periods of time; accordingly, balancing water demand with its supply is difficult. The regularity and quantity of rainfall in Darfur has been decreasing with time due to many factors among which is the climatic changes, (Mohamed , (2000).

The annual rain in North Darfur which is situated in dry land is ranging between 200-300 mm/ annum, thus the interest in water harvesting is one of the most important work to ensure food crops and surplus for export (F.A.O 1996).

Many studies of rain were carried out in North Darfour for example the mean rainfall in Kutum has dropped from 345mm to 243mm between 1967 9and 1982 respectively, (Practical Action, 2005).In the Sudan, research on water harvest was practiced under tradition rain fed area e.g. Mohamed (2000) reported that in the western Sudan inhabitants devised several indigenous techniques for rain water harvesting (collecting) system, Like hafirs, rahads, fulas and terraces. (Omer and Elamin 1996) in Kordafan reported that the ploughting and contour bunding of gardud soil improved physical properties of soil moisture storage and sorghum yield. Many researchers believe that the key solution for Sudan situation is rain water harvesting (Ahamed and Eldaw, 2003). Intermediate Technology Development Group (ITDG, 1998) working food security water harvesting project in Northern Darfur State, explained that the C-shaped micro catchment plough and training helped farmer to cultivate Wadi soil and increase crop production.

Through intercropping the farmer could secure some leguminous crop production without reducing the staple cereal crop (millet) thus minimizing the risk of crop failures, in addition of getting higher returns than mono cropping in the same area. Intercropping is another issue in which simultaneous growing of two or more crops in the same field, (Legwalla, *et al* ,2012). Many intercropping studies were conducted in the semi-arid area the most common intercropping is cereal –legume combination. Yield advantage was mentioned by several workers. In Sudan, research on intercropping was undertaken in traditional rainfed during the period of 1985-2003.

The objectives of this study were to compare between the growth and yield of millet and cowpea intercropped to their monoculture. The study also aimed to determine the production of crops under rainfall conditions and water harvesting techniques under North Darfur conditions.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Many residence in the northern part of the Kekkabiya have been based primarily on nomadic and migratory grazing while in the south & east areas of Kebkabiya they depend mainly on rain fed agriculture, whereas, few others depend on herd stocking and dry season irrigated cultivation along wadis. Generally the food security of the area is based largely on livestock raring& crop production. Local farmers are still practicing their traditional ways of crop production, the main rain crops grown include, millet, sorghum and groundnuts. Irrigated agriculture is concentrated in Wadi Borgo, barya, Aramb, Nara, and its tributaries. Onion, faba beans, potatoes and other vegetables and forage crops beside mango and citrus trees are main irrigated crops,(KSCS, 2013).

2.2 Rain water harvest

Water is essential to all life- human, animal and vegetation, it is therefore important that adequate supplies of water be developed to sustain such life, as land pressure rises, much of this land is located in the arid or semi-arid belts where rain fall is irregular and much of the precious water is soon lost as surface runoff. Recent droughts have highlighted the risks to human beings and livestock, which occur when rains fall or fail, (FAO, 1991).

According to Proud (1988) the way to improve the soil moisture for use by plants, can be enhanced to managing the supply of water so that the losses through run-off and evaporation are minimized and managing the plant to reduce their demand for moisture. While irrigation may be the most obvious response to drought, it has proved costly. Now is there increasing interest in a low cost alternative - generally referred to as "water harvesting".

Water harvesting is the collection of runoff water for production purposes. Rain water harvesting has many definitions the common factor in the them is capture, diversion and storage of rain water from many uses in irrigation in which water is made available to the crop to satisfy its requirement, (Yassienm, 2010).

Bloom (2003) defined rain water harvesting as any physical or chemical or morphological processing done on the soil to benefit from rain water, either directly, helping the soil to store a high quantity of rain fall and reduce the flow velocity, or indirectly by collecting surface water runoff in drainage and storing area to use it for domestic use for human beings or animal consumption, supplemental irrigation, or for ground water recharge.

Water harvest can also be described as the complete facility for collecting and storing the runoff water (FAO, 1994).

Water harvest has also been defined as the interception and concentration of rainfall runoff and its storage in the soil profile for use by trees, crops, or by (grasses Proud, 1988). Oweis *et al*,2001) gave similar definition to Proud, (1988) by considering it as a concentration of precipitation through runoff and storage for beneficial use.

2.2.1 Water harvesting systems:

History of rain water harvesting has origins in many parts of the world. Various forms of water harvesting (WH) have been used traditionally throughout centuries. Extensive rain water harvesting apparatus existed 4000 years ago in the Negev Desert where runoff agriculture can be traced back (Gerson, 2003).Signs of early water harvesting structures in the Edom mountains in southern Jordan believed to have been developed about 9000 year ago (FAO, 1994).

Water harvesting systems dating back 4000 years or more have been described by (Evanari et al. 1971). These schemes involved the clearing of hillsides from vegetation to increase runoff, which was then directed to fields on the plains.

Flood water farming has been practiced in many parts of the world such as Arizona and northwest New Mexico for at least 1000 years ago, (Zaunderer and Hutchinson 1988). In the "Khadin" system of India, floodwater is impounded behind earth bunds, and crops then planted into the residual moisture when the water infiltrates. However," Pacey and Cullis (1986) described micro catchment techniques for tree growing, used in southern Tunisia, which were discovered in the nineteenth century by travelers.

The importance of traditional, small scale systems of Water Harvesting in Sub-Saharan Africa were reported by Critchley and Reij (1989). Earth bund systems example found in Eastern, western Sudan and the Central Rangelands of Somalia, and simple stone lines are used, in some West African countries.

Water harvesting awareness was raised for improved crop production arose in the 1970s and 1980s, with the widespread droughts in Africa leaving a trail of crop failures. The stimulus was the well-documented work on water harvesting in the Negev desert, (Evanari et al. 1971). In Australia and USA water harvesting techniques are applied for domestic and livestock water supply. Research is directed towards improving runoff yields from treated catchment surfaces. However, much of the experience with rain water harvest gained in countries such as USA and Australia has limited relevance to resource-poor areas in the semi-arid regions of Africa and Asia. (Critchley and Reij 1989).

2.2.2 Recent developments

Water harvesting techniques had been developed and improved to keep pace with the growing needs for water for agricultural domestic purpose. a rapid increase in water harvesting techniques and storage began in different parts of the world such as India, Palestine, Sudan, Iran, China and Kenya. This rapid increase had contributed to opportunity of modern material to be used in constructing the storage, tank, and catchments surfaces, Dams and large reservoirs were constructed using the ferro-cement, steel and other material to harvest and store water, in some arid zones (UNICEF,1989)

Water harvest projects have been established in Sub-Saharan Africa during the past decades. Their objectives were to reduce the effects of drought by improving plant production (usually annual food crops), and in certain areas rehabilitating abandoned and degraded land. But few of the projects have succeeded in combining technical efficiency with low cost and acceptability to the local farmers or agro pastoralists. This is be due to the lack of technical "know how" or also may be due to the selection of an inappropriate approach with regard to the prevailing socio-economic conditions, (Critchley and Reij 1989).

2.2.3 Future directions

Ideal systems should evolve from the experience of traditional techniques - where these exist. They should also be based on lessons learned from the previous implemented projects. Above all it is necessary that the systems are appreciated by the communities where they are introduced. Without communities support, and participation, projects are unlikely to succeed.

Water harvesting techniques are essential to the semi-arid and arid areas where the problems of, drought and environmental degradation and land pressures are most evident. It is an important component of the package of remedies for these problem zones, and there is no doubt that implementation of water harvest techniques will expand (FAO, 1994)

2.3 Classification of water harvesting

Classification of water harvesting techniques is as varied as the terminology (Reij et al. 1988). Rain water harvesting techniques have been developed for various types of water collection from domestic rain water harvesting schemes through the micro to the macro flood control levels. Two of the famous classification types of water harvesting techniques are given in figs (2-1 and 2- 2)

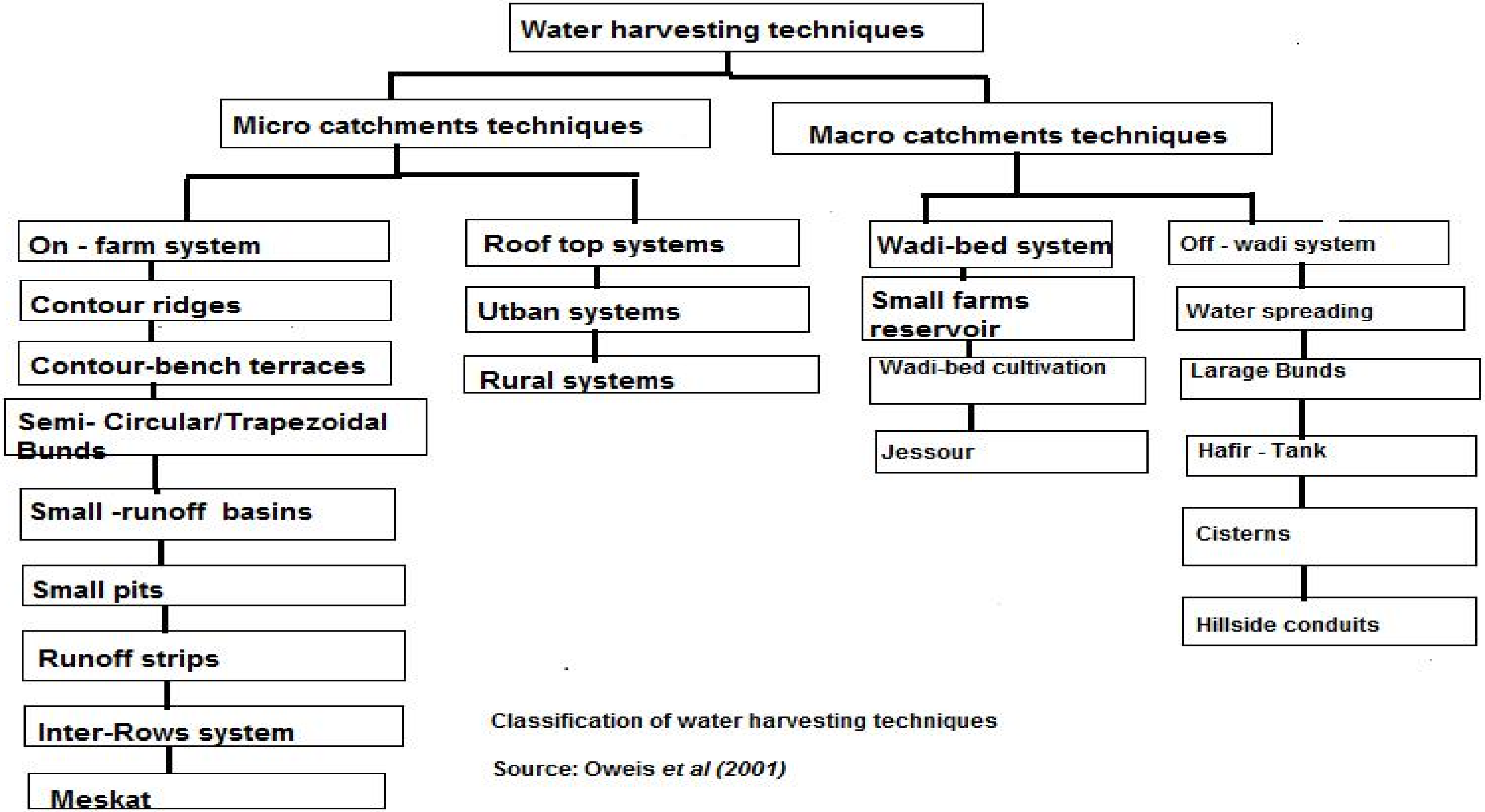

Fig 2.1: Classification of water harvesting techniques (Oweis 2001)

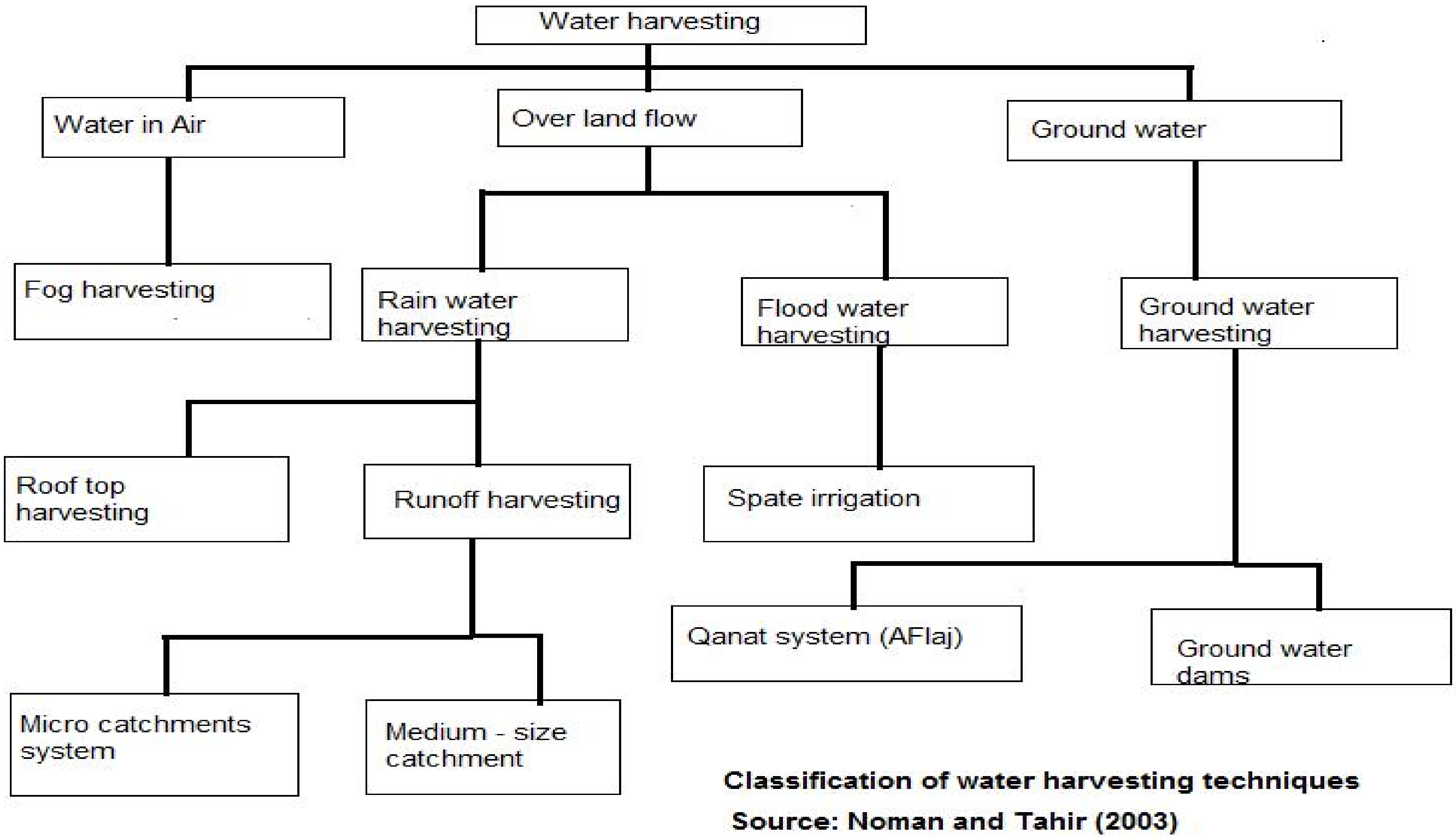

Fig 2.2: Classification of water harvesting techniques (Norman and Tahhir)

2.4 Rainfall and Water harvesting (Run Off)

Among the various factors affecting life and development in all parts of the world is water. Rain fall is the basic source of water and because of seasonal and variable nature; it is greatly limiting water availability for the different purposes, specially agriculture. Not all rainwater is available to plants (effective) because some losses occur in forms of evapotranspiration, deep percolation beyond the root zone and surface run off. If not properly utilized, surface runoff can be the major form of water loss (Mohammed. 2000)

Runoff is the portion of the precipitation which makes its way towards stream channels, lakes, seas or oceans (FAO, 1987). It is divided into surface , sub- surface and ground water components (Duriel, 1985). The water that travels over the ground or in stream channels is the surface run off (overland flow) in the upper layers of the soil, sub- surface lateral movement of water which has infiltrated may be considerable (through-flow or inter-flow) and may re-emerge at some point on the surface (return flow) and reaches stream or lakes. However, movement is less rapid than that of overland flow. Surface run off and interflow are viewed as direct runoff, which dominates the cumulative runoff, because no adequate method exists to separate them (Tauer and Humborg, 1992). Some water may percolate to deeper layers to become ground water some of which, by lateral movement, may eventually, seep into stream, lakes or oceans as ground water runoff or base flow (Jackson, 1989). Moreover, rainfall occurring where the main water table intersects the surface will also produce saturation overland flow.

Surface runoff develops either when rain fall intensity exceeds the infiltration capacity of soil (Bache and MacAskill, 1984) or when the volume of rain water exceeds the storage capacity of the soil (Dunne and Black, 1970). In the former mechanism, surface runoff occurs before the soil has become fully saturated, so is more appropriate on bare shallow soil, and on upper slopes. While in the latter mechanism, surface run off occurs after saturation of the soil, even with rainfall of low intensity and volume, because it occurs particularly in soils with shallow water table, thus, it is more likely on area near drainage channels (Tauer and Humborg ,1992) or with topsoil layers overlaying most impermeable subsoil or rock(Betson and Marius,1969). In both cases, runoff occurs on a partial area basis after the surface depressions are filled with water (FAO, 1991). For these reason, short- lived intense storms contribute more runoff than prolonged storms of low intensity (Hudson, 1981). This is because in the former case the infiltration capacity of the soil is exceeded, whereas in the latter case most of the rainwater infiltrates into the soil.

2.5 Causes and purposes of water harvesting:

Water has an essential role in sustaining life and development especially in arid and semi arid regions, the gap between water demand in terms of quantity and quality, and water supply is getting wider and wider. People all over the world are deeply concerned to bridge this gap by any means in order to survive (Yassien, 2010)

Water harvesting is an ancient method of water supply that has recently received more attention as a potential source of water, especially in area of erratic and uneven distribution of rain fall, where irrigation facilities are not available. The purposes for collecting rain water are to provide adequate water for arable land, fishing industries, domestic uses, animal consumption, strategic purposes (defensive purposes), recreational purposes and wildlife consumption. When the goal is to store water, as moisture, to support the plant growth the practice is sometimes referred to as runoff farming((Eger, 1989).

Agriculture is the major user of water, with an average of 69% over the world, followed by industry, with 23% and domestic uses (cities) with 8% (FAO, 1997). The World Meteorological Organization has estimated that water use had tripled in the last two decades and has been increasing at twice the rate of population growth.

In order to meet future food and water needs, attention has to be focused on better use of all available water resources by employing all possible techniques (Spore, 1997).

2.6 Water harvesting techniques:

Water harvesting is based on utilization of surface runoff and requires a runoff area (catchment area), for collecting and concentrating the precipitation, and storage area (storage facility) for holding the collected water for later use (FAO, 1994) the harvested water is either collected from direct rainfall or from rain water runoff which is generated from different types of catchments (water harvest areas). FAO (1998) has defined the catchment or watershed area as the area which supplies water by surface and subsurface flows from rain to a given point in the drainage system. Different types of catchments are used, in tropical and semi- arid area, to utilize rainwater such as roof tops, artificial and natural soil surfaces. Catchment areas can vary in size from a few square meters to several square kilometer.

There are several methods and techniques of natural surface catchments which are used to provide water for agricultural purpose such as contour furrows, micro-catchment techniques and runoff farming techniques by building high bunds, banks or terraces along the contour, water infiltrates slowly or evaporates and thereby crop can be planted (Pacey and Cullis, 1986)

2.6.1Terrace techniques:

Is one of the oldest and most widespread means of retarding runoff (and retaining a level strip of soil for planting) where ground is sloping, is terracing (Barrow, 1987). Terracing is earth embankments or combined channels and earth embankments constructed across sloping land, at fixed vertical interval, down the slop (FAO, 1971).

Terracing is known by different names in different countries and according to purpose of construction. Hudson (1981) stated that any earth bank with a strip of land above it is called bund, a terrace or contour ridge

Terracing has also been defined by Das (1977) as series of mechanical barriers across the land slope length and also to reduce the slope degree wherever necessary. This definition indicates that the main function of terracing is to break up slope , shorten the effective length and degree of the slope of the land and hold back runoff, thus reducing the hazard of erosion and runoff. Also through collecting, controlling and safely conveying the excess water , terracing can encourage water infiltration, improve moisture conservation and crop yield (FAO, 1971)

When improperly designed and constructed, terraces can create many problems to farmers. The exposure of less fertile subsoil or shallow soil may reduce crop yield. Irregular terrace layout, on irregular slopes, can retard the use of farm machinery (Kohnke and Bertrand, 1959). Terrace failure and consequent damaging runoff and land slide is also common in case of severe storm (Hudson, 1981)

2.6.2 Contour farming

Contour farming is the simplest way of retarding runoff for the cultivator to plant or plough along the contour (Barrow, 1987). Contour farming means plowing and planting sideways across the slope and along the contour. It includes formation of furrow, 25-35 cm deep and 2 m wide (Bensalem, 1877), or terrace every 30 to 40 m (USDA, 1984), additional as protection measures against runoff and erosion by water and to increase the surface storage capacity.

The contour furrows or terraces break up the slope and cause more of soil to be splashed uphill (Schwab and Frevert,1985), thus reducing erosion losses by 50% on slope less than 10% as compared to up- and – downhill operation. Also, through throwing the furrow uphill the downward movement of soil due to erosion can be checked (Fitzpatrick *et al*, 1970)

2.6.3 Trapezoidal bunds

According to FAO,(1991) manual the trapezoidal bunds are used to enclose larger areas (up to 1 ha) and to impound larger quantities of runoff which is harvested from an external or "long slope" catchment. Plant is sown within the enclosed area. Overflow discharges around the tips of the wing walls. The layout, consisting of a base bund connected to wing walls a common traditional technique in parts of Africa. The name is derived from the layout of the structure which has the form of a trapezoid -a base bund connected to two side bunds or wing walls which extend upslope at an angle of usually 135 degree. The concept is similar to the semi-circular bund technique: in this case, three sides of a plot are enclosed by bunds while the fourth (upslope) side is left open to allow runoff to enter the field. The simplicity of design and construction and the minimum maintenance required are the main advantages of this technique. Trapezoidal bunds can be used for growing crops, trees and grass. Their most common application is for crop production under the following site conditions:

Soils: agricultural soils with good constructional properties i.e. significant (non-cracking) clay content.

Rainfall: 250 mm - 500 mm; arid to semi-arid areas.

Slopes: from 0.25% - 1.5%, but most suitable below 0.5%. Topography: area within bunds should be even, (FAO, 1991)

2.7 Advantages of rain water harvesting

Rain water harvesting has many advantages; some of these advantages are reported by Ahamed and Naggar, (2003) as follows:

A – Rain water harvesting succeeds in providing good quality water for both irrigation and domestic use.

B- Rain water harvesting solves, to a great extent the problem of satisfying water requirement with time by smoothing out the variations in water availability, by collecting the rain water and storing it more efficiently, in closed reservoirs or dug pits.

C- Rain water collected and used in site can supplement, replace and become a relatively reliable source of household water.

D- Rain water harvesting has low input for its exploitation, and simple construction and management techniques.

E- harvesting rain water can reduce the use of drinking water for landscape irrigation. Coupled with the use of native and desert adapted plants, rain water harvest is an effective water conservation tools because it provides (free) water that is not from the municipal supply.

F- rain water harvest, not only reduces dependence on ground water, but also reduces the amount of money spent on water

G- Limitations of water harvesting are few and are easily met by good planning and design. There are many water harvesting opportunities on developed sites, even very small yards can benefit from water harvest.

2.8 Water harvesting in Sudan:

In the water- deficient arid regions of the Sudan the availability of water resources, throughout the year, and fertile lands have largely determined the population distribution pattern. The inhabitants of these areas such as the Northern parts of Darfur and Kordofan have devised several indigenous ways of collecting and storing rainwater for human and animal consumption during the dry season. Some of these techniques occurred naturally, where as others have been constructed or modified by man. Fulas, Turdas, Haffirs , Rahad, Seraf, rock wells, Baobabs tree trunk storage, burnt clay pot, barrels and empty oil drum, cisterns are techniques adopted to increase the year – round availability of water, for human and animal consumption, in different parts of the Sudan (Mohammed., 2000) .

The water provided by these supply sources, which are generated mainly from rainwater runoff, is below the needs of the inhabitants. This is because, in most seasons, the potential runoff water exceeds the storage capacity of the local system.The excess water can be utilized for crop production in these areas where rainfall is low and erratic (Ahmed and Nagger, 2003).

Mohamed (1994) has mentioned that the prerequisites for successful water harvesting involve the following:

1. A minimum mean rainfall of 80 mm per rainy season, if the rainy season coincides with cold period of the years more than 80 mm are required if the rain season occur during summer when evaporation rate is high.

2. Presence of impermeable soils on catchment areas

3. Soils in cultivated part with high water storage capacity in order to ensure an ample moisture supply for the crop during periods having no precipitation.

4. No more than 2-3% salinity in the cultivated soils.

Furthermore, Tauer and Humborg (1992) added that the topographic and climatic conditions must be appropriate for harvesting rain water and directing runoff to cultivate sites.

Several water harvesting techniques and agricultural practices were still practiced by local farmers, in sloping lands and in areas with variable and unreliable rainfall , to reduce the risk of crop failure, farmer adopted bench-terracing system, for many thousand year ago, the signs of which are still found in hilly areas such as Jebel Marrah (HTS, 1958).

Spore (1997) noted that water harvesting was developed by the ancient Nabateans over 3000 years ago the Jordan, and it is probably not a coincidence that very similar techniques have been developed and have survived in the Red Sea Hills of North - East Sudan and in Darfur region.

Earth bund systems are found in most parts of the Sudan, particularly in areas with clay soil of 100- 400 mm rainfall. In Kassala region, eastern Sudan, earth embankments (terraces) are constructed to intercept sheet- wash runoff , from adjacent catchment, following heavy storms Van DiJk and Ahamed,(1993), thus harvesting nutrients and controlling erosion (FAO, 1994).

Water spreading which is an ancient method of irrigation, is practiced in small and large scale farms in western and eastern Sudan. It is a technique in which flood water is diverted from a stream channel and allowed to flood over an adjacent land surface such as in Delta Tokar in eastern Sudan, and Khur Abu Habil in Kordofan (Mohamed, 1994)

Planting on river banks following falling water levels is still practiced which is locally known as Gerouf cultivation in North Sudan.

Limited research work has been carried out on the rain water harvesting for agricultural purpose in the Sudan.

Mulching and intercropping are practiced in small scale farms, mainly to modify the microclimate. Positive results were obtained especially for horticultural crop production (Abdel-Hafeez, 1976).

Salih and Ageeb (1983) studied the effect of water regime and mulching on yield of faba bean at Shambat and Wad Medani, they found positive results; increase in grain yield in both areas.

In western Sudan (Kordofan) many studies on gardud soil had been conducted during the last decades. Omer and Elamin (1997) found that chisel and 10-m contour bunds resulted in improved soil physical properties, soil moisture storage and crop yield as compared to other tillage system.

Mohamed (2000) studied the effect of water harvesting techniques and land slope on some soil physical properties, soil moisture status, soil loss, surface runoff and crop performance under Zalingei condition- western Sudan. He found that water harvesting techniques affected the soil structure and consequently its moisture content, infiltration rate, bulk density and porosity in upper the 30 cm layer.

Hamid (2004) found that the water harvesting techniques affect the soil structure and soil physical properties especially on the upper layer (0-30 cm). This is subject to excavation tools and consequently the soil moisture content as result of improving infiltration rate, porosity, field capacity and reducing rain water runoff.

Abdalla and Mustaf (2005) investigated the effect of the shape of micro-catchments water harvesting methods on sorghum growth, yield and water use efficiency at Mershing village north Nayala- western Sudan. They found that the C- shaped micro- catchment was the most effective in water harvesting, soil water conservation and crop growth and productivity.

2.9. Agronomic (Measure)

The principle of crop and vegetation is to utilize the role of plant cover in helping to conserve soil and water. They are inexpensive, easily adopted by farmers and more effective slopes (FAO, 1989). Agronomic measure proved adequate on areas of low rain fall intensities, permeable and less erodible soils and gentle slopes (USDA, 1984).

2.9.1 Millet

Pearl millet (*Pennisetum glaucum*) is believed to be originated in west Africa, it is now widely cultivated in different part of the World, the crop is the the sixth most important cereal crop in the World following wheat, rice, maize, barley and sorghum (Stoskopf ,1985). Millet is of great importance in the semi - arid where it's the stable food for millions of people, the crop grown under the most difficult farming condition, drought- stricken area, low soil fertility, and food supplies are depending on rainfall Abdellateef, (1995). Peal millet growing area suffer from erratic rain fall which has high within and between year variability,(Vanderlip, 1991), the crop is a dual – purpose crop, its grain is used for human consumption and fodder which serves as a feed for animal.According to Adam (2002) dry zone accounted for more than 50% of the Sudan in addition to the area of the desert which represents one third of the country.

Pearl millet (*Pennisetum glaucum (L). R. Br*) belongs to the family Poaceace Sub family Panicoideae, section Penicillarium, that originated in western Africa and was introduced to eastern Africa and India sub continent many years ago (Gill,1991). The term "millet" is applied to various grass crops whose seeds are harvested for human food or animal feed. Sorghum is called millet in many parts of Asia and Africa, and broom corn is called broom millet in Australia.

peal millet ranks the sixth among the cereals in the world in term of production, after wheat, rice, maize, barley and sorghum, the Sudan production is around 1.055 millions Mt with an average grain yield of 400 Kg/ha in 2014 (FAO, 2015). The crop is locally known as "Dukhun", which is one of the important cereal crops in the Sudan, coming as the second most-important cereal crop, after sorghum in both area and total production. It is the preferred staple food crop for the majority of the inhabitants of western Sudan (Kordofan and Darfur States).

The average total area annually planted in the country is about 6 million feddans (2.5 million ha). About 95% of this area is found in Western Sudan. (Abulgasim, 1997).

2.9.1.1 Adaptation

Millet is well adapted to dry, infertile soil than most other crops, and is therefore cultivated under extremely hard conditions, for example, high temperature, low erratic precipitation, short growing season and infertile soil with poor water holding capacity, most millets have strong, deep rooting system and short life cycle, and growing rapidly when moisture is available. As the result, they can survive and produce small quantities of grain in area where mean annual precipitation is as low as 300 mm per annum, compared to minimum water requirement of 400 mm for sorghum and 500-600 mm for maize (FAO, 1996)

2.9.1.2 Soil

Since pearl millet is a drought and heat tolerant crop capable of producing grain in regions of low soil fertility and limited moisture, where other summer cereals like sorghum and maize, may fail, it occupies the marginal low-rainfall areas of western Sudan. This is mainly due to its extensive and more efficient root system, as well as its high ability to produce tillers. Although the crop is grown in areas where rainfall ranges between 200 mm to more than 1000 mm, most of it occurs in areas receiving 250-700 mm.

In Western Sudan Region, most of the pearl millet production is centered in the extensive sandy soils “Goz” occupying the northern parts of the region. Reff. These are marginal areas with less than 400mm rainfall. In these areas, pearl millet is the most extensively grown crop, and therefore, a millet-based farming system prevails. However, the cultivation of the crop extends further south into the clay soils where rainfall goes up to 700 mm. Within these southern areas, usually locations of lighter and sandier soils are used for pearl millet (Abulgasim, (1999).

2.9.1.3 Chemical composition of Millet grain

The grain of pearl millet is comparatively more nutritive than the grain of other cereals, its protein content is not high, it ranges from 11.31- 19.62% but protein is of good quality, however, the crop is deficient in lysine (Gill, 1991)

2.9.1.4 Utilization

In Europe and North America, pearl millet is chiefly cultivated for livestock and poultry feed. It is grown extensively for human food in Asia, Africa and countries of the former U.S.S.R, Millet is high energy, nutritious food, especially recommended for children, convalescents and the elderly, it is nutritionally equivalent or superior to other cereals (Anon, 1996).

The grain is consumed as human food mainly in the form of porridge, called "aseeda" or in the form of a thin pancake called "kisra". The stalks can be used as feed for animals but they are mostly used as building material or fuel. (Abulgasim. 1997).

2.9.2 Cowpea

Cowpea *Vigina sinensis* is originated in Africa where it was domesticated in Neolithic age. Cowpea is cultivated in tropical, subtropical and warm temperature region of the word. In Africa it is grown chiefly in sub- Saharan lowlands, in East Africa and from Ethiopia to the cape. cowpea is cultivated extensively in 16 African countries yield two third of world production ,estimated at 2.5 million tons of dry beans, the main African producing countries are Nigeria, Niger, Burkina Faso, Ghana, Kenya, Uganda, Malawi and Senegal (Romain and Raemaekers, 2001) need more information about cowpea ,

2.9.2.1 Adaptation

cowpea is well adapted to semi- arid regions with annual precipitation of less than 600 mm, and sub –humid zones (1000- 1500 mm) some cultivars are very drought- resistant, the plant does not withstand frost and growth may be affected by excessive heat. Cowpea is a low- altitude plant and as a rule is not grown above 1000-1200 m above sea level (Romain and Raemaekers, 2001) .

Skerman *et al*. (1988) reported that cowpea is tolerant to moderate shade and can be crown with tall crops such as maize, sorghum, the crop prefers warm moist condition, and it was found that a day temperature of 27 C gave optimum growth but it is sensitive to cold conditions.

2.9.2.2 Soil

Cowpea is tolerant to a wide range of soil textures from sands to heavy, well-drainage clays. It is adapted to a wide range of pH, but prefers slightly acid to slightly alkaline soils. It has little tolerance to salinity (Skerman *et al*, 1988, and Romain and Raemaekers 2001)

2.9.2.3 Chemical composition of cowpea grain

Romain and Raemaekers (2001) reported that cowpea seed contain on average per 100 g of edible matter, 10.0 g water, 22.0 g protein 1.4g fat, 59.1g carbohydrate 3.7g fiber, 3.7g ash, 1.04 g Ca and other element. Skerman *et al* (1988) stated that the seed contains 24% crude protein, 53% carbohydrate and 2% fat.

2.9.2.4 Utilization

Singh *et al*,. (1997) reported that cowpea is important for the livelihood of millions of relatively poor people in less developed countries of the tropics. Cowpea is an important legume in the tropics and has many uses. In fresh form, the young leaves, immature pods and peas are used as vegetables while several snacks and main meal dishes are prepared from grain. All parts of the plant are used for food and nutritious, providing protein, vitamins and minerals. The cowpea haulm is also a source of livestock feed.

2.10 Intercropping

Intercropping is the mixing or inter planting of two (or more) crop species, simultaneously or partly overlapping, on the same area of land in the same season (Ker, 1996 and Willy, 1979). In the literature, the words intercropping, mixed cropping, mixed culture, poly culture cropping system, companion planting and cropping in association are used as synonymous.

Intercropping is an old practice of cultivation and an important characteristic of traditional farming systems in tropics and sub tropics in Africa, Asia and South America (Yunusa, 1989). It was practiced in China 2000 years ago (Mitchell, 1984) and continues to be an important component of Chinese agriculture.

Although it is a common practice in developing world, intercropping was common cropping system in south eastern U.S.A before mechanization (Knaft, 1984)

Historically, it has been regarded as a primitive practice, but recently it has been realized that intercropping remains an extremely wide- spread practice and is likely to continue so far at least for the foreseeable future (Willey, 1979)

2.10.1 Intercropping of cereals and grain legumes

Biological N_2 fixation occupies an important place in soil N- cycle. Legumes are the major source of N_2 fixation. It is generally accepted that N_2 fixation by legumes reduce the rate of soil N_2 depletion and a major part of nitrogen fixed by legume crops become available directly or indirectly to associated or succeeding crops (Christianson, 1988). Osman and Elamin (1996) have shown that ground nut yields were considerably higher in mixture than in monoculture when intercropped with millet rather than with sorghum or sesame were recommended because they gave higher yield and land equivalent ratio. Osman, (1996) indicated that intercropping has yield advantage and proper resources utilization compared to sole crops. Intercrops suffer less disease than pure crops, because the density of susceptible plants is lower. The non-susceptible crops act as barrier to spread of disease Sullivan, (2001) and Degri, *etal*. (2014) studied the effect of intercropping on panicle weight and grain yield of pearl millet intercropped using different patterns. For pearl millet intercropped with ground nut using the pattern of 1:1 ratio and1:2 ratio panicles weight (1049.20 kg and 1249.33 kg) and grain yield (975.62 kg and 1209.33 kg/ha) were significantly higher than from crops intercropped using the pattern of 2:1 ratio as well as the sole crop (1:0 ratio), however, that was lower stem borer infestation rates and abundance as well as higher panicle weight and grain yield, the intercrop pattern of one row of pearl millet to one (1:1 ratio) or two (1:2 ratio) rows of ground nut tested in this study proved to contribute greatly in managing the attack and destruction or losses caused by these pests in pearl millet.

2.10.2 Advantages and disadvantages of Intercropping:

Although knowledge is lacking regarding the interactive effects of plants in mixtures, but through intercropping, non-legume with a legume crop, the following merits could be achieved Arnon, (1975); Netting *et al*, 1978; Singh and Jha, 1984; Brandjes, (1989), and Alemseged, 1991) reported the following advantage:

1- Plants with different rooting behavior and growth cycle, can exploit the soil (water and nutrients) and light more completely.

2-intercropping provides security, reduces and spreads labor peaks, minimizes the risks of pest and disease incidence (Ofori, 1974) and total crop failure (Fisher, 1977) through diversity, and thus providing a high balanced diet and greater stability of yield over different seasons.

3- Mixing nitrogen- fixing legumes with the other crops gives the advantages of implicit rotation within each year rather than from year to year.

4- Total yield and gross returns per unit area are relatively higher and more stable than those of pure stands.

5- The dense basal and aerial covers that are produced by the intercrops have good effect on smothering and reducing weed competition, intercepting more light energy and protecting the soil from action of rain/wind and reducing evaporative losses.

These advantages are probably the main reason for the persistence and widespread adoption of this system among subsistence farmers, and ordinary outweigh any reasonable objections which can be made to intercropping.

In spite of these advantages it must be mentioned that there can be some disadvantages of intercropping. Being traditional cropping system, intercropping is handicap to mechanization and yield increasing innovations (weed control, pest and disease control, rational fertilizer application …etc.) which are suited in pure stand. The adverse competitive effects can reduce the yield of intercrops under severe drought conditions as compared to sole cropping.

2.10.3 Cropping patterns:

There are four cropping patterns associated with intercropping systems (Netting *et al,* 1978):

1- Strip cropping patterns.

2- Row intercropping, which is the central concept of intercropping and consists of two methods?

i- Inter-row intercropping.

ii- Intra-row intercropping.

3- Random cropping pattern (also known as mixed intercropping)

4- Relay intercropping.

2.10.4 Intercropping combinations:

Under rain fed condition, in developing countries, cereals are seldom grown in pure stands but in mixtures with other crops. The combination often consists of cereal and legume, with the cereal being considered as a base crop (Venkateswarlu and Subramanian, 1990). Similarly, mixtures of grasses and forage legumes are common in many temperate countries (Narmbiar *et al*, 1983).In Nigeria, mixed cropping with two to six types of plants, interspersed in the same field, is common in Hausa agriculture (Netting et al, 1978).In Tanzania, sorghum, maize or millet is intercropped with a legume such as groundnuts, bean, cowpeas or green-gram (Nyambo et al, 1980)

In India, intercropping of upland rice with grain legumes such as cowpeas, groundnuts, pigeon pea and green gram is common (Ramakrihna and Ong, 1994).

Intercropping of perennials such as banana, furit trees, cassava and cocoyam with low-growing annual crops have been reported in Africa, Asia and Latin America (Rao and Edmunds, 1984,and Ikeorgu and Odurukwe,(1990).

In Sudan, intercropping is practised by rain fed subsistence farmers mainly in the Northern, Southern and Western states. The most popular combinations are sorghum, millet with sesame cowpea, groundnuts and/or water melon, sorghum or millet with sesame or Karkadeh (*Hibscus sabdariffa*) in western Sudan. In the Northern State, sorghum or maize is intercropped with legumes such as cowpeas.(Mohamed,2000)

In selecting combination of crops the growth habit of each crop, the climatic and economic conditions and the personal preference of farmers have been considered. Various studies found a scope for achieving greater productivity by growing the late and early maturing genotypes together in an intercropping system (Andrews, 1972, Bebawi, 1983; Ntare, 1990 and Reddy et al, 1990)

2.11. Effect of intercropping on vegetative growth

Enyi (1973) found that intercropping a cereal crop with cowpea or pigeon pea tended to increase its height. In Sudan Gezira Ibrahim, (1994) reported that most mixtures showed higher plant height than sole crops. In another study, there was almost no significant difference in cereal plant height in pure stand and intercrop system (Farist *et al*, 1983). In another experiment, 14 sorghum verities grown in pure stands or intercropped with soybeans showed significant differences in plant height of sorghum (Dabhokar *et al* 1985).In field experiment three cereals (maize, millet and sorghum) were combined with two legumes (soybean and green gram). Number of leaves in the legumes in three different arrangements showed only a slight variation, indicating that photosynthetic activity was almost uniform (Nyamba *et a*l, 1980).Wahua Miller (1978) showed that intercropping sorghum with soybean decreased the number of seeds per head of sorghum and attributed this to the effect of shading which might have reduced the number of seeds by reducing sorghum photosynthesis. Bandyopadhyay an De, (1986) showed that the number of sorghum grains was influenced significantly by intercropping treatments. The number of grains was highest in sorghum with groundnut intercrops and lowest in sole sorghum.

2.11.4 Number of pods per plants

Intercropping cereal sorghum with pigeon pea or mung bean caused in reduction in number of pods only in pigeon pea but both number of pods and number of grains/pod in mung bean (Subramanian and Rao, 1988)

Farist (1983) showed that in sorghum intercropped with cowpeas or common bean, unfertilized common beans produced significantly more pods/plant in intercrop systems as compared to pure stands. Under better moisture regime and with fertilizers, the pulses produced greater number of pods and seed size was increased slightly, except in case of cow pea under sorghum. The fertilized sorghum with cow pea system gave higher number of pods/plant compared to the monocrop system, (Nyambo et al, 1980).

2.11.5 Number of seeds/pod

Wahua and Millar (1978) reported that number of seeds per pod was reduced by 12% in soybean mixture with sorghum. Farist (1983) reported that intercropping sorghum or maize with cowpea or common beans increased the number of seeds/pod in both legumes with unfertilized sorghum, whereas the fertilized sorghum with cowpea gave increased number of seeds/pod compared to monoculture.

2.11.6 Seed weight

Salih (2002) found that application of chicken manure and inoculation significantly increased 100 seed weight of soybean seeds in both monoculture and intercropping. Intercropping of sorghum with soybean increased 100 seed weight of soybean seed but the increment was not significant. Farist (1983) reported that intercropping sorghum or maize with cowpea or common beans reduced 100-seed weight in intercropped cowpea in comparison to pure stand.

Farist *et al*, (1983) showed that cowpea when intercropped with sorghum or maize cowpea or common beans, no significant differences in cereal seed weight between pure stand and intercropping system were observed. Bandyopadhyay and De, (1986) showed that intercropping of sorghum with groundnut or cowpea treatment, significantly influenced 1000 seed weight of sorghum.

2.11.7 Seed yield/hector

Mailafiya, and Degri (2012) studies indicated that crop diversification through intercropping, such as cereal with legumes, is effective in reducing insect pest damage and increase the yield. Bandyopadhyay and De (1986) showed that the grain yield of legumes was reduced when intercropped with sorghum. Edje ,(1982) stated that intercropping maize with groundnut was significantly reduced seed yield. Rajendra, and Hegde,(1996) investigated the effect of intercropping on cow pea, soybean, *Setaria italica*, sorghum and *Pennisetum typhoides*. They reported that none of the intercrops was able to improve the grain yield of intercropped pigeon pea over the yield of sole pigeon pea. However, the total economic return from cowpea, soybean and Setaria italica intercrops were more than from the monoculture. Reddy, (1980) found that the yield of pigeon pea in other mixed stand was greatly decreased, especially with intercrops of sorghum and cow pea or *Vigna Radiata* but they gave the highest pigeon seed equivalent yield of 2.52 -2.72 t/ha. Raw and Willey (1980) reported that cowpea was drastically suppressed by intercropped sorghum. In intercrops of maize or sorghum with cowpea or pigeon pea, grain yield of legume crops was significantly higher in sorghum than in maize plots (Enje 1973.and Myaka 1995). Maize increased cowpea yield by 59% compared with alternating single rows with maize.

CHAPTER THREE

MATERIALS AND METHODS

Two field experiments were conducted during the season 2011/2012-2012/2013, under rain fed condition, to study the effect of water harvesting techniques on growth and yield of pearl millet intercropped with cow pea.

3.1 Location

Kebkabyia locality is situated in the western part of North Darfur State, Sudan, Appendix (1), latitude 13 38^o Longitude N- 24 04^0 E, and politically divided into two administrative units,(Kebkabyia and Jabel SI areas). It is a productive area from Agriculture, natural resource and animal point of view, due to its moderate soil fertility and climate suitability Appendix. (2), (HIC, 2005).The experiments were carried out at Umhojora Village, three kilometer from Kabkabiya town, North Darfur State, latitude 13. 64 N and Longitude 24.58 E, with altitude of 850m above sea level). (Fig 3.1).

3.2 Site description

The area lies on semi- arid- savannah zone, which is affected by the elevation of Jabel Marra Massif (rain and temperature) for the larger part of area under consideration The climate is generally characterized by cold dry winter and hot rainy summer, The average temperature does not significantly vary between months, especially during the rainy season, where the relative humidity is high. The annul mean temperature ranges from 25C^o- 27C^o. the hottest month during the year is May (20C^o min-42C^o max), while the coldest month is January (10C^o min-35C^o max). (ClIft – Hill,1987,HTS,1958,1995)

The rainy season usually begins in first July and extends to first of October, with occasional limited showers in May and November. The average rain during the last ten years varied from 279mm to 561mm per annum (KSCS

2013). The annual rain at the experimental site during the course of study was measure by the rain gauge installed at the site (Appendix 3) .

The Soil of the area is closely related to geology and geomorphic development of various land surfaces (HTS, 1994). Soils are rather shallow and compact, derived mainly from the basement complex rocks and volcanic material, with

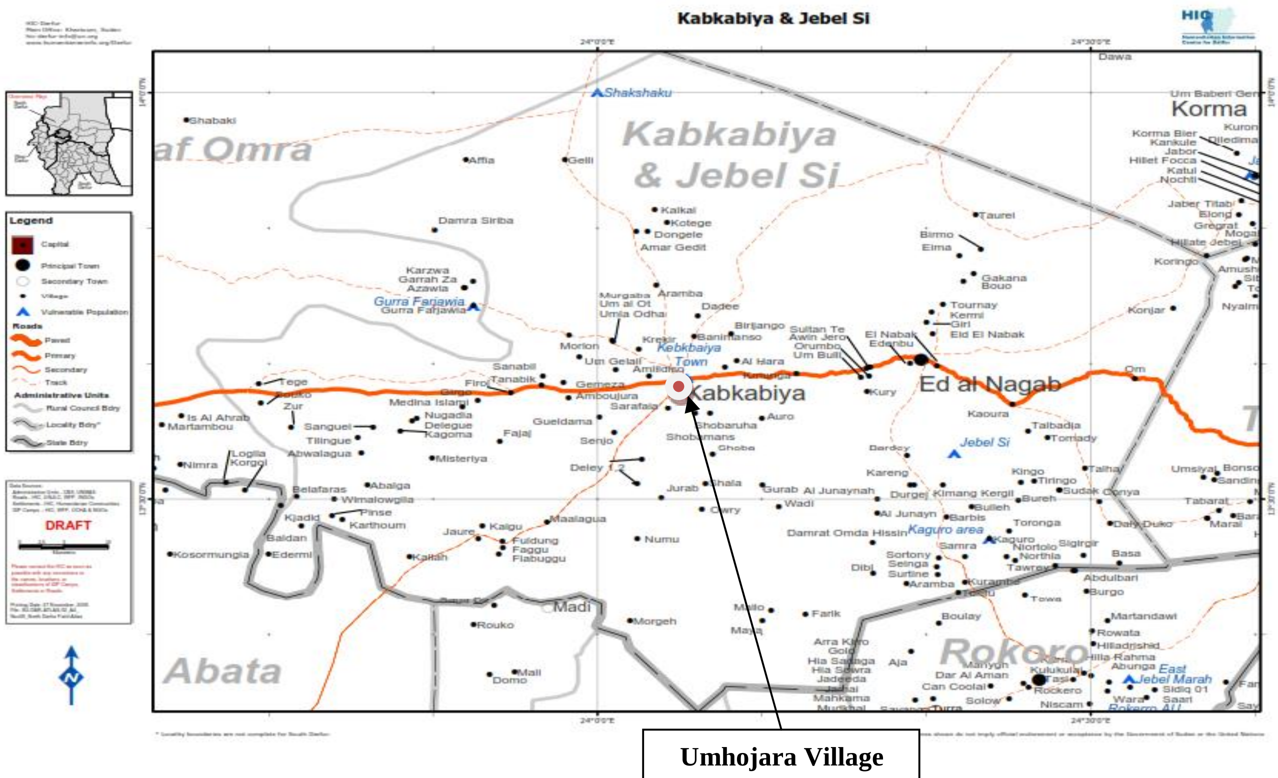

Fig 3. 1: Kabkabiya locality and Umhojara Village study area

rocks close to the surface or exposed mainly along water courses. The predominant topsoil is sandy loam, becoming loam or sand clay with depth, the pH range from 6.3- 7.2 (Gafar. 2001).

3.3 Land use and vegetation:

Agriculture has been practiced in the study area for centuries and crop production is based on rainfall through various traditional farming systems.

Average cultivated land per farmer ranges from about 0.3 to 1.0 hecters on the alluvial wadi and low-lying area to more than 1.8 hecters on lighter soil (sandy loam). The continuous cultivation of shallow soil has led to reduced productivity and enormous erosion and most of the valuable agricultural land was washed away and abandoned, as a result, most of subsistence farmers shifted into wadi valleys of alluvial zone where moisture reserves are adequate for crop production.

The main feature of the study area is a poor Savannah type vegetation (thorn scrub, thorn savannah and deciduous savannah woodland) with short to medium grasses predominating, (Mohammed, 2000)

Grazing by nomadic and settler livestock (principally cattle, goats, and sheep) is practiced by many tribal groups in the area, and camels predominate in northern part of the locality. Except for the alluvial land all other areas were being overgrazed and the quality of the rangelands has been reduced.

3.4 Seed source:

The seeds of pearl millet and cowpea were obtained from Kabkabiy Agricultural Sector, North Darfur State locally namedes, Darmassa and Eyn Elghazal, respectively,

3.5 Treatments and experimental design:

Three methods of intercropping were chosen (Millet and cowpea as follows:

Ms = Millet sole

Cs = Cowpea sole

CMs = Millet +Cowpea

Water conservation treatments**:**

Five water harvest techniques were selected and applied based on local farmers technical knowhow and the availability of local construction materials. The water harvesting techniques were as follows:

1 - W1 = Terracing system

2- W2 = V- shape micro- catchments

3- W3 = Contour bunds

4 - W4 = Trapezoidal bunds method

5- W5 = rain fall control.

The main treatments were represented by three plots 10x50 m each plot had five subplot (10X10m) Fig (3.2). Hand tools such as hoe and shovels were used to construct small earth bunds. Terracing was raised 30 cm, with base of 30cm, water would accumulate.

The treatments were:

MsW1 = Millet sole + terrace system

MsW2 = Millet sole + V-shape micro catchment

MsW3 = Millet sole + Contour bunds

MsW4 = Millet sole + Trapezoid bunds

MsW5 = `Millet sole + rain fall control

CsW1 = Cowpea sole + Terrace system

CsW2 =Cowpea sole+ V- Shape-micro catchment

CsW3 =Cowpea sole+ Contour Bunds

CsW4 =Cowpea sole + Trapezoid

CsW5 = Cowpea sole + Rainfall control

CMW1 = Intercropping (Cowpea- Millet) + Terrace

CMW2 = Intercropping (Cowpea- Millet) + V-shape micro catchment

CMW3 = Intercropping (Cowpea- Millet) + Contour

CMW4 = Intercropping (Cowpea- Millet) + Trapezoid

CMW5 = Intercropping (Cowpea- Millet) + Rainfall control

All treatments were sown on the same day, on the fifth of July for the first season, and ninth of July for second.

3.6 Experimental design:

The Experimental design used was split- plot design, with four replications to make a total of 60 plots (3x5x4) the plot area is 10 x 10 m . The main plots were allotted for the intercropping and sub plots for the water harvesting Techniques. Appendix (4).

- Parameters measured:-

Measurement commenced 30 days after sowing when plants were well established. Measured parameters included, plant height, number of leaves per plant, stem diameter and leaf area.

3.7 Cultural practices:

For both experiments, the seed rate was 5 kg for millet and 20 kg for cowpea per Fadden. All plots had an equal seed rate to standardize the plant population. Cowpea seeds were planted on holes alternating with millet seeds, row intercropping (1:1). Seeds were sow manually in holes 25 cm apart, with five seeds per hole for millet and four seeds for cowpea. Re-sowing was done after one week. Germination started after four days. Cowpea was thinned to 3 plants per hole, while millet was thinned to 2-4 plants per hole. Hand weeding was practiced three times for each season. The insecticide Marchalla was used to control insects and grasshoppers after two months during the flowering stage of cowpea. Harvesting was after 100 days from sowing.

3.8 Intercropping:

Cowpea (Eyn Elgazal) local verities were intercropped with local varieties of grain millet in 1:1 row ratio. The spacing between cowpea and millet was maintained at 75 cm. inter and interaraw spacing of 100 and 50 cm were allowed respectively, for monocropping, whereas 70 and 50 cm spacing were provided for millet. Sole cowpea spacing was 70 cm between row and 100 cm between plants.

3.9 Soil moisture determination:

Soil moisture content was determined for three depths, 0-20cm, 20-40cm, and 40-60cm using gravimetric method (w/w) each treatment was represented by four plots and one sample was taken for each plot, using an auger at different growth stages (seedling, flowering and maturity stage). Small cans were used for soil sample, the moist and oven dry weights for each sample were determined using a sensitive balance, the oven dry weight was determined after 24 hours at a temperture of 105 C.

The Soil moisture content was calculated according to following:

$$\textbf{Moisture content (\%)} = \frac{\textbf{Moist weight- dry weight}}{\textbf{Moist weight}} \textbf{ X 100}$$

Parameters measured:

3.10 Growth attributes:

In each subplot, five plants were randomly selected and tagged to determine the plant height, number of leaves per plant, leaf area index, stem diameter and plant density. This was taken three times at seedling, flowering and maturity stage, in addition to; days to 50% flowering , days to maturity and straw yields.

3.10.1 Millet growth attributes

Five plants were randomly selected and tagged in each sub-plot to measure the following vegetative parameters.

3.10.1.1 Plant heigh (cm)t:

Five plants from each sub plot were randomly selected, tagged and labelled. Then measurements were taken from a point immediately above the soil surface to the tip of the youngest leaf, then to the base of the head after ear formation, using a meter tape, the mean of the five plants was then expressed in cm

3.10.1.2 Number of leaves per plant:

Leaves of five tagged and labelled plants in each plot were counted. The average number was recorded as the number of leaves per plant.(the number of green leaves was counted in all tagged plants and average mean number of leave/plant was determined.

3.10.1.3 Leaf area (LA):

Only green leaves were counted to determine the leaf area. Leaves were considered green when more than one- third of the blade remained green). Leaf area was determined using the following formula.

LA = leaf length X width X0.75.

3.10.1.4 Steam diameter (cm):

It was measured using Vernia Scale device.

3.10.1.5 Plant density:

An area of one meter square in the middle of each treatment was determined and number of plants / meter^2 was taken three times (seeding, flowering and maturity stage)

3.10.1.6 Time to 50% flowering

Days from sowing until 50% of plants in each plot flowered was determined

3.10.2 Cowpea

3.10.2.1 Plant height (cm):

Five plants from each sub plot were randomly selected, tagged and labelled. The measurements were taken from a point immediately above the soil surface to the tip of the youngest leaf; the mean of five plants was expressed in cm.

3.10.2.2 Number of leave per plant:

Leaves of five tagged and labeled plants in each plot were counted. The average numbers were recorded as the number of leave per plant.

3.11.2.3 Steam diameter (cm):

It was measured using Vernia Scale device.

3.10.2.4 Plant density:

An area of one square meter in the middle of each treatment was chosen to count the number of plants three times (seeding, flowering and maturity stage)

3.10.2.5. Time to 50% flowerings

Day from sowing until 50% of plants in each plot flowered was determined.

3.11 Yield attributes

This parameter includes panicle length (cm), yield (kg/ha). and 1000- seed weight (g)) for millet. For cowpea;(number of flowers per raceme, number of pods per flower, number of seeds per pod, 100- seed weight (g) and total yield (ton/ha).

3.11.1 Millet yield attributes

3.11.1.1 Panicle length (cm)

Mean Length of the panicle were measured from a sample of five panicles measured from the base to the tip of panicle.

3.11.1.2 Thousand seed weight (g)

Weight of 1000 seeds was determined by weighing replicate sample of 1000 pearl millet grains obtained for each sub-plot using.

3.11.1.3 Total yield (ton/ha):

Seed yield was determined by harvesting the heads of millet in each plot, the heads were left to dry then threshed and weight. Then the total yield (ton/ha) was calculated.

3.11.2 Cowpea yield attributes

3.11.2.1 Number of flowers per raceme:

The same five tagged plants used for measuring plant height were also used for counting number of flowers per raceme; the mean of the five plants was obtained and expressed as number of flower per raceme.

3.11.2.2 Number of pods per plant:

The same five plants that were used for counting the number of flowers/raceme were used for counting the number of pods/plant.

3.11.2.3 Number of seeds per pod:

The same five plants that were used for counting the number of pods/plant, were used for counting the number of seeds per pod. Pod were picked, threshed, and then number of seeds for each pod was counted, the average number of seeds/pod was then recorded.

3.11.2.4 100- seeds weight (g):

A sample containing 100 seeds of cowpea was counted from seeds of each experimental plot and weighed. The mean was then expressed in g.

3.11.2.5 Total yield (ton/ha):

Seed yield was determined by harvesting the pods of cowpea plants in each plot were air dried threshed and weighed to determine total yield (ton/ha).

3.12 Chemical Analysis

From the samples of millet and cowpea dry seed, samples were randomly taken for the determination of the crude protein and phosphorus content (mineral, ash**.**

3.13 Protein Content

The total nitrogen was estimated according to method described by (Chapman and Part,1961) using the micro-Kjeldahl method.)

$$N\% = \frac{\text{mls HCLXNX14X100}}{\text{Weight of SampleX1000}}$$

Crude protein% = N%X6.25

3.14 Phosphorus content (mg/g)

The phosphorus content was determined according to the method described by Chapman and Part (1961).

$$P\% = \frac{\text{c (meg) reading curve ash diluteX100}}{10^6 \text{X Sample weight (2g)}}$$

C(mg): obtained from graph

3.16 Statistical analysis

Analysis of variance (ANOVA) was carried for each character separated by using of least significant difference at ($p \leq 0.05$) using statistic 8 soft ware pakage program.

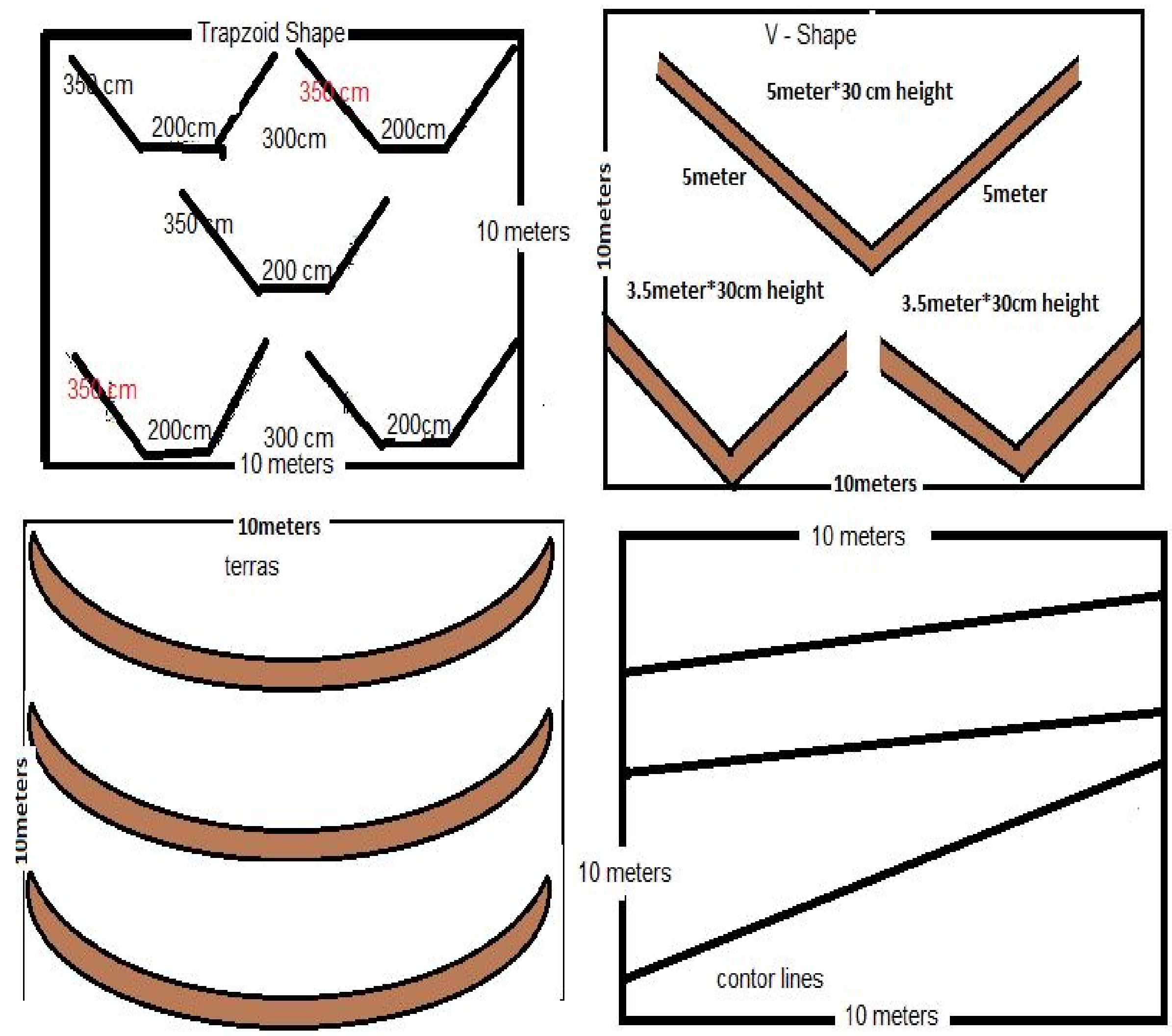

Fig 3. 2: Type of water harvesting technique using, Trapezoid, V- shape. Terras, Contour Bundle.

CHAPTER FOUR

RESULTS

4.1 Soil moisture depletion

The data for soil moisture depletion are presented in Table (1a), (1b) and(2a), 2b), for the different water harvesting techniques and intercropping at seedling, Flowering and maturity for two growing seasons(2012/13).The data show that soil moisture depletion at seedling and flowering stage increased with depth and decreased at maturity stage.

The general trend for soil moisture depletion was increased up to flowering stage and decreased at maturity stage Table (4.1b and 4.2b).

4.1.1 Effect of treatments on soil moisture content at different growth stages:

During the seedling stage of the first season (2011/2012)at depth less than 20cm ,20-40cm and 40- 60, cm the treatments WI,W2,W3 and W4 showed no statistical effect on soil moisture content, although there was an increase in soil moisture content of W2 and W4 plot of both crops compared to other plots. As shown in Table 1. Higher values of soil moisture content were recorded for Ms W4 (19.30) treatment at depth (0-20) at seedling stage. However, at depth less than 20, 40 and 60 cm at seedling, flowering and maturity stage control plots resulted in significant decrease in soil moisture over treated plots.

During the seedling and flowering stage of growth there was an increase in soil moisture content especially at flowering stage at depth 40-60cm reaching 12.35, 11.55 of treatments LsW4 and MsW3 respectively, and the difference between the treatments reached the level of significance as shown in Table 1a

As shown in Table 1b, all water harvesting techniques applied (W1, W2,W3, W4) significantly increased soil moisture content in all readings at different depths and at different growth stages (seedling, flowering and maturity), compared to control treatment (W5).

During the first season as shown in Table 1b, despite the greater change in moisture content at different depths and different growth stages, water harvesting techniques showed no statistical difference on soil moisture content in almost all depths and at growth stage level except at the control (W5) in all readings of depth and stages, in addition to (W1, W2) in depth less than 20 cm at flowering stage, and (WI, W2) in depth cm at maturity stage. As shown in Table (1b) the treatment significantly showed low moisture content compared to others. On the other hand, water harvesting technique and intercropping in both crop showed significant effect on soil moisture content in all depths and at different growth stages of the crops (Table 1).

As presented in table (2a) of the second growing season (2012/2013), results showed that water harvesting techniques have significant effect on soil moisture content.

The mixture of Ms W5, CsW5 and MLs showed significant decrease in soil moisture content compared to other treatments. On the other hand, W5 showed statistical effect on soil moisture content at different depths and different growth stages as shown in Table 2a and 2b, respectively.

Generally, moisture content levels in all treatments of water harvesting technique appeared near to soil surfaces during the seedling emergence, in the middle during the flowering stage and far away from soil surface during maturity stages of both crops under study, which coincided with the development of their roots.

Table 1a.Effect of water harvesting techniques and intercropped of millet and cowpea on soil moisture content at different growth stage (%). 2011/2012 season

Treatment	Growth stage								
	Seedling			Flowering			Maturity		
Depths cm	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60
MsW1	11.75^{bcd}	11.55^{ab}	8.28^{abc}	10.275^{bc}	9.25^{ab}	10.70^{ab}	5.60^{abc}	6.28^{abc}	6.20^{abcd}
MsW2	9.40^{bcd}	11.1^{abc}	10.58^{ab}	14.975^{a}	11.18^{a}	10.05^{ab}	3.85^{bc}	5.50^{abcd}	5.70^{abcd}
MsW3	11.15^{bcd}	12.23^{ab}	10.70^{ab}	8.475^{cde}	9.68^{ab}	11.55^{a}	8.33^{ab}	6.10^{abc}	5.88^{abcd}
MsW4	19.30^{a}	11.06^{abc}	10.08^{abc}	13.700^{ab}	10.00^{a}	11.33^{a}	3.55^{c}	5.23^{abcd}	6.43^{abcd}
MsW5	9.4^{bcd}	5.88^{cd}	3.58^{c}	5.175^{e}	5.40^{cd}	4.73^{c}	3.13^{c}	4.20^{bcd}	3.43^{d}
CsW1	10.95^{bcd}	11.35^{ab}	11.50^{a}	9.700^{c}	10.83^{a}	10.73^{ab}	3.08^{c}	7.75^{a}	4.50^{cd}
CsW2	14.55^{ab}	16.05^{a}	11.80^{a}	8.45	9.35^{ab}	9.13^{ab}	6.18^{abc}	7.03^{ab}	6.48^{abcd}
CsW3	8.475^{cd}	12.53^{ab}	12.10^{a}	10.825^{bc}	10.93^{a}	10.25^{ab}	4.33^{bc}	6.25^{abc}	7.83^{abc}
CsW4	8.950^{bcd}	11.18^{ab}	11.70^{a}	11.175^{abc}	11.40^{a}	12.35^{a}	5.23^{abc}	6.73^{abc}	8.65^{a}
CsW5	8.925^{bcd}	7.83^{bcd}	6.85^{abc}	5.525^{de}	4.98^{d}	6.93^{bc}	2.38^{c}	4.6^{bcd}	4.90^{bcd}
CMW1	11.625^{bcd}	12.83^{ab}	11.88^{a}	8.050^{cde}	10.85^{a}	9.95^{ab}	9.60^{a}	6.83^{ab}	8.05^{ab}
CMW2	12.475^{bc}	11.43^{ab}	12.43^{a}	10.65^{bc}	9.28^{ab}	10.45^{ab}	6.70^{abc}	3.83^{cd}	5.15^{bcd}
CMW3	12.225^{bc}	12.23^{ab}	11.68^{a}	9.925^{bc}	10.85^{a}	9.025^{ab}	4.58^{bc}	6.63^{abc}	7.03^{abc}
CMW4	9.575^{bcd}	10.68^{bc}	9.68^{abc}	9.125^{cd}	8.78^{abc}	9.58^{ab}	5.33^{abc}	7.08^{ab}	6.75^{abcd}
CMW5	6.050^{d}	3.35^{d}	4.63^{bc}	5.600^{de}	6.40^{bcd}	8.625^{abc}	3.00^{c}	2.80^{d}	4.95^{bcd}
SE ±	2.111	1.853	2.347	1.3462	1.2066	1.4633	1.6142	1.048	1.1821
C.V%	38.43	34.48	47.77	28.52	26.02	30.20	64.72	36.22	38.59

Means followed by the same letter (s) within a given column are not significantly different at ($p<0.05$) level.
W1: terracing, W2: V-shape, micro catchment, W3: Contour bunds, W4: Trapezoid bunds, W5: Rain fall as control, Ms: Millet sole Cs: cowpea sole, CM : Millet+ cowpea (inter cropping.

Table 1b. Effect of water harvesting techniques on soil moisture content (%) at different growth stages. 2011/2012 season

Treatment	**Growth stage**								
	Seedling			**Flowering**			**Maturity**		
Depths cm	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60
W1	11.44[ab]	11.91[a]	10.55[a]	9.34[a]	10.31[a]	10.46[a]	6.09[a]	6.95[a]	6.25[ab]
W2	12.14[a]	12.86[a]	11.60[a]	11.36[a]	9.93[a]	9.88[a]	5.58[a]	5.45[ab]	5.78[ab]
W3	10.62[ab]	12.33[a]	11.49[a]	9.74[a]	10.48[a]	10.28[a]	5.74[a]	6.33[a]	6.91[a]
W4	12.61[a]	10.97[a]	10.48[a]	11.33[a]	10.6[a]	11.08[a]	4.70[ab]	6.34[a]	7.28[a]
W5	8.13[b]	5.68[b]	5.02[b]	5.43[b]	5.59[b]	6.76[b]	2.83[b]	3.87[b]	4.43[b]
SE ±	1.2189	1.07	1.355	0.7772	0.6966	0.8448	0.9319	0.605	0.683
C.V%	38.43	34.48	47.77	28.52	26.02	30.20	64.72	36.22	38.59

Means followed by the same letter (s) within a given column are not significantly different at ($p<0.05$) level.

W1: terracing W2: V-shape micro catchment   W3: Contour bunds W4: Trapezoid bundsW5: Rain fall as control

Table 2a . Effect of water harvesting techniques and intercropped treatments on soil moisture content (%). 2012/2013 season

Treatment	Growth Stage								
	Seedling			Flowering			Maturity		
Depths cm	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60
MsW1	11.45^{ab}	7.58^{bc}	11.10^{abc}	11.30^{ab}	14.28^{a}	11.10^{ab}	5.78^{a}	6.78^{abc}	6.90^{abcde}
MsW2	10.18^{abcde}	10.48^{abc}	11.20^{ab}	10.30^{abc}	9.50^{bc}	11.25^{ab}	4.43^{ab}	7.78^{ab}	9.50^{a}
MsW3	9.90^{abcde}	11.35^{abc}	10.10^{abc}	8.48^{bcd}	11.58^{ab}	7.76^{bcde}	3.03^{bcde}	6.35^{abcd}	6.50^{abcde}
MsW4	14.25^{a}	17.2^{a}	10.83^{abc}	8.90^{bc}	12.03ab	9.68^{abc}	4.98^{ab}	7.90^{a}	8.55^{abc}
MsW5	4.15^{e}	7.38^{bc}	7.43^{bcd}	5.28^{de}	6.78^{cd}	5.80^{cde}	1.68^{de}	5.55^{cd}	4.15^{e}
LsW1	7.58^{abcde}	8.30^{bc}	11.70^{ab}	9.03	10.13^{bc}	10.60^{ab}	3.80^{abcd}	5.88^{bcd}	7.38^{abcd}
LsW2	4.55^{de}	11.03^{abc}	7.88^{bcd}	7.20^{cde}	8.88^{bcd}	12.83^{a}	3.95^{abc}	5.45^{cd}	5.78^{cde}
LsW3	13.20^{ab}	8.43^{bc}	10.88^{abc}	8.83^{bc}	10.83^{ab}	9.83^{abc}	5.48^{a}	5.80^{cd}	5.73^{cde}
LsW4	6.68^{cde}	12.78^{ab}	13.15^{ab}	8.90^{bc}	10.48^{bc}	11.20^{ab}	4.53^{ab}	6.53^{abcd}	9.05^{ab}
LsW5	6.18^{cde}	4.43^{c}	3.63^{d}	5.33^{de}	5.28^{de}	4.40^{e}	2.20^{cde}	4.75^{de}	4.75^{de}
MLW1	14.15^{a}	17.08^{a}	11.25^{ab}	11.18^{ab}	11.40^{ab}	9.30^{abcd}	5.00^{ab}	5.58^{cd}	6.18^{bcde}
MLW2	13.03^{ab}	11.18^{abc}	15.45^{a}	10.18^{abc}	11.10^{ab}	8.5^{bcd}	4.73^{ab}	4.83^{cde}	6.00^{bcde}
MLW3	13.15^{ab}	9.25^{abc}	9.13^{bcd}	9.13^{bc}	10.63^{ab}	10.13^{ab}	4.53^{ab}	5.53^{cd}	6.30^{bcde}
MLW4	10.63^{abcd}	8.30^{bc}	10.43^{abc}	12.85^{a}	11.93^{ab}	8.68^{bcd}	4.20^{abc}	5.88^{bcd}	5.13^{de}
MLW5	5.83^{cde}	7.30^{bc}	4.85^{cd}	4.20^{e}	2.33^{e}	5.58^{de}	1.28^{e}	3.15^{e}	5.33^{de}
SE ±	2.1997	2.9177	2.1969	1.1890	1.3078	1.4335	0.745	0.6897	1.106
C.V%	45.55	57.58	44.24	27.22	26.67	31.48	37.53	23.59	34.15

Means followed by the same letter (s) within a given column are not significantly different at ($p<0.05$) level.

W1: terracing , W2: V-shape, micro catchment , W3: Contour bunds, W4: Trapezoid bunds,W5: Rain fall as control,Ms: Millet sole, Cs: cowpea sole, CM : Millet+ cowpea inter cropping.

Table 2b. Effect of water harvesting techniques on soil moisture content (%). 2012/2013) season

Treatment	**Growth stage**								
	Seedling			**Flowering**			**Maturity**		
Depths cm	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60
W1	11.06[a]	10.98[ab]	11.35[a]	10.5[a]	11.93[a]	10.33[a]	4.86[a]	6.08[a]	6.82[a]
W2	9.25[a]	10.89[ab]	11.51[a]	9.23[a]	9.83[a]	10.86[a]	4.37[a]	6.02[a]	7.09[a]
W3	12.80[a]	9.68[ab]	10.03[a]	8.81[a]	11.01[a]	9.24[a]	4.34[a]	5.89[a]	6.18[ab]
W4	10.52[a]	12.76[a]	11,47[a]	10.22[a]	11.48[a]	9.85[a]	4.57[a]	6.77[a]	7.58[a]
W5	5.38[b]	6.37[b]	5.30[b]	4.93[b]	4.49[b]	5.26[b]	1.72[b]	4.48[b]	4.74[b]
SE ±	1.2700	1.6845	1.2684	0.6865	0.755	0.8276	0.4301	0.3982	0.6387
C.V%	45.55	57.58	44.24	27.22	26.67	31.48	37.53	23.59	34.15

Means followed by the same letter (s) within a given column are not significantly different at ($p<0.05$) level.

W1: terracing W2: V-shape micro catchment W3: Contour bunds W4: Trapezoid bundsW5: Rain fall as control

4.2 Millet

4.2.1 Effect of water harvesting technique on growth of millet sole and intercropped with cowpea

4.2.1.1 Plant height

Effect of water harvesting techniques on plant height of sole millet and intercropped with cowpea is presented in Table (3) and (4) of the two growing seasons.

Plant height of millet was influenced by water harvesting technique and intercropping in both seasons. The overall mean plant height increased from 18.8 cm at seedling stage to 164.24 cm at maturity stage in the first season, and from 22.27 cm to 195.22 cm in the second season but there were no significant differences in plant height for intercropping treatment during seedling, flowering and maturity stages. However, higher values of plant height were recorded in sole millet at flowering and maturity, 161.38 and 164.73 cm respectively, but during seedling stage the high value was obtained in intercropping. (Table 3 and 4)

Generally, there was no significant difference in plant height for water harvesting techniques W1, W2, W3, W4, for seedling, flowering and maturity stages.

As shown in Tables (3 and 4), the interaction between techniques significantly increased plant height during the three growing stages for both seasons. During the second season water harvesting technique significantly increased plant height compared to control, W5. (Tables 3 and 4)

In the first season, there were also no significant differences in plant height between W1, W2, W3, W4 at flowering and maturity stages, while in the second season W1and W3, significantly recorded taller plants when compared to W2 and W4 treatments at seedling stage, but not significantly different at flowering and maturity stages.

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Table 3: Effect of water harvesting techniques on plant height of sole millet and intercropped with cowpea at different growing stages in the first season.(2011/2012)

Treatment	Growth Stage								
	Seedling			Flowering			Maturity		
	Ms	CM	means	Ms	CM	Means	Ms	CM	Means
W1	14.85[b]	18.37[ab]	16.61[b]	149.55[abc]	169.92[a]	159.36[a]	156.75[cd]	169.1[abcd]	162.93[a]
W2	20.05[ab]	20.4[a]	20.23[ab]	175.7[a]	162[ab]	168.85[a]	187.25[a]	174.21[abc]	180.73[a]
W3	19.65[ab]	19.22[ab]	19.44[ab]	177.8[a]	175.82[a]	176.81[a]	170.8[abc]	161.75[bcd]	166.28[a]
W4	21.4[a]	21.07[a]	21.24[a]	165.35[ab]	166.9[ab]	166.13[a]	164.02[abcd]	181.37[ab]	172.7[a]
W5	16.4[ab]	16.65[ab]	16.5[b]	138.5[bc]	122.28[c]	130.39[b]	144.85[de]	132.25[e]	138.55[b]
means	18.47[a]	19.14[a]	18.8	161.38[a]	159.38[a]	160.25	164.73[a]	163.74[a]	164.24
CV%			20.19			13.32			10.2
SE Crop			0.85			4.777			3.7466
SE W			1.34			7.5531			5.9239
SECxW			1.9			10.682			8.3776

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing W2: V-shape micro catchment W3: Contour bunds W4: Trapezoid bundsW5: Rain fall as control Ms: Millet sole, CM : Millet+ Cowpea (inter cropping)

Table 4: Effect of water harvesting techniques on plant height of sole millet and intercropped with cowpea at different growth stages during the second season. (2012/213)

Treatment	Growth stage								
	Seedling			Flowering			Maturity		
	Ms	CM	Means	Ms	CM	Means	Ms	CM	Means
W1	20.58[ab]	23.05[ab]	21.81[ab]	154.75[abc]	171.40[ab]	163.08[a]	190.20[ab]	216.25[a]	203.22[a]
W2	22.35[ab]	27.35[a]	24.85[a]	162.95[abc]	188.00[a]	175.47[a]	204.40[a]	203.50[a]	203.95[a]
W3	21.90[ab]	24.50[ab]	23.20[ab]	159.25[abc]	182.50[a]	170.87[a]	204.55[a]	199.58[a]	202.06[a]
W4	18.60[b]	26.85[a]	22.73[ab]	171.75[ab]	185.00[a]	178.38[a]	192.72[ab]	216.63[a]	204.68[a]
W5	18.65[b]	18.90[b]	18.78[b]	132.10[bc]	126.00[c]	129.05[b]	166.90[bc]	157.45[c]	162.17[b]
means	20.42[a]	24.13[b]	22.273	156.16[a]	170.58[a]	163.37	191.75[a]	198.68[a]	195.22
CV%			21.34			17.13			9.8
SE Crop			1.0628			6.2589			4.276
SE W			1.6804			9.8962			6.761
SECxW			6.2589			13.995			9.5615

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Ms: Millet sole, CM: Millet+ Cowpea (inter cropping

4.2.1.2 Number of leaves per plant:

Effect of water harvesting technique on number of leaves of sole millet and intercropped with cowpea is presented in Tables (5) and (6).

Intercropping significantly affected the number of leaves of millet at seedling and flowering stages, sowing millet 1:1 row with cowpea significantly increased number of leaves per plant in comparison to sole millet at seedling and flowering stage in the first and second growing seasons.

The mean number of leaves/ plant increased with advance of plant age for treatment W1, W2.W3.W4 and W5 for both season.

The analysis of variance revealed that different water harvesting techniques significantly increased the number of leaves/plant in both growing seasons.

Although the differences between water harvesting techniques were not significant at flowering stage in the first season, but the highest number of leaves per plant was obtained by W2 and W3, and W2, W3 and W4 in the second growing seasons, the lowest leaf number was found at W5 treatment for the first and second seasons.

As shown in Tables (5 and 6) and Appendixes 4 and 5, the interaction of water harvesting techniques and intercropping had no significant effect on number of leaves per plant for both growing season except at seedling and flowering stages in the first season, where the treatments resulted in higher number of leaves/plant.

Table 5: Effect of water harvesting techniques on number of leaves/plant of sole millet and intercropped with cowpea at different growth stages during the first season (2011/2012).

Treatment	**Growth stage**								
	Seedling			**Flowering**			**Maturity**		
	Ms	**CM**	**Means**	**Ms**	**CM**	**Means**	**Ms**	**CM**	**Means**
W1	6.50^{bc}	6.50^{bc}	6.50^{b}	8.50^{ab}	11.00^{a}	9.75^{a}	8.00^{a}	7.25^{a}	7.63^{ab}
W2	6.00^{bc}	6.75^{b}	6.38^{b}	9.00^{ab}	11.00^{a}	10.00^{a}	8.00^{a}	7.50^{a}	7.75^{ab}
W3	6.25^{bc}	6.25^{bc}	6.25^{b}	9.75^{ab}	10.25^{ab}	10.00^{a}	8.00^{a}	8.00^{a}	8.00^{a}
W4	6.75^{b}	7.75^{a}	7.25^{a}	8.25^{b}	11.00^{a}	9.63^{a}	7.25^{a}	7.50^{a}	7.38^{ab}
W5	5.75^{c}	6.25^{bc}	6.00^{b}	7.75^{b}	10.25^{ab}	9.00^{a}	7.00^{a}	6.75^{a}	6.88^{b}
means	6.25^{b}	6.70^{a}	6.48	8.65^{b}	10.70^{a}	9.68	7.65^{a}	7.40^{a}	7.53
CV%			8.39			18.06			12.26
SE Crop			0.12			0.39			0.21
SE W			0.19			0.62			0.33
SECxW			0.27			0.87			0.46

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Ms: Millet sole, ML: Millet+ Cowpea (inter cropping

Table 6: Effect of water harvesting techniques on number of leaves /plant of sole millet and intercropped with cowpea at different growth stages during the second season (2012/ 2013).

Treatment	**Growth stage**								
	Seedling			**Flowering**			**Maturity**		
	Ms	**CM**	**Means**	**Ms**	**CM**	**Means**	**Ms**	**CM**	**Means**
W1	8.50^{a}	8.75^{a}	8.63^{a}	8.00^{c}	8.75^{abc}	8.38^{ab}	9.25^{a}	9.00^{a}	9.13^{a}
W2	8.00^{a}	9.00^{a}	8.50^{a}	9.00^{abc}	9.25^{ab}	9.13^{a}	9.50^{a}	9.00^{a}	9.25^{a}
W3		8.75^{a}	8.75^{a}	8.50^{abc}	9.50^{a}	9.00^{a}	8.75^{ab}	9.25^{a}	9.00^{a}
W4	8.00^{a}	8.75^{a}	8.38^{a}	8.75^{abc}	9.25^{ab}	9.00^{a}	8.75^{ab}	9.25	9.00^{a}
W5	8.00^{a}	8.00^{a}	8.00^{a}	8.25^{bc}	8.00^{c}	8.13^{b}	8.00^{bc}	7.75^{c}	7.88^{b}
means	8.25^{a}	8.65^{a}	8.45	8.50^{a}	8.95^{a}	8.73	8.85^{a}	8.85^{a}	8.85
CV%			9.08			9.68			7.28
SE Crop			0.17			0.19			0.14
SE W			0.27			0.30			0.23
SECxW			0.38			0.42			0.32

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Ms: Millet sole, CM: Millet+ Cowpea (inter cropping

4.2.1.3 Leaf Area (LA): (cm^2)

The Effect of water harvesting techniques on leaf area of sole millet and intercropped with cowpea during the two growing season is presented in Tables (7) and (8).

Intercropping significantly $p<0.05$ affected the leaf area of millet at flowering stage in the first and second growing seasons, but there was no significant difference in leaf area between all other treatment means during seedling and maturity stages in both seasons. However, the effect of water harvesting techniques W1, W2, W3 and W4 was significant in the first and second seasons compared to W5 as control. The means of leaf area increased gradually from seedling to flowering stage and decreased at maturity stage, 142.13 cm^2, 248.80 cm^2, 150.88 cm^2 in the first season, while they were 147 cm^2, 248.8 cm^2 and 132.55 cm^2 for the second season, respectively. V-shape micro catchment (W2) water harvesting techniques gave the highest leaf area during the two growing stages (flowering and maturity stages) in the first season and at seedling, flowering and maturity stage in the second season. The analysis of variance revealed that the interaction of water harvesting techniques and intercropping had significant effect on leaf area for both growing seasons except at seedling stage.

The least Leaf area (LA) was obtained from control (W5) water harvesting techniques, compared to other water harvesting techniques.

Table 7: Effect of water harvesting technique on leaf area (cm^2) of sole millet and intercropped with cowpea at different growth stages during the first season (2011/2012).

Treatment	**Growth stage**								
	Seedling			**Flowering**			**Maturity**		
	Ms	**CM**	**Means**	**Ms**	**CM**	**Means**	**Ms**	**CM**	**Means**
W1	118.42^{cd}	157.17^{ab}	137.80^{ab}	233.25^{bc}	255.75^{ab}	244.50^{a}	152.85^{bc}	162.65^{abc}	157.75^{a}
W2	139.66^{abcd}	147.27^{abc}	143.47^{ab}	256.75^{ab}	288.75^{a}	272.75^{a}	148.13^{bcd}	190.43^{a}	169.28^{a}
W3	151.85^{abc}	176.05^{a}	163.95^{a}	230.00^{bc}	288.75^{a}	259.38^{a}	174.38^{ab}	160.95^{abc}	167.67^{a}
W4	132.92^{bcd}	160.45^{ab}	146.69^{a}	234.25^{bc}	282.00^{a}	258.13^{a}	130.35^{cde}	164.45^{abc}	147.4^{a}
W5	132.82^{bcd}	103.47^{d}	118.15^{b}	202.75^{c}	215.75^{bc}	209.25^{b}	109.63^{e}	114.92^{de}	112.28^{b}
means	135.13^{a}	148.88^{a}	142.01	231.40^{b}	266.20^{a}	248.80	143.07^{a}	158.68^{a}	150.88
CV%			18.45			12.31			17.16
SE Crop			6.0097			6.8478			5.7876
SE W			9.2616			10.827			9.151
SECxW			13.098			15.312			12.941

Means with the same letters are not significantly different at($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Ms: Millet sole, CM: Cowpea+ Millet (inter cropping

Table 8: Effect of water harvesting techniques on leaf area (cm^2) of sole millet and intercropped with cowpea at different growth stages during the second season (2012/ 2013).

Treatment	Growth stage								
	Seedling			**Flowering**			**Maturity**		
	Ms	**CM**	**Means**	**Ms**	**CM**	**Means**	**Ms**	**CM**	**Means**
W1	119.42^{bc}	158.63^{ab}	139.03^{ab}	233.25^{bc}	255.75^{ab}	244.50^{a}	139.32^{ab}	134.18^{bc}	136.75^{ab}
W2	148.05^{ab}	181.70^{a}	164.88^{a}	256.75^{ab}	288.75^{a}	272.75^{a}	139.94^{ab}	168.43^{a}	154.19^{a}
W3	151.88^{ab}	181.93^{a}	166.90^{a}	230.00^{bc}	288.75^{a}	259.38^{a}	148.41^{ab}	132.35^{bc}	140.38^{ab}
W4	131.88^{bc}	161.30^{ab}	146.59^{ab}	234.25^{bc}	282.00^{a}	258.13^{a}	124.85^{bc}	136.30^{bc}	130.58^{b}
W5	133.38^{bc}	103.85^{c}	118.61^{b}	202.75^{c}	215.75^{bc}	209.25^{b}	108.42^{cd}	93.27^{d}	100.85^{c}
means	136.92^{b}	157.48^{a}	147.00	231.40^{b}	266.20^{a}	248.80	132.19^{a}	132.91^{a}	132.55
CV%			20.66			12.31			15.54
SE Crop			6.8002			6.8478			4.6065
SE W			10.752			10.827			7.2836
SECxW			15.206			15.312			10.301

Means with the same letters are not significantly different at($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Ms: Millet sole, CM: Cowpea+ Millet (inter cropping)

4.2.1.4 Stem diameter:

The Effect of water harvesting techniques on stem diameters of sole millet and intercropped with cowpea is presented in Tables (9) and (10). During the first season results showed that intercropping millet and cowpea has no significant effect on stem diameter at different growth stages, whereas intercropping significantly increased stem diameter during the second season at flowering and maturity stages.

The analysis of variance as shown in Tables (9 and10) revealed that water harvesting technique significantly increased stem diameter at the three stages of growth in the first and second seasons, compared to W5 which recorded the lowest stem diameter at flowering and maturity stages.

The highest stem diameter was found in W4 at seedling stage, W1 at flowering stage and W2 at maturity stage in first season, while in the second season W2 at seedling stage and W3 at flowering and maturity stages gave the highest stem diameter.

The interaction between intercropping and water harvesting techniques was significantly different.

Table 9: Effect of water harvesting techniques on stem diameter (cm) of sole millet and intercropped with cowpea at different growth stages during the first season (2011/ 2012).

Treatment	Growth stage								
	Seedling			Flowering			Maturity		
	Ms	CM	Means	Ms	CM	Means	Ms	CM	Means
W1	0.575[b]	0.62[b]	0.60[b]	1.50[a]	1.31[ab]	1.40[a]	1.11[b]	1.14[ab]	1.12[a]
W2	0.645[ab]	0.695[ab]	0.67[ab]	1.37[ab]	1.31[ab]	1.34[a]	1.05[b]	1.25[a]	1.15[a]
W3	0.72[ab]	0.73[ab]	0.73[a]	1.27[ab]	1.33[ab]	1.30[ab]	1.13[ab]	1.11[b]	1.12[a]
W4	0.605[b]	0.815[a]	0.71[ab]	1.27[ab]	1.35[ab]	1.31[ab]	1.08[b]	1.05[b]	1.07[a]
W5	0.605[b]	0.625[b]	0.62[ab]	1.18[b]	1.10[b]	1.14[b]	0.84[c]	0.86[c]	0.85[b]
means	0.63[a]	0.70[a]	0.67	1.32[a]	1.28[a]	1.30	1.04[a]	1.08[a]	1.06
CV%			18.7			14.88			8.72
SE Crop			0.0277			0.0431			0.0207
SE W			0.0439			0.0682			0.0327
SECxW			0.062			0.0965			0.0463

Means with the same letters are not significantly different at (p<0.05) level

W1: terracing,W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control,Ms: Millet sole, CM; Cowpea+ Millet (inter cropping)

Table 10: Effect of water harvesting techniques on stem diameter (cm) of sole millet and intercropped with cowpea at different growth stages during the second season (2012/ 2013).

Plant stage	Growth stage								
	Seedling			Flowering			Maturity		
Treatment	Ms	CM	Means	Ms	CM	Means	Ms	CM	Means
W1	0.745[bc]	1.0[abc]	0.87[ab]	1.14[abc]	1.22[abc]	1.18[ab]	1.15[bc]	1.23[ab]	1.1875[a]
W2	0.96[abc]	1.2[a]	1.08[a]	1.18[abc]	1.27[ab]	1.22[a]	1.11[bc]	1.23[ab]	1.1663[a]
W3	0.86[abc]	0.96[abc]	0.91[ab]	1.16[abc]	1.31[a]	1.23[a]	1.11[bc]	1.35[a]	1.2275[a]
W4	0.78[bc]	1.10[ab]	0.94[ab]	1.22[abc]	1.31[a]	1.26[a]	1.11[bc]	1.23[ab]	1.165[a]
W5	0.82[bc]	0.71[c]	0.77[b]	1.06[c]	1.13[bc]	1.09[b]	1.00[c]	1.07[bc]	1.0325[b]
means	0.83[a]	0.99[a]	0.91	1.15[b]	1.24[a]	1.20[a]	1.09[b]	1.22[a]	1.1557
CV%			27.81			10.14			10.14
SE Crop			0.0568			0.0271			0.0254
SE W			0.0897			0.0429			0.0401
SECxW			0.1269			0.0607			0.0567

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Ms: Millet sole, CM; Cowpea+ Millet (inter cropping)

4.2.1.5 Plant density:

Plant density was measured in the middle of the plots for both growing seasons. The effect of water harvesting technique on plant density per (m^2) of sole millet and intercropped with cowpea at different growth stages during the two growing seasons, was represented on Tables (11) and (12).

The number of plants per (m^2) was greater in the first season as compared to the second season with total means of 8, 8, 8 and 7.95, 7.9, 7.9 respectively at seedling, flowering and maturity stage for first and second seasons.

Both intercropping and water harvesting techniques had significant effect on plant density in both growing seasons.

Plant densities were significantly lower in W5 treatment compared with other treatments, but there were no significant differences between W3 and W4 at the three growing stages in the first season. On the other hand, W4 showed the highest plant densities of 9.5 and 9 plant per square meter in the first and second seasons respectively, though it did not reach the level of significance.

Table 11: The Effect of water harvesting techniques on plant density per (m^2), of sole millet and intercropped with cowpea at different growth stages during the first season (2011/ 2012).

Treatment	Growth stage								
	Seedling			Flowering			Maturity		
	Ms	CM	Means	Ms	CM	Means	Ms	CM	Means
W1	10.5^{ab}	6^{def}	8.25^{ab}	10.5^{ab}	6^{def}	8.25^{ab}	10.5^{ab}	6^{def}	8.25^{ab}
W2	9^{bc}	5.5^{ef}	7.25^{bc}	9^{bc}	5.5^{ef}	7.25	9^{bc}	5.5^{ef}	7.25^{bc}
W3	10.75^{ab}	6.5^{def}	8.63^{a}	10.75^{ab}	6.5^{def}	8.63^{a}	10.75^{ab}	6.5^{def}	8.63^{a}
W4	12^{a}	7^{de}	9.5^{a}	12^{a}	7^{de}	9.5^{a}	12.00^{a}	7^{de}	9.5^{a}
W5	7.75^{cd}	5^{f}	6.38^{c}	7.75^{cd}	5^{f}	6.38^{c}	7.75^{cd}	5^{f}	6.38^{c}
means	10.00^{a}	6.00^{b}	8.00	10.00^{a}	6.00^{b}	8.00	10.00^{a}	6.00^{b}	8.00
CV%			16.65			16.65			16.65
SE Crop			0.2978			0.2978			2978
SE W			0.4709			0.4709			0.4709
SECxW			0.666			0.666			0.666

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing,W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Ms: Millet sole, CM; Cowpea+ Millet (inter cropping)

Table 12: Effect of water harvesting techniques on plant density per (m^2), of sole millet and intercropping with cowpea at different growth stages during the second season (2012/ 2013).

Treatment	Growth stage								
	Seedling			Flowering			maturity		
	Ms	CM	Means	Ms	CM	Means	Ms	CM	Means
W1	10.75^{ab}	6^{d}	8.375^{ab}	10.75^{ab}	6^{f}	8.375^{ab}	10.75^{ab}	6^{f}	8.375^{ab}
W2	8.75^{c}	6.5^{d}	7.625^{bc}	8.75^{cd}	6.5^{ef}	7.625^{bc}	8.75^{cd}	6.5^{ef}	7.625^{ba}
W3	9.5^{bc}	6.5^{d}	8^{ab}	9.5^{bc}	6.5^{ef}	8^{ab}	9.5^{bc}	6.5^{ef}	8^{ab}
W4	11.5^{a}	6.5^{d}	9^{a}	11.5^{a}	6.5^{ef}	9^{a}	11.5^{a}	6.5^{ef}	9^{a}
W5	8.25^{c}	5.25^{d}	6.75^{c}	7.75^{de}	5.25^{f}	6.5^{c}	7.75^{de}	5.25^{f}	6.5^{c}
means	9.75^{a}	6.15^{b}	7.95	9.65^{a}	6.15^{b}	7.90	9.65^{a}	6.15^{b}	7.9
CV%			13.84			13.95			13.95
SE Crop			0.2461			0.2465			0.2465
SE W			0.3891			0.3897			0.3897
SECxW			0.5503			0.7794			0.5511

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Ms: Millet sole, CM; Cowpea+ Millet (inter cropping)

4.2.2 Effect of water harvesting techniques and intercropped on reproductive stage

4.2.2.1 Days to 50% flowering of millet

.The Effect of water harvesting techniques on days to 50% flowering of sole millet and intercropped with cowpea during two growing seasons is presented on Table (13).

There were no significant differences in day to 50% flowering on intercropping and sole millet between all treatments. However, intercropped (CM) treatment tended to flower earlier than others in first and second seasons, compared to sole millet (Ms) in both seasons. The analysis of variance revealed that water harvesting techniques had significant effect on days to 50% flowering of millet in both growing seasons. There was no significant difference between W1, W2, W3 and W4 (55.88, 55.63, 55.63 and 56.72). On the other hand W5 showed the lowest days to 50% flowering in the second season, while it showed the highest days to 50% flowering (57,63) in first the season.

4.2.2.2 Day to maturity of Millet

The Effect of water harvesting techniques on day to maturity of sole millet and intercropping with cowpea in the two growing seasons is presented on Table (14). There was no significant difference in days to maturity on intercropping and sole millet, between all treatments. However, monocropped millet tended to mature earlier than intercropping with cowpea in the first and second seasons, whereas intercropping tended to mature later than other treatments in both seasons. There were no significant differences in all water harvesting techniques on days to maturity in the first and second seasons. Generally, the interaction between water harvesting techniques and intercropping had no significant effect on days to maturity in both growing seasons. Table (14)

Table 13: Effect of water harvesting techniques on days to 50% flowering of sole millet and intercropped with cowpea for two seasons (2011/2012 and 2012/ 2013).

Treatment	Day to 50% flowering season 2011/2012			Day to 50% flowering season 2012/2013		
	Ms	**CM**	**Means**	**Ms**	**CM**	**Means**
W1	54.00^{bcd}	52.50^{cde}	53.25^{c}	56.75^{a}	55^{abc}	55.88^{a}
W2	52.00^{de}	52.00^{de}	52.00^{c}	56.5^{ab}	54.75^{abc}	55.63^{a}
W3	56.00^{b}	55.00^{bc}	55.50^{b}	56.5^{ab}	55.25^{abc}	55.63^{a}
W4	51.00^{e}	53.75^{bcde}	52.38^{c}	58^{a}	55.5^{abc}	56.75^{a}
W5	59.00^{a}	56.25^{ab}	57.63^{a}	52^{c}	53.25^{bc}	52.88^{b}
Means	54.40^{a}	53.90^{a}	54.15	55.95^{a}	54.75^{a}	55.35
CV%			3.51			4.31
SE Crop			0.426			0.5339
SE W			0.673			0.8441
SECxW			0.952			1.1937

Means with the same letters are not significantly different at($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Ms: Millet sole, CM; Cowpea+ Millet (inter cropping)

Table 14: Effect of water harvesting techniques on days of maturity of sole millet and intercropped with cowpea for the two seasons (2011/2012 and 2012/ 2013)

Treatment	Days of maturity season 2011/2012			Days of maturity season 2012/2013		
	Ms	**CM**	**Means**	**Ms**	**CM**	**Means**
W1	88.75[a]	89.25[a]	89.00[a]	88.75[a]	89.25[a]	89[a]
W2	89.50[a]	89.50[a]	89.50[a]	89.5[a]	89.5[a]	89.5[a]
W3	87.50[a]	90.25[a]	88.88[a]	87.5[a]	90.25[a]	88.875[a]
W4	90.50[a]	91.00[a]	90.75[a]	90.5[a]	91[a]	90.75[a]
W5	79.00[b]	78.25[b]	78.63[b]	79[b]	78.25[b]	78.625[b]
means	87.05[a]	87.65[a]	87.35	87.05[a]	87.65[a]	87.35
CV%			2.91			2.91
SE Crop			0.568			0.5678
SE W			0.898			0.8978
SECxW			1.2697			1.2697

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Ms: Millet sole, CM; Cowpea+ Millet (inter cropping)

4.2.3 Effect of water harvesting techniques and intercropping on yield and yield components

4.2.3.1 Panicle length of millet

The Effect of water harvesting techniques on panicle length, of sole millet and intercropping with cowpea of the two growing seasons is presented in Table (15). No significant differences were found between intercropping during the first season, but there were significant effects during second season. However, the effect of water harvesting techniques was significant during the first and second seasons, W5 produced shorter panicle length 18.74 cm and 19.36 cm in first and second seasons respectively. No significant differences were detected between W1, W2, W3 and W4 in the first and second seasons, in addition W1 produced longer panicle length (22.58 cm and 22.40cm) in the first and second seasons respectively, followed by W2 (22,28cm) in the first season and W4 (22.21cm) and W3 (21.81cm)in the second season.

4.2.3.2 Millet 1000 – seed weight

Table (16). Showed the effect of water harvesting technique on 1000-seed weight, of sole millet and intercropped with cowpea during both growing seasons. The weight of the 1000 grains of millet was not affected by intercropping during both growing seasons, while it was significantly affected by water harvesting technique in the first and second season.

The average 1000 seed weight was higher in the second season (with an overall mean of 9.31g) than in first season (with an overall mean of 9.08 g)
In both growing seasons, the 1000-seed weight was higher in W4 (10.25g and 10.86g than with other treatments. On the other hand, W5 significantly resulted in the lowest 1000-seed weight (6.35g and 6.75g) when compared with other treatments in the first and second growing seasons, while there were no significant differences between W1,W2,W3 and W4 during the first season, whereas there were significant differences in the second season.

Table 15: Effect of water harvesting techniques on panicle length (cm), of sole millet and intercropped with cowpea in the two growing seasons (2011/2012 and 2012/ 2013)

	Panicle length season 2011/2012			Panicle length season 2012/2013		
Treatment	**Ms**	**CM**	**Means**	**Ms**	**CM**	**Means**
W1	22.15[ab]	23.00[a]	22.58[a]	21.10[bc]	23.70[a]	22.40[a]
W2	22.75[ab]	21.80[ab]	22.28[a]	21.00[bcd]	22.15[ab]	21.58[a]
W3	22.70[ab]	20.75[ab]	21.73[a]	21.48[bc]	22.15[ab]	21.81[a]
W4	21.10[ab]	21.08[ab]	21.09[a]	22.28[ab]	22.15[ab]	22.21[a]
W5	19.80[bc]	17.68[c]	18.74[b]	18.90[d]	19.83[cd]	19.36[b]
means	21.70[a]	20.86[a]	21.28	20.95[b]	22.00[a]	21.47
CV%			9.59			6.91
SE Crop			0.456			0.3316
SE W			0.721			0.5243
SECxW			1.0199			0.7415

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Ms: Millet sole , CM; Cowpea+ Millet (inter cropping)

Table 16: Effect of water harvesting techniques on 1000-seed weight (g), of sole millet and intercropped with cowpea during both growing seasons (2011/2012 and 2012/2013).

	1000 seed weight season 2011/2012			1000 seed weight season 2012/2013		
Treatment	**Ms**	**CM**	**Means**	**Ms**	**CM**	**Means**
W1	9.35[a]	9.48[a]	9.41[a]	9.90[abc]	9.85[abc]	9.88[ab]
W2	9.40[a]	9.80[a]	9.60[a]	9.95[abc]	10.10[abc]	10.03[ab]
W3	9.75[a]	9.83[a]	9.79[a]	10.38[a]	7.73[cd]	9..050[b]
W4	9.70[a]	10.80[a]	10.25[a]	10.30[ab]	11.43[a]	10.86[a]
W5	5.45[c]	7.25[b]	6.35[b]	5.58[d]	7.93[bcd]	6.75[c]
means	8.73[a]	9.43[a]	9.08	9.22[a]	9.41[a]	9.31
CV%			12.73			17.89
SE Crop			0.2584			0.3726
SE W			0.4086			0.589
SECxW			0.5779			0.8332

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Ms: Millet sole, CM; Cowpea+ Millet (inter cropping)

4.2.3.3 Total seed yield of Millet

As shown on Table (17) analysis of variance showed significant effect of water harvesting technique on total seed yield of sole millet and intercropped with cowpea during the first and second seasons. All water harvesting techniques showed greater grain yield in the second season than in the first season. The overall grain mean yields were 0.913 and 1.012 ton/ha for 2011/20012 and 2012/2013 growing seasons, respectively.

Water harvesting techniques W1, W2, W3, and W4treatments significantly increased total seed yield compared to W5 in which the W3 and W4 treatments produced the highest total seed yield during both growing season.

Generally, the analysis of variance, as shown in Table (15) there was significant differences of intercropping on total seed yield for both growing season.

Table 17: Effect of water harvesting techniques on total seed yield (ton/ha), of sole millet and intercropped with cowpea during both growing seasons.

plant stages	Total seed yield season 2011/2012			Total seed yield season 2012/2013		
Treatment	**Ms**	**CM**	**Means**	**Ms**	**CM**	**Means**
W1	0.888^{b}	1.005^{b}	0.946^{b}	0.985^{c}	1.145^{bc}	1.065^{b}
W2	0.940^{b}	1.010^{b}	0.975^{b}	1.012^{c}	1.125^{bc}	1.069^{b}
W3	0.947^{b}	1.050^{b}	0.998^{b}	1.055^{c}	1.300^{ab}	1.177^{ab}
W4	1.128^{ab}	1.325^{a}	1.226^{a}	1.205^{bc}	1.460^{a}	1.332^{a}
W5	0.463^{c}	0.380^{c}	0.421^{c}	0.410^{d}	0.420^{d}	0.415^{c}
means	0.873^{a}	0.954^{a}	913	0.93^{4b}	1.090^{a}	1.012
CV%			19.04			16.48
SE Crop			38.89			37.282
SE W			61.491			58.949
SECxW			86.962			83.366

Means with the same letter are not significantly different at ($p<0.05$) level.

W1: terracing,W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Ms: Millet sole, CM; Cowpea+ Millet (inter cropping)

4.2.3.4 Straw yield of Millet

As illustrated in Table (18) the straw dry matter weight , at harvest, of e millet was influenced by water harvesting techniques and intercropping in the 2011/2012 and 2012/2013 growing seasons. Water harvesting techniques significantly resulted in high straw dry matter yield compared to control (W5) the in first and second seasons, Moreover, the effect of water harvesting techniques on straw dry matter yield between W1,W2, W3 and W4 was not significant in both seasons.

Intercropping had significant effect on straw dry matter weight during both growing seasons. Lower straw dry matter yield was observed in season 2011/212 than in the 2011/2013 growing season, as illustrated in Appendix (18).W4 treatment produced the highest straw dry matter yield values (3.468 dry ton/ha) in the first growing season, whereas W5 the produced lowest values (1.170 dry ton/ha) in first growing season.

In the high rain fall season (2012/2013) the straw dry matter yield was higher for both sole and intercropped cowpea as compared to the yields in the lower rain fall season (2011/2012), as shown on Table. (4.18)

Table 18: The Effect of water harvesting techniques on straw yield (ton/ha), of sole millet and intercropping with cowpea during both growing seasons (2011/2012 and 2012/2013).

plant stages	Straw yield season (2011/2012)			Straw yield season (2012/2013)		
Treatment	**Ms**	**CM**	**Means**	**Ms**	**CM**	**Means**
W1	3.198[ab]	3.320[ab]	3.258[ab]	3.012[c]	3.230[ab]	3.121[b]
W2	3.058[b]	3.115[b]	3.086[b]	2.962[c]	3..255[ab]	3.108[b]
W3	3.130[b]	3.220[ab]	3.175[b]	3.077[bc]	3.250[ab]	3.163[ab]
W4	3.407[ab]	3.530[a]	3.468[a]	3.117[bc]	3.415[a]	3.266[a]
W5	1.482[c]	1.790[c]	1.636[c]	1.910[d]	2.085[d]	1.997[c]
means	2.855[a]	2.995[a]	2.925	2.816[b]	3.047[a]	2.931
CV%			9.00			4.38
SE Crop			58.862			28.739
SE W			93.069			45,440
SECxW			131.62			64.261

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing,W2: V-shape micro catchment,W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Ms: Millet sole, CM; Cowpea+ Millet (inter cropping)

4.2.3.5 Nutritive value (crude protein, ash and phosphorus) for millet seed

The effect of water harvesting techniques and intercropping on nutritive value, crude protein, ash and phosphorus, percentage of sole millet is presented on Table (19). There were no significant differences observed between the treatments for both crude protein, and ash, the control (W5) produced more phosphorus (27, 48%) followed by (W1, W2, W3 and W4) and it reached significant difference. Statistical analysis of intercropping showed no significant differences between treatments for both crude protein and phosphorus, while there were significant differences for ash content. The highest ash percent was recorded for CM (8.54%) and the lowest value for Ms, (2.29%). Generally intercropping produced low phosphorus content and more crude protein and ash compared to sole millet.

4.2.3.6 Mineral content (magnesium, calcium and potassium) for millet

The effect of water harvesting techniques and intercropping on (mineral content) magnesium, calcium and potassium content for sole millet is presented in Table (20).

As shown in table (18) the analysis of variance showed that there was significant effect, of water harvesting technique on mineral content for millet seed for both magnesium and potassium but there was no significant effect on calcium. . Lower value of magnesium and potassium were recorded by W5, (10.75% and 4.70%) respectively. While the highest value was recorded for W4 and W1, (14.13% and 6.20%) and there were no significant differences between WI, W2, W3 and W4 in terms of potassium content. Intercropping results indicated that there was significant difference in calcium content, while there were no significant effects for magnesium and potassium among intercropping treatments. Generally, sole millet seed content had higher magnesium and potassium and low calcium content compared to intercropped treatments.

Table 19: Effect of water harvesting techniques on crud protein, ash and phosphorus (%), of sole millet and intercropped with cowpea in first growing season (2011/2012)

Treatment	Crud protein			Ash			Phosphorus		
	Ms	**CM**	**Means**	**Ms**	**CM**	**Means**	**Ms**	**CM**	**Means**
W1	16.28[a]	16.69[a]	16.48[a]	2.29[b]	5.51[ab]	3.90[a]	26.73[ab]	28.01[a]	27.37[ab]
W2	16.89[a]	17.51[a]	17.20[a]	3.69[b]	6.43[ab]	5.06[a]	28.81[a]	21.37[ab]	25.09[ab]
W3	17.72[a]	18.62[a]	18.17[a]	3.44[b]	5.97[ab]	4.70[a]	26.37[ab]	19.67[b]	23.02[ab]
W4	17.75[a]	16.75[a]	17.25[a]	5.51[ab]	8.54[a]	7.02[a]	23.68[ab]	19.87[b]	21.77[b]
W5	16.72[a]	17.57[a]	17.15[a]	3.89[b]	5.53[ab]	4.71[a]	27.00[ab]	27.96[a]	27.48[a]
means	17.07[a]	17.43[a]	17.25	3.76[b]	6.40[a]	5.08	26.52[a]	23.73[a]	24.94
CV%			12.01			60.5			21.96
SE Crop			0.4634			0.687			1.2247
SE W			0.7326			1.0862			1.9365
SECxW			1.0361			1.5361			2.7386

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing,W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds

W5: Rain fall as control, Ms: Millet sole, CM; Cowpea+ Millet (inter cropping)

Table 20: Effect of water harvesting techniques on magnesium, calcium and potassium (%), of sole millet and intercropped with cowpea in first growing season (2011/2012)

Treatment	Magnesium			Calcium			Potassium		
	Ms	**CM**	**Means**	**Ms**	**CM**	**Means**	**Ms**	**CM**	**Means**
W1	14.50[a]	9.25[a]	11.88[ab]	11.00[a]	15.50[a]	13.25[a]	6.57[a]	5.84[a]	6.20[a]
W2	7.00[a]	9.50[a]	8.25[b]	13.50[a]	13.00[a]	13.25[a]	6.50[a]	5.35[a]	5.93[a]
W3	10.00[a]	12.50[a]	11.25[ab]	11.00[a]	12.00[a]	11.50[a]	6.06[a]	5.61[a]	5.83[a]
W4	14.00[a]	14.25[a]	14.13[a]	11.00[a]	15.00[a]	13.00[a]	6.60[a]	5.14[a]	5.87[a]
W5	12.50[a]	9.00[a]	10.75[ab]	11.50[a]	14.00[a]	12.75[a]	3.62[b]	5.79	4.70[b]
means	11.60[a]	10.90[a]	11.25	11.60[b]	13.90[a]	12.75	5.87[a]	5.55[a]	5.71
CV%			49.82			26.1			18.01
SE Crop			1.2533			0.7442			0.2299
SE W			1.9816			1.1767			0.3635
SECxW			2.8024			1.66.42			0.514

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Ms: Millet sole, CM; Cowpea+ Millet (inter cropping)

4.3. Cowpea

4.3.1 Effect of water harvesting techniques and intercropping on Growth of cowpea

4.3.1.1 Plant height (cm)

Effect of water harvesting technique on plant height of sole cowpea and intercropped with millet is presented on Tables (21-.22)**.** Plant height was measured three times at (seedling, flowering and maturity stage) for two growing seasons throughout the course of the study.

Mean plant height of cowpea for the first and second growing seasons was influenced by water harvesting technique, the increase in plant height was gradual during seedling, then the increase was quite steep during flowering stage. The overall mean plant height increased from 8.57 cm at seedling stage to 178.06 cm at maturity in the first season and from 19.3 cm at seedling stage to 181 cm at maturity stage in the second growing season.

No significant differences, of intercropping were found for plant height at the three plant growth stage in both growing seasons, where the intercropping significantly increased plant height at flowering stage in the second season. However, W3 water harvesting techniques recorded the highest plant height at maturity stage followed by W4 in both growing seasons. There were no significant effects in plant height between W1, W2, W3 and W4 at flowering and maturity stages for both growing seasons .At flowering and maturity stages, intercropping treatment caused marked reduction in plant height, but the reduction did not reach the level of significance in the first season, while in the second season intercropping treatment caused an increase in plant height at seedling and flowering stages but was not significant.

Table 21: Effect of water harvesting techniques on plant height (cm) of sole cowpea and intercropped with millet at different growth stage in the first season.(2011/2012)

Treatment	Growth stage								
	Seedling			Flowering			Maturity		
	Cs	CM	Means	Cs	CM	Means	Cs	CM	Means
W1	9.95[a]	6.90[b]	8.43[a]	170.82[a]	183.50[a]	177.16[a]	190.38[a]	194.38	192.38[a]
W2	9.30[ab]	9.25[ab]	9.28[a]	177.80[a]	160.00[a]	168.90[a]	192.35[a]	175.53[ab]	183.94[a]
W3	8.40[ab]	9.13[ab]	8.76[a]	169.20[a]	182.33[a]	175.76[a]	189.10[a]	218.08[a]	203.58[a]
W4	7.55[ab]	10.00[a]	8.78[a]	170.50[a]	166.25[a]	168.38[a]	188.30[a]	186.30[a]	187.30[a]
W5	6.98[b]	8.20[ab]	7.58[a]	141.90[a]	73.33[b]	107.61[b]	136.02[bc]	110.25[c]	123.14[b]
means	8.44[a]	8.70[a]	8.57	166.04[a]	153.08[a]	159.56	179.23[a]	176.90[a]	178.06
CV%			23.04			19.88			18.39
SE Crop			0.4412			7.091			7.3208
SE W			0.6976			11.21			11.575
SECxW			0.9866			15.857			16.37

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

Table 22: Effect of water harvesting techniques on plant height (cm) of sole cowpea and intercropped with millet at different growth stage in the second season.(2012/2013)

Treatment	Growth stage								
	Seedling stage			Flowering stage			Maturity stage		
	Cs	CM	Means	Cs	CM	Means	Cs	CM	Means
W1	16.00^{abc}	20.20^{abc}	18.10^{ab}	126.80^{ab}	191.75^{a}	159.28^{a}	193.60^{ab}	198.13^{ab}	195.86^{a}
W2	18.15^{abc}	21.55^{ab}	19.85^{a}	152.75^{ab}	165.00^{ab}	158.88^{a}	181.27^{ab}	173.82^{ab}	177.55^{a}
W3	18.35^{abc}	24.75^{a}	21.55^{a}	159.95^{ab}	182.25^{a}	171.10^{a}	192.25^{ab}	220.47^{ab}	206.36^{a}
W4	22.30^{ab}	23.93^{a}	23.11^{a}	165.95^{ab}	186.25^{a}	176.10^{a}	223.75^{a}	187.32^{ab}	205.54^{a}
W5	12.15^{c}	13.95^{bc}	13.05^{a}	105.75^{c}	106.00^{c}	105.87^{b}	133.60^{cd}	108.28^{d}	120.94^{b}
means	17.39^{a}	20.88^{a}	19.13	142.24^{b}	166.25^{a}	154.25	184.90^{a}	177.61^{a}	181.00
CV%			31.83			18.97			17.94
SE Crop			1.3615			6.5411			7.271
SE W			2.1528			10.342			11.496
SECxW			3.0445			14.626			16.258

Means with the same letters are not significantly different at ($p<0.05$) level

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

4.3.1.2 Number of leaves per plant

Tables (23) and (24), show the effect of water harvesting techniques on number of leaves per plant of sole cowpea and intercropped with millet for both growing seasons.

The analysis of variance revealed that water harvesting techniques had significant affect on number of leaves/plant in both growing seasons, while intercropping showed no significant difference. Generally, intercropping reduced the number of leaves per plant in cowpea at all stages, except in the second season at seedling and flowering stage, but the reduction was not significant in both growing seasons. In the first season, the number of total mean leaves/plant ranged between 6.13 and 17.38, while in the second season it ranges between 9.35 and 16.95 at seedling and maturity stages. There were significant differences between water harvesting techniques and control (W5) on number of leaves per plant for both growing seasons except at seedling stage in the first season. A significant difference was also recorded at flowering stage in W3 and W5 compared to other techniques.

On other hand, there were no significant effects between W1, W2, W3 and W4 at flowering and maturity stages in both seasons except at flowering stage.

Table 23: Effect of water harvesting techniques on number of leaves /plant of sole cowpea and intercropped with millet at different growth stages in the first season.(2011/2012)

Treatment	Growth stage								
	Seedling stage			Flowering stage			Maturity stage		
	Cs	CM	Means	Cs	CM	Means	Cs	CM	Means
W1	7.00[a]	5.50[b]	6.25[a]	16.75[a]	16.50[a]	16.63[a]	16.75[a]	18.25[a]	17.50[a]
W2	5.75[ab]	5.25[b]	5.50[a]	17.50[a]	14.25[ab]	15.88[a]	16.75[a]	15.25[a]	16.00[a]
W3	6.00[ab]	5.75[ab]	5.87[a]	16.50[a]	13.50[ab]	15.00[ab]	18.25[a]	18.50[a]	18.38[a]
W4	6.25[ab]	6.00[ab]	6.13[a]	15.25[a]	17.75[a]	16.50[a]	16.75[a]	18.00[a]	17.38[a]
W5	5.75[ab]	5.25[b]	5.50[a]	13.75[ab]	9.50[b]	11.63[b]	14.50[ab]	10.25[b]	12.38[b]
means	6.15[a]	5.55[a]	5.85	15.95[a]	14.30[a]	15.13	16.60[a]	16.05[a]	16.33
CV%			17.25			25.29			18.53
SE Crop			0.226			0.8553			0.6766
SE W			0.3575			1.3524			1.0697
SECxW			0.5055			1.9126			1.5128

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

Table 24: Effect of water harvesting techniques on number of leaves/plant of sole cowpea and intercropped with millet at different growth stages in the second season.(2012/2013).

Treatment	Growth stage								
	Seedling stage			Flowering stage			Maturity stage		
	Cs	CM	Means	Cs	CM	Means	Cs	CM	Means
W1	9.50[abc]	10.00[ab]	9.75[a]	16.00[a]	16.50[a]	16.25[a]	19.50[ab]	18.00[ab]	18.75[a]
W2	9.00[abc]	9.25[abc]	9.13[ab]	14.50[a]	15.00[a]	14.75[a]	17.00[abc]	15.75[bc]	16.38[a]
W3	9.50[abc]	10.25[a]	9.88[a]	15.25[a]	16.00[a]	15.63[a]	18.00[ab]	19.25[ab]	18.63[a]
W4	10.00[ab]	10.25[a]	10.13[a]	14.75	16.50[a]	15.63[a]	20.50[a]	18.25[ab]	19.38[a]
W5	8.00[bc]	7.75[c]	7.88[b]	11.00[b]	11.25[b]	11.13[b]	13.25[cd]	10.00[d]	11.63[b]
means	9.20[a]	9.50[a]	9.35	14.30[a]	15.05[a]	14.68	17.65[a]	16.25[a]	16.95
CV%			15.61			10.64			17.53
SE Crop			0.3263			0.349			0.6646
SE W			0.5159			0.5518			1.0508
SECxW			0.7297			0.7804			1.486

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

4.3.1.3 Stem diameter

Effect of water harvesting techniques on stem diameter of sole cowpea and intercropped with millet is presented on Table (25) and (26).

Statistical analysis showed that the overall mean stem diameter for sole cowpea was higher compared to intercropping but the difference was not significant at the seedling and flowering stages, but a significant difference was observed at maturity in the first season, while in the second season the overall mean of stem diameter for intercropping was greater compared to sole cowpea but the different was not significant at three stage of growth.

Stem diameter increased with time for all treatments and reached its maximum at maturity stage, intercropping produced thicker stem diameter compared to sole sowing in both seasons.

The analysis of variance revealed that water harvesting techniques significantly increased stem diameter at the three stages of growth in the first and second seasons. The lowest stem diameter was recorded for W5 at seedling stage (0.40cm) in the first season, the highest stem diameter was found in W4 at maturity stage, (1.49cm) during second season.

There were no significant differences between water harvesting techniques W1, W2, W3 and W4 in the first season, while they were significantly different in the second season.

Table 25: Effect of water harvesting techniques on stem diameter (cm) of sole cowpea and intercropped with millet at different growth stages in the first season.(2011/2012).

Treatment	Growth stage								
	Seedling			Flowering			Maturity		
	Cs	CM	Means	Cs	CM	Means	Cs	CM	Means
W1	0.48[a]	0.44[a]	0.46[a]	1.09[cde]	1.35[a]	1.22[a]	1.22[bcd]	1.34[abc]	1.28[a]
W2	0.47[a]	0.45[a]	0.46[a]	1.24[abcd]	1.06[de]	1.15[ab]	1.17[cd]	1.35[ab]	1.26[a]
W3	0.46[a]	0.50[a]	0.48[a]	1.25[abc]	1.24[abcd]	1.24[a]	1.30[bcd]	1.36[ab]	1.33[a]
W4	0.49[a]	0.47[a]	0.48[a]	1.125[bcde]	1.27[ab]	1.20[a]	1.18[bcd]	1.51[a]	1.34[a]
W5	0.47[a]	0.40[a]	0.44[a]	1.08[cde]	0.99[e]	1.03[b]	1.14[de]	0.96[e]	1.05[b]
means	0.47[a]	0.45[a]	0.46	1.16[a]	1.18[a]	1.17	1.199[b]	1.30[a]	1.25
CV%			14.01			10.66			10.12
SE Crop			0.0145			0.0279			0.0283
SE W			0.0229			0.044			0.0448
SECxW			0.0623			0.0623			0.0633

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

Table 26: Effect of water harvesting techniques on stem diameter (cm) of sole cowpea and intercropped with millet at different growth stages in the second season.(2012/2013)

Treatment	Growth stage								
	Seedling			**Flowering**			**Maturity**		
	Cs	**CM**	**Means**	**Cs**	**CM**	**Means**	**Cs**	**CM**	**Means**
W1	0.50^{b}	0.61^{b}	0.56^{ab}	1.01^{abc}	1.17^{a}	1.09^{a}	1.40^{ab}	1.36^{ab}	1.38^{ab}
W2	0.54^{b}	0.89^{a}	0.72^{a}	1.04^{abc}	0.97^{abc}	1.00^{ab}	1.30^{b}	1.35^{ab}	1.33^{ab}
W3	0.52	0.66^{ab}	0.59^{ab}	1.01^{abc}	1.15^{ab}	1.08^{ab}	1.23^{bc}	1.36^{ab}	1.29^{b}
W4	0.54^{b}	0.63^{b}	0.58^{ab}	1.03^{abc}	1.14^{ab}	1.09^{a}	1.43^{ab}	1.55^{a}	1.49^{a}
W5	0.46^{b}	0.50^{b}	0.48^{b}	0.92^{c}	0.94^{bc}	0.93^{b}	1.07^{cd}	0.95^{d}	1.01^{c}
means	0.51^{b}	0.66^{a}	0.58	1.00^{a}	1.07^{a}	1.06	1.28^{a}	1.31^{a}	1.30
CV%			28.46			14.61			12.02
SE Crop			0.0371			0.0339			0.0349
SE W			0.0587			0.0536			0.0552
SECxW			0.0830			0.0758			0.078

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

4.3.1.4 Plant density

The plant density was measured in the middle of both growing seasons, the effect of water harvesting techniques on plant density (m^2) of sole cowpea and intercropped with millet at seedling, flowering and maturity stages, is presented on Tables (27) and (28). The number of plants per square meter (m^2) was greater in the second season as compared to the first season at maturity stage.

The analysis of variance showed significant effect of water harvesting technique and intercropping on plant density in both growing seasons.

The plant densities were significantly lower in W5 than in other treatment, there were no significant differences between W3 and W4 at seedling and flowering stages, while there were significant effects at maturity stage in the first season, W1 and W2 had the same number of plant density 5.50 and 4,75 at three stages in the second growing season. On the other hand, W4 and W3 showed the highest plant densities ranging between 5.13 to 5.50 plants per square meter (m^2) in the first and second seasons, respectively.

Table 27: Effect of water harvesting techniques on plant density (m^{-2}) of sole cowpea and intercropped with millet at different growth stages, during the first season.(2011/2012)

Treatment	Growth stage								
	Seedling			Flowering			Maturity		
	Cs	CM	Means	Cs	CM	Means	Cs	CM	Means
W1	6.00[ab]	3.75[f]	4.88[ab]	6.00[ab]	3.75[f]	4.88[ab]	6.00[a]	3.50[d]	4.75[ab]
W2	5.50[abc]	4.00[ef]	4.75[bc]	5.50[abc]	4.00[ef]	4.75[bc]	5.75[ab]	3.75[d]	4.75[ab]
W3	6.25[a]	4.50[def]	5.38[a]	6.25[a]	4.50[def]	5.38[a]	6.25[a]	4.25[cd]	5.25[a]
W4	5.25[bcd]	5.50[abc]	5.38[a]	5.25[bcd]	5.50[abc]	5.38[a]	5.50[ab]	4.00[d]	4.75[ab]
W5	4.75[cde]	3.75[f]	4.25[c]	4.75[cde]	3.75[f]	4.25[c]	5.00[bc]	3.50[d]	4.25[b]
means	5.55[a]	4.30[b]	4.93	5.55[a]	4.30[b]	4.93	5.70[a]	3.80[b]	4.75
CV%			12.03			12.03			13.5
SE Crop			0.1325			0.1325			0.1434
SE W			0.2094			0.2094			0.2267
SECxW			0.2962			0.2962			0.3206

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as Control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

Table 28: Effect of water harvesting techniques on plant density (m^{-2}) of sole cowpea and intercropped with millet at different growth stages during the second season.(2012/2013)

Treatment	Growth stage								
	Seedling			Flowering			Maturity		
	Cs	**CM**	**Means**	**Cs**	**CM**	**Means**	**Cs**	**CM**	**Means**
W1	5.25^{abc}	3.75^{e}	4.50^{b}	5.25^{abc}	3.75^{e}	4.50^{b}	5.25^{abc}	3.75^{e}	4.50^{b}
W2	5.75^{ab}	3.75^{e}	4.75^{b}	5.75^{ab}	3.75^{e}	4.75^{b}	5.75^{ab}	3.75^{e}	4.75^{b}
W3	6.25^{a}	4.00^{de}	5.13^{ab}	6.25^{a}	4.00^{de}	5.13^{ab}	6.25^{a}	4.00^{de}	5.13^{ab}
W4	6.00^{ab}	5.00^{bcd}	5.50^{a}	6.00^{ab}	5.00^{bcd}	5.50^{a}	6.00^{ab}	5.00^{bcd}	5.50^{a}
W5	5.25^{abc}	4.25	4.75^{b}	5.25^{abc}	4.25^{cde}	4.75^{b}	5.25^{abc}	4.25^{cde}	4.75^{b}
means	5.70^{a}	4.15^{b}	4.93	5.70^{a}	4.15^{b}	4.93	5.70^{a}	4.15^{b}	4.93
CV%			14.61			14.61			14.61
SE Crop			0.1609			0.1609			0.1609
SE W			0.2544			0.2544			0.2544
SECxW			0.3597			0.3597			0.3597

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

4.3.2 Effect of water harvesting techniques and intercropping on reproductive stage

4.3.2.1 Days to 50% flowering of cowpea

The effect of water harvesting techniques on days to50% flowering sole cowpea and intercropped with millet at two growing seasons is presented on Table (29).

There were no significant differences in days to 50% flowering between intercropping and sole cowpea for all treatments. However, sole cowpea tended to flower earlier than other intercropping in the first and second seasons.

The analysis of variance revealed that significant affect of water harvesting techniques was observed on days to 50% flowering of cowpea in both growing seasons. There was no significant difference between W1, W2, W3 and W4 on days to 50 % flowering.

4.3.2.2 Days to maturity of cowpea

The effect of water harvesting techniques on days to maturity of sole cowpea and intercropped with millet at the two growing seasons is presented on Table (30).

There were no significant differences in days to maturity between intercropping and sole cowpea, for all water harvesting techniques W1,W2,W3 and W4 treatments significantly affected days to maturity compared to W5 in both growing seasons. However, monocropped cowpea tended to mature earlier than other intercropping treatments in the first and second seasons.

Table 29: Effect of water harvesting techniques on days to 50% flowering of sole cowpea and intercropped with millet at two growing seasons

Treatment	Day to50% flowering season 2011/2012			Day to 50% flowering season 2012/2013		
	Cs	CM	Means	Cs	CM	Means
W1	55.75[a]	57.75[a]	56.75[a]	56.00[ab]	57.50[a]	56.75[a]
W2	56.25[a]	56.00[a]	56.13[a]	56.50[ab]	56.75[ab]	56.63a
W3	55.25[a]	56.75[a]	56.00[a]	55.25[b]	56.50[ab]	55.88[a]
W4	56.25[a]	55.25[a]	55.75[a]	55.75[ab]	56.25[ab]	56.00[a]
W5	51.50[b]	50.00[b]	50.75[b]	51.75[c]	51.75[c]	51.75[b]
means	55.00[a]	55,15[a]	55.08	55.05[a]	55.75[a]	55.40
CV%			3.9400			2.56
SE Crop			0.4857			0.3177
SE W			0.7679			0.5023
SECxW			1.086			0.7104

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

Table 30: Effect of water harvesting techniques on days to maturity of sole cowpea and intercropped with millet at two growing seasons

Treatment	Day to maturity season 2011/2012			Day to maturity season 2012/2013		
	Cs	CM	Means	Cs	CM	Means
W1	88.75[ab]	91.00[a]	89.87[a]	88.75[ab]	90.25[ab]	89.50[a]
W2	87.00[b]	90.00[ab]	88.50[a]	87.00[b]	89.75[ab]	88.38[a]
W3	89.50[ab]	91.25[a]	90.37[a]	89.50[ab]	91.00[a]	90.25[a]
W4	90.00[ab]	89.25[ab]	89.63[a]	90.00[ab]	89.50[ab]	89.75[a]
W5	75.25[d]	80.50[c]	77.88[b]	75.25[d]	79.75[c]	77.50[b]
means	86.10[b]	88.40[a]	87.25	86.10[b]	88.05[a]	87.08
CV%			2.500			2.67
SE Crop			0.4871			0.519
SE W			0.7701			0.8207
SECxW			1.0891			1.1606

Means with the same letters are not significantly different at ($p<0.05$) level.
W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as Control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

4.3.3 Effect of water harvesting techniques and intercropping on yield and yield components

4.3.3.1 Number of flowers per raceme

The effect of water harvesting techniques on number of the flowers per raceme of sole cowpea and intercropped with millet during two growing seasons is presented on Table (31).

The analysis of variance revealed that water harvesting techniques significantly affected the number of flowers per raceme in both growing seasons, while intercropping had no significant effect. In the first season the number of flowers per raceme ranged between11.38 to 11.88, while in second season it ranged between 9.38 to 13. W1 and W4 showed the highest number of flowers per raceme (13) in the second season, whereas the W5 treatment significantly produced the lowest number of flowers per raceme in the first and second seasons (10.4 and 9.4) respectively, compared to other treatment (W1, W2, W3, and W4).

4.3.3.2 Number of pods per plant

The effect of water harvesting techniques on number of pods per plant of sole cowpea and intercropped with millet in the two season is presented on Table (32). Sowing cowpea in alternate row with millet, increased the number of pods per plant but not significantly in the first and second seasons, The analysis of variance showed that there were significant effects of water harvesting techniques on number of pod per plant in both growing seasons. W5 treatment significantly produced the lowest number of pods per plant in the first and second seasons 1.5, 1.4 respectively as compared to W1, W2, W3 and W4. On the other hand W2 significantly produced the highest number of pod per plant 5.5, compared to W1, W3 and W4 in the two growing seasons; however, there was no significant differences between W1, W3 and W4 treatments in first and second growing seasons. Generally, the interaction between water harvesting techniques and intercropping significantly affected number of pods per plant**.**

Table 31: The effect of water harvesting techniques on number of flowers per raceme of sole cowpea and intercropped with millet in the two seasons (2011/2012 and 2012/ 2013).

Treatment	Number of Flowering Per raceme season 2011/2012			Number of flowering per raceme season 2012/2013		
	Cs	**CM**	**Means**	**Cs**	**CM**	**Means**
W1	11.50[abc]	12.00[ab]	11.75[a]	13.00[ab]	13.00[ab]	13.00[a]
W2	12.25[ab]	10.75[bc]	11.50[ab]	12.25[ab]	12.25[ab]	12.25[a]
W3	12.00[ab]	10.75[bc]	11.38[ab]	12.25[ab]	11.25[bc]	11.75[a]
W4	11.00[abc]	12.75[a]	11.88[a]	12.25[ab]	13.75[a]	13.00[a]
W5	10.00[c]	10.75[bc]	10.38[b]	9.25[c]	9.50[c]	9.38[b]
means	11.35[a]	11.40[a]	11.38	11.80[a]	11.95[a]	11.88
CV%			10.87			13.24
SE Crop			0.2765			0.3516
SE W			0.4371			0.556
SECxW			0.6182			0.7863

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

Table 32: Effect of water harvesting techniques on number of pods per plant of sole cowpea and intercropped with millet in the two seasons (2011/2012 and 2012/ 2013).

Treatment	Number of pods per plant (season 2011/2012)			Number of pods per plant (season 2012/2013)		
	Cs	**CM**	**Means**	**Cs**	**CM**	**Means**
W1	2.75[b]	3.25[ab]	3.00[a]	3.50[b]	3.25[b]	3.38[ab]
W2	3.25[ab]	3.00[ab]	3.12[a]	2.75[b]	8.25[a]	5.50[a]
W3	2.75[b]	3.75[a]	3.25[a]	3.00[b]	4.00[ab]	3.50[ab]
W4	3.25[ab]	2.50[b]	2.88[a]	3.50[b]	3.50[b]	3.50[ab]
W5	1.50[c]	1.50[c]	1.50[b]	1.50[b]	1.25[b]	1.38[b]
means	2.70[a]	2.80[a]	2.75	2.85[a]	4.05[a]	3.45
CV%			24.84			94.02
SE Crop			0.1528			0.7253
SE W			0.2415			1.1469
SECxW			0.3416			1.6219

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

4.3.3.3 Number of seeds per pod

The effect of water harvesting techniques on number of seeds per pod of sole cowpea and intercropped with the millet in the two growing seasons is presented on Table (33).There were significant differences in number of seeds per pod for intercropping and water harvesting techniques in the first and second seasons, however, higher values of number of seeds per pod were recorded in the first season compared to second one 13.85 and 13.33 seeds pod respectively. Intercropping significantly reduced the number of seeds per pod in the first and second seasons. Their total means were 14,65 and 13.75 and13.05 and 12.90 in the first and second seasons respectively. The number of seeds/pod for intercropped cowpea was reduced by 12.3 and 6.6% in first and second seasons respectively. W5 treatment produced the lowest number of seeds per pod (12.38 and 12.50) in first and second seasons, respectively compared to other treatments.

4.3.3.4 100 seed weigh

Tables (34) represent the effect of water harvesting techniques on 100 seed weight of sole cowpea and intercropped with millet during the two growing seasons. The weight of the 100 seeds of cowpea was not affected by intercropping treatment on both growing seasons, while it was significantly affected by water harvesting techniques in the first and second season.

The average 100 seed weight was more in the second season with an overall mean of 9.20.55g than in the first season (with an overall mean of 20.47 g). In both growing seasons, the 100-seed weight was higher with W3 (21.51g and 21.65g respectively than with all other treatment. On the other hand, W5 significantly resulted in the lowest 100-seed weight (17.99g and 18.48 g) compared to other treatments in the first and second growing seasons, but there were no significance different between W1,W2,W3and W4 water during the first season, Whereas there were significant difference in second season.

Table 33: Effect of water harvesting techniques on number of the seeds per pod of sole cowpea and intercropped with millet in the two season (2011/2012 and 2012/ 2013).

Treatment	Number of seeds per pod (season 2011/2012)			Number of seeds per pod (season 2012/2013)		
	Cs	**CM**	**Means**	**Cs**	**CM**	**Means**
W1	15.25[ab]	13.50[cde]	14.38[a]	14.00[ab]	13.25[abc]	13.63[a]
W2	15.75[a]	13.25[cde]	14.50[a]	13.75[ab]	13.00[bc]	13.38[ab]
W3	14.25[abc]	14.00[bcd]	14.13[a]	13.75[ab]	14.00[ab]	13.88[a]
W4	15.25[ab]	12.50[de]	13.88[a]	14.50[a]	12.00[c]	13.25[ab]
W5	13.50[cde]	12.00[e]	12.38[b]	12.75[bc]	12.25[c]	12.50[b]
means	14.65[a]	13.05[b]	13.85	13.75[a]	12.90[b]	13.33
CV%			7.51			6.54
SE Crop			0.2325			0.1947
SE W			0.3677			0.3079
SECxW			0.52			0.4354

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing, W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

Table 34: Effect of water harvesting techniques on 100 seeds weight of sole cowpea and intercropped with millet in the two seasons (2011/2012 and 2012/ 2013).

Plant stages	**100 seeds weight season (2011/2012)**			**100 seeds weight season (2012/2013)**		
Treatment	**Cs**	**CM**	**Means**	**Cs**	**CM**	**Means**
W1	21.38[a]	20.65[ab]	21.01[a]	21.65[a]	20.33[abcd]	20.99[a]
W2	20.48[ab]	22.08[a]	21.28[a]	20.80[abcd]	22.08[a]	21.44[a]
W3	20.95a	22.08[a]	21.51[a]	21.20[abc]	22.10[a]	21.65[a]
W4	22.18[a]	18.91[bc]	20.54[a]	21.50[ab]	18.91[bcd]	20.21[ab]
W5	16.88[c]	19.10[ab]	17.99[b]	18.65[cd]	18.30[d]	18.48[b]
means	20.37[a]	20.56[a]	20.47	20.76[a]	20.34[a]	20.55
CV%			8.36			8.86
SE Crop			0.3826			0.4072
SE W			0.6049			0.6438
SECxW			0.855			0.9105

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing,W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

4.3.3.5 Total seed yield of cowpea (ton/ha)

Analysis of variance in Table (35) showed that there was a significant effect in first and second seasons, due to of water harvesting technique on total seed yield of cowpea. All water harvesting techniques showed greater grain yield in the first season than in the second season. The overall grain mean yield were 0.588 and 0.550 (t/ha) for 2011/20012 and 2012/2013 growing seasons, respectively.

W4 significantly produced the highest total seed yield compared toW1, W2 and W3in both growing seasons, on the other hand, W5 significantly produced the lowest seed yield compared to W1, W2, W3 and W4 treatments in first and second seasons.

Generally the analysis of variance on table (35) showed that there was a significant effect of intercropping on total seed yield for both growing seasons.

Generally, all intercropping treatments significantly reduced final seed yield of cowpea, the greater reduction occurring with CMW5 in the first season, giving 0.235 ton/ha.

Table 35: Effect of water harvesting techniques on total yield (ton/ha) of sole cowpea and intercropped with millet in the two grown seasons (2011/12 and 2012/2013).

	Total yield season (2011/12)			Total yield season (2012/13)		
Treatment	**Cs**	**CM**	**Means**	**Cs**	**CM**	**Means**
W1	0.628^{c}	0.590^{c}	0.609^{b}	0.650^{bc}	0.580^{de}	0.615^{b}
W2	0.6280^{c}	0.580^{c}	0.604^{b}	0.608^{cd}	0.525^{e}	0.566^{c}
W3	0.658^{ab}	0.625^{c}	0.641^{b}	0.615^{cd}	0.575^{de}	0.595^{bc}
W4	0.798^{a}	0.735^{a}	0.764^{a}	0.755^{a}	0.695^{ab}	0.725^{a}
W5	0.333^{d}	0.310^{d}	0.321^{c}	0.260^{f}	0.235^{f}	0.248^{d}
means	0.608^{a}	0.568^{a}	0.588	0.578^{a}	0.522^{b}	0.550
CV%			11.67			8.500
SE Crop			15.331			10.452
SE W			24.241			16.525
SECxW			34.282			23.371

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing,W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

4.3.3.6 Dry matter yield of cowpea (ton/ha)

The dry matter yield, of cowpea was influenced by water harvesting technique and intercropped in growing seasons as illustrated on Table (36) in which significant increase of water harvesting techniques on dry matter yield was compared to control (W5) in first and second seasons. Moreover, the effect of water harvesting techniques on straw dry matter yield between W1,W2, W3 and W4 was not significant in both seasons.

Intercropping had significant effect on dry matter weight during both growing seasons. Lower dry matter yield was observed in season 2011/212. W2 produced the highest dry matter yield values (1.180 ton/ha) in the second growing season, whereas W5 produced lowest values (0.545 ton/ha) in the second growing season. There was no significant difference in dry matter weight between, V-shape, contour bund, terrace and trapezoid shape in all treatments.

Dry matter yield of cowpea was significantly reduced by all intercropping treatments, in both growing seasons the greatest reduction occurring in the second season.

Table 36: Effect of waters harvesting techniques on final straw yield (ton/ha) of sole cowpea and intercropped with millet in the two seasons (2011/2012 and 2012/ 2013).

Grown Season	**Final straw yield season (2011/2012)**			**Final straw yield season (2012/2013)**		
Treatment	**Cs**	**CM**	**Means**	**Cs**	**CM**	**Means**
W1	1.013^{bcd}	0.900^{f}	0.956^{b}	1.055^{bcd}	0.970^{d}	1.013^{b}
W2	1.050^{bc}	0.990^{cde}	1.020^{b}	1.063^{bc}	0.970^{d}	1.016^{b}
W3	1.002^{cd}	0.920^{de}	0.961^{b}	1.075^{b}	0.980^{cd}	1.028^{b}
W4	1.230^{a}	1.105^{b}	1.168^{a}	1.240^{a}	1.120^{b}	1.180^{a}
W5	0.627^{f}	0.568^{f}	0.598^{c}	0.600^{f}	0.490^{f}	0.545^{c}
means	0.984^{a}	0.897^{b}	0.950	1.007^{a}	0.906^{b}	0.956
CV%			6.99			6.56
SE Crop			14.706			14.023
SE W			23.253			22.172
SECxW			32.884			31.356

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing,W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

4.3.4 Nutritive value

4.3.4.1 Phosphorus crude fibre and crude protein content of cowpea

The effect of water harvesting techniques on nutritive value of phosphorus, crude fibre and crude protein content of sole cowpea and intercropped with millet in first season is presented in Table (37).

There were no significant difference between the treatments for phosphorus and crude protein, while there were significant differences between treatments in crude fibre. Intercropping recorded the highest phosphorus, crude fibre and crude protein content (29.06, 9, 97 and 26.66%) respectively compared to sole cowpea crop treatment which recorded (26.70. 8.64 and 25.49%).

Analysis of variance table (Table 4.37) showed that there was no significant effect, of water harvesting technique on nutritive value of cowpea for both phosphorus and crude fibre, but reached significant level with crude protein. . Lower phosphorus, crude fibre and crude protein were recorded in W4, W3 and W2 (24.42, 8.51and 23.08) respectively. There were no significant differences between WI, W3 and W5 in terms of crude protein content, while there were significant differences between W2 and W4.treament.Crude fibre of cowpea seed was significantly increased when intercropping with millet

Table 37: Effect of water harvesting techniques on (nutritive value) phosphorus, crude fibre and crude protein contents of sole cowpea and intercropped with millet in the first season (2011/2012).

	Phosphorus			Crude fiber			Crude protein		
Treatment	**Cs**	**CM**	**Means**	**Cs**	**CM**	**Means**	**Cs**	**CM**	**Means**
W1	29.47[a]	28.50[a]	28.98[a]	9.67[ab]	10.25[ab]	9.96[a]	28.02[a]	27.66[a]	27.84[a]
W2	27.07[a]	33.47[a]	30.27[a]	8.91[ab]	10.97[a]	9.94[a]	21.30[b]	24.87[ab]	23.08[b]
W3	27.60[a]	29.40[a]	28.50[a]	7.70[b]	9.32[ab]	8.51[a]	26.94[a]	26.92[a]	26.93[a]
W4	23.40[a]	25.44[a]	24.42[a]	8.58[ab]	10.09[ab]	9.33[a]	25.05[a]	26.14[a]	25.59[ab]
W5	25.97[a]	28.50[a]	27.23[a]	8.36[ab]	9.24[ab]	8.80[a]	26.16[a]	27.74[a]	26.95[a]
means	26.70[a]	29.06[a]	27.88	8.64[b]	9.97[a]	9.31	25.49[a]	26.66[a]	26.08
CV%			31.12			21.23			9.9
SE Crop			1.9403			0.4418			0.5775
SE W			3.0679			0.6986			0.9132
SECxW			4.3387			0.9879			1.2914

Means with the same letters are not significantly different at ($p<0.05$) level.

W1: terracing,W2: V-shape micro catchment, W3: Contour bunds. W4: Trapezoid bunds.W5: Rain fall as control, Cs: Cowpea sole, CM: Cowpea+ Millet (inter cropping)

CHAPTER FIVE

DISCUISSION

5.1 Introduction:

In the study area the long- term average of annual rainfall was 561.83 mm/annum the main problem is that the area is characterized by compacting, slope lands, soil surface sealing, which are conducive to runoff. As a consequence water depletion is reduced. There was a great decline and variability in amount and distribution of rain fall during the last three decades. This imposed a degree of uncertainty and initiate A positive response to effective utilization of rain water through collection and storage of surface runoff and direct rain fall into the root zoon of plants (Mohamed, 2000)

5.2 Soil moisture depletion

The pattern of soil moisture content at the depth of 20- 40 and 60 cm from the surface was affected by the water harvesting techniques. All treatments terrace, V- shape, contour bund and trapezoid micro- catchment had layers of soil above the surface compared to flat. This layer of loose soil improves water infiltration with depth and is also favourable for the initial stages of root growth, different water harvesting techniques were reflected in the values for soil moisture depletion for example contour bunds and trapezoid bunds in maturity stage for both growing seasons, moisture depletion increased with depth from 20,40 to 60 cm. Similar results were reported by Abdellateef (1995), who stated that the soil moisture content increased with soil depth, this was in contrast with the finding of Pandey *et al* (1975) and (Anyangaluong, 1993) who reported that the moisture content decreased with soil depth. It was observed that the soil moisture content was higher at depth (0- 20 cm) near the soil surface during seedling stage, almost moderate at depth 20-40 cm during flowering stage and lowest at depth 40-60 cm during the maturity stage, the same results were reported by Mohamed (2000).This could be probably due to the fact that seedling emergence is usually compatible with the beginning of rainfall where large amount of water accumulates near the surface and then depleted with depth during flowering and maturity stages. The results indicated that the high value of soil moisture content obtained in W4 at depth 40-60 cm during maturity stage for both growing seasons followed by W3 and W2 and this result had high final grain and straw yield.

5.3 Millet

5.3.1 Growth attributes of millet

Generally there was a significant difference in plant height for water harvesting technique at seedling, flowering and maturity stages for sole millet and intercropping with cowpea, compared to W5 as control which produced short plants. This result may due to low soil moisture content, also Cruz. and' Toole, (1984) reported similar findings. Osmanzai (1992) showed that the plant height decreased with water deficit imposed at different stages of plant growth , However the effect of intercropping on plant height of millet was not significantly different at three the stages of growth with exception in the second season at seedling stage.

The effect of water harvesting on number of leaves per plant was almost significant at all stage of growth in both growing season, except at flowering stage in the first season and at seedling stage in the second season. On the other hand, the effect of intercropping on number of leaves was not significant for first and second seasons except at seedling and flowering stages in the first growing season. Generally the number of leaves increased with plant age during the growth stage but it decreased at maturity stage as a result of defoliation. Several investigation reported that number of leaves increased with plant age and then decreased at maturity (Fisher and Kohn, 1966, Abdellateef, 1995).

The effect of water harvesting techniques on leaf area was significantly different at seedling, flowering and maturity in both seasons compared to W5 control, the leaf area increased with plant age but it was reduced with moisture stress. Similar results were obtained by Seetharaman, *et al* (1984) and ELdikhery (1992) who justified the reduction in leaf area could be due to leaf senescence. However intercropping had no significant effect on leave area of millet, except at flowering stage for both seasons and at seedling stage in the second season. A similar result was reported by Hameed, (2005) who observed no significant difference between watering treatment on mean of leaf area index, but stressed plants had lower leaf are index compared to well-watered plants.

Generally, water harvesting techniques of sole millet had significant effect on stem diameter at seedling, flowering and maturity stages in the first and second seasons. Whereas intercropping of millet had no significant effect on stem diameter at all growing stage in both growing seasons, except at flowering and maturity in the second season.

The effect of water harvesting techniques on plant density of millet resulted in significant difference at the three stages of plant growth in the two seasons, the number of plants per square meter (m^2) was greater in the first season compared to the second season, was mainly due to the continuity of rain. The first rain after planting was in a 14-hour period; consequently the soil was rather uniformly wetted regardless of the technique applied. Plant population results were consistent with final seedling emergency percentage; this may be because they are directly related to each other. These results agreed with findings of (Mohammed, 2000) and (Yassien (2010).

5.3.2 Reproductive attributes of millet

There were no significant differences in days to 50% flowering on intercropping and sole millet between all treatments whereas intercropped (CM) treatment tended to flower earlier than other in first and second seasons. However, water harvesting techniques had significant effect on days to 50% flowering of millet at seedling, flowering and maturity stages in both growing seasons, these might due to effect of drought stress on the phonology of peal millet, however, the stress during vegetative growth reduced the days to 50%maturity, this result was in accordance with that reported by Mahalakshmi, (1987) who stated that the time to early flowering was effected by drought stress.

There were significant differences in all water harvesting technique (W1, W2, W3 and W4) on days to maturity, compared to W5 as control in both seasons. On the other hand there were no significant differences in days to maturity on intercropping and sole millet, between all treatments. However monocropped millet tended to mature earlier than other intercropped treatments, W5 as a control tended to mature earlier than other water harvesting techniques. In the present study, water stress significantly reduced the number of days to physiological maturity,. This result agrees with Seetherma (1986) findings. He suggested that physiological maturity was hastened by drought stress, thus curtailing the length of the grain filling period.

5.3.3 Yield and yield components of millet

The effect of water harvesting on panicle length of millet plant was not significant at all growing stages in both growing seasons, except for W5 in both growing seasons). W5 produced shorter panicle length in first and second seasons respectively. Similar results were obtained by (Lathiri and Kharabanada 1965) and (Abdellateef 1995) who reported that the stress at boot stage decreased millet head length. On the other hand, there were no significant differences observed among intercropping treatments during the first season, but there were significant effects during the second season. While in both growing seasons, the 1000-seed weight was higher with W4 compared to other treatments. On the other hand, W5 resulted in the lowest 1000-seed weight with significant difference from other treatments in first and second growing seasons, These results were in accordance with those reported by (Chaudhry *et al* 1975, Osmanzai 1992 and EL Dikhery 1992) , who stated that the reduction in 1000 seed weight was due to low soil moisture content. W1 also showed no significance different in dry matter weight compared to W2, W3 and W4 in the first season, whereas there were significant differences in the second season. These differences were in accordance with the differences in soil moisture content.

In this study the results showed reduction in total seed yield of millet per hectare for the control treatment (W5), this may be connected with the reduction in soil moisture content which reached the significant difference in first and second seasons, similar reduction in grain yield due to water stress was reported by Seethararma *et al* (1984) and Mahalakshmi and Bidinger (1985) and (1986). The reduction in grain weight due to water stress compared to control, may be due to low photosynthesis rate in grain itself and reduced translocation from the stem and leaves (Dennis *et al*1982).Intercropping millet (CM) increased the seed yield compared to monocropped (sole millet) in first and second season . However, higher seed yields were obtained during the second season, this attributed to good rainfall amount and distribution compared to the first season and adequate soil moisture in all techniques, in addition to appearance of pest in the first season. The reduction in dry matter production under control treatments (W5) observed in this study may be due to effect of drought on some of the biological components of the crop such as leaves. The increase in leaf senescence and abscission as well as reduced growth and expansion under drought might have accounted for loss of biomass as reported by (Suliman, 2007). W3 treatment produced the highest straw dry matter yield values in second growing season, whereas W5 produced the lowest values in first growing season.

5.3.4 Chemical composition of millet sole

Millet nutritive value in terms of crude protein, ash and phosphorus content was estimated. There were no significant differences observed between the treatments for both crude protein, and ash, the control (W5) produced more phosphorus (27, 48%) followed by the (W1, W2, W3 and W4) and the difference was significant. Statistical analysis of intercropping showed no significant differences between treatments for both crude protein and phosphorus, while there were significant differences for ash content, the highest ash percent recorded was for CM (8.54%) and the lowest value was for M, (2.29%). Generally intercropping produced low phosphorus content and more Crude protein and ash compared to sole millet**.**

There was a significant effect of water harvesting technique on mineral content for sole millet seed for both magnesium and potassium but there were no significant differences for calcium percentages. Lower values of magnesium and potassium were found in W5, (10.75% and 4.70%) respectively, while the highest value was recorded for W4 and W1, (14.13% and 6.20%). There were no significant differences between WI, W2, W3 and W4 in terms of potassium content. Results of intercropping indicated that there were significant differences in calcium content, while there were no significant effects for magnesium and potassium among intercropping treatments. Generally, sole millet seed contained higher magnesium and potassium and lower calcium compared to intercropped treatments.

5.4 Cowpea

5.4.1 Growth attributes of Cowpea

The effect of water harvesting on plant height of sole cowpea was not significant at seedling, flowering and maturity stage in first and second growing season except for the treatment W5 at two stage of growth(flower and maturity for both growing season .However W3 water harvest technique recorded the highest plant at maturity stage followed by W4 in both growing season.

W5 treatment recorded significantly the shortest plant height in both seasons compared to all other treatments, however, no statistically significant difference attributed to intercropping was found for plant height at the three growing stages (seedling, flowering and maturity) in both growing seasons except at flowering stage in the second season. Generally sole cowpea showed increase in plant height at flowering in the first season and maturity stage for both growing seasons, This is in agreement with, Abdelrahman 2005), who found that intercropping sorghum with cowpea inhibited vegetative growth of cowpea in comparison with monoculture cowpea.

The effect of water harvesting on number of leaves per plant had no significant effect in both growing seasons, except W5 at the three stage in the second season and at flowering and maturity stages in first season, supporting evidences were reported by Bates and Hall (1982), and Suliman (2007) who stated that under field condition cowpea exhibits extreme drought avoidance at the vegetative stage to the extent that water conservation by remaining tissue ensures plant survival. On the other hand, Diputado et al (1985) attributed that reduction in number of leaves per plant under water stress cause a reduction in leaf turgidly and accumulation of abscisic acid which promoted leaf abscission. The of effect water harvesting on stem diameter of cowpea had significant effect at three stage of growing in first and second season, except at seedling stage in first season.

Generally, intercropping millet with cowpea had depressing effect on the vegetative growth the cowpea. This is in agreement with Abdelrahaman (2005) who found that intercropping sorghum with cowpea inhibited vegetative growth of cowpea in comparison with monoculture cowpea.

The effect of water harvesting technique and intercropping on plant density of cowpea was significant difference at seedling, flowering and maturity in both growing seasons

The plant densities were significantly lower in W5 than in other treatment, there were no significant differences between W3 and W4 at seedling and flowering growing stage

5.4.2 Reproductive attributes of cowpea

The effect of water harvesting on days to 50% flowering of cowpea plant had significant effect at the three stages of growing in first and second seasons, except W5 treatment which was significantly different in two growing seasons. The effect of intercropping on days to 50% flowering of cowpea plant was not significant at first and second season, This is in agreement with Abd Elrahman (2005), and disagree with Dabholkar *et al.* (1985)who found that intercropping sorghum with bean significantly affected days to 50% day of flowering. However sole cowpea treatment tended to flower earlier than other intercropping in first and second seasons, whereas intercropped (CM) treatment tended to flower later than other treatments in both seasons, this might be due to the effect of drought on both vegetative and reproductive stages. Supporting evidence were reported by (suliman, 2007; Turk and Hall 1980). In contrast, Lawn (1982) reported that delayed flowering in cowpea under drought attributing this to the extreme dehydration avoidance of the crop.

The effect of intercropping on days to maturity of cowpea plant had significant difference at seedling, flowering and maturity in first and second seasons. However, monocropped cowpea tended to mature earlier than other intercropped cowpea and millet in first and second seasons, whereas intercropping tended to mature later than other treatments in both seasons.

5.4.3 Yield and yield components of cowpea

There were significant effects of water harvesting techniques on number of pods per plant in both growing seasons. W5 produced the lowest number of pods per plant in the first and second seasons, the reduction in number of pods under control (water stress) may be attributed to abscission of flower and newly formed pods, Similar results were reported by Ziska et al (1985) and Suliman (2007)**.** They attributed the reduction in number of pods per plant to abscission of flowers and pods when plant was subjected to water stress during the flowering stage. However, sowing cowpea in alternate row with millet, increased the number of pods per plant but not significantly in first and second seasons

There were significant differences in number of seeds per pod for intercropping and water harvesting techniques in first and second seasons, however, higher values of number of seeds per pod were recorded in first season compared to second season. Intercropping significantly reduced the number of seeds per pod at first and second seasons, intercropped cowpea was reduced the number of seeds/pod. Supporting evidences were reported by Abd Rahman (2005).

The weight of the 100 grains of cowpea was not affected by intercropping treatment on both growing seasons, while it was significantly affected by water harvesting technique in first and second seasons. W4 showed no significant difference form W1, W2 and W3 in the first season, whereas there was significant difference in the second season. These differences were in accordance with the differences in soil moisture content. The reduction in 100 seed weight under W5 control may be attributed to the effect of water stress during seed filling, similar finding, were reported by Wien (1980) and Suiliman (2007) and Lawn (1982) who attributed the reduction in seed weight in response to water stress to source limitation where the photosynthesizes were distributed to different parts of plant at the expense of seed filling,

There was a significant effect in first and second seasons, of water harvesting technique on total seed yield of cowpea. All water harvesting techniques showed greater grain yield in the first season than in the second and W5 produced lower cowpea yield in both growing seasons. Generally, under the present study, total grain yield of cowpea per unit area was significantly reduced under water stress treatment (W5), this reduction was associated with significant reduction in yield component, such as number of pods per plant, number of seeds per/pod and weight of 100 seeds. This was further confirmed by correlated analysis where total seed yield was positively correlated with its component, Ravindra *et al* (1990) attributed that in seed yield as result of water stress (drought) to low fruiting efficiency and lack of filling time for pods, but , Turk and Hall (1980) attributed the reduction in grain yield of cowpea under drought to secondary detrimental effects avoidance on CO_2 assimilation

There was a significant difference of intercropping on total seed yield for second growing season, intercropping cowpea (CM) decrease the seed yield compared to monocropped (C) in first and second seasons. The reduction of total yield of cowpea observed in this study could be due to the reduced population density as well as low yield per plant. Similar results were obtained by Nyambo *et al*, (1980) and Abdrahaman (2005) and Farist *et al.* (1983) who reported that the lower yield of cowpea in mixture may be due to fewer plant/hectare. In contrast, other studies showed that intercropping produced higher seed yield than sole crop, Rao and Willey (1983) reported that intercropped yield become larger between cereal and pigeon pea and pea increased, this support the argument that the effect of intercropping depend on types of crop grown in mixture and their growth habits

All water harvesting techniques treatments significantly reduced final straw dry matter yield compared to control W5 for both growing seasons, moreover, the effect of water harvesting techniques on straw dry matter yield between W1,W2, W3 and W4 was not significant in both seasons. However similar to final seed yield, all intercropping treatments significantly reduced straw yield of cowpea in both growing season. The greatest reduction occurred in the first season. the reduction in straw yield may be due to shading effect, This result is in agreement with Dalal (1974) who found that intercropping of maize with pea in mixture stand and alternate rows produced less dry matter than pure stands, great reduction in total straw of cowpea intercropped with sorghum was observed by Ibrahim (1994) who stated that shading of cowpea by the taller sorghum reduced straw yield.

5.4.4 Phosphorus, crude fibre and crude protein content of cowpea

The effect of water harvesting techniques and intercropping on (nutritive value) phosphorus, crude fibre and crude protein content of cowpea showed no significant differences between the treatments both for phosphorus and crude protein, while there were significant difference as far as crude fibre was concerned, Intercropping recorded highest phosphorus, crude fibre and crude protein percentages (29.06, 9,97 and 26.66) respectively, compared to sole cowpea, which recorded (26.70. 8.64 and 25.49), respectively.

Analysis of variance revealed that there were no significant effects of water harvesting technique on nutritive value of cowpea for both phosphorus and crude fibre, but the effect reached significant level with crude protein. Lower phosphorus, crude fibre and crude protein percentages were found in W4, W3 and W2 (24.42, 8.51and 23.08) respectively. There were no significant differences between WI, W3 and W5 in terms of crude protein content, while there were significant differences between W2 and W4.treaments.Crude fibre of cowpea seed was significantly increased when it was intercropping with millet

Conclusions and recommendations:

1. Water harvesting Techniques (terracing, V- shape micro catchments W2, Contour bunds W3, Trapezoidal bunds method W4), increased some parameters of growth, and productivity attributes, that were reflected in increase of yield, total grain and straw yield of millet compared to rain fall plot as control.

2. Superiority in soil moisture content (conservation) can be achieved by Trapezoidal bunds, contour bunds, V- shape micro catchment and terracing.

3. The effect of water harvesting in soil and soil moisture content, growth and total grain yield is consistent with crop yield components.

4. Intercropping is beneficial under adverse situation of calamite, except at time of extreme water shortage.

5. The result of this study had shown considerable high millet yields for mixture than from sole cropping. Moreover, this intercropping is expected to give better control of soil movement observed in millet soil.

Recommendations

1. Based on the results of this experiment, the highest, millet and cowpea yields can be obtained under water harvesting technique (terracing, Trapezoid, V-shape and contour bunds.

2. For obtaining the high yield of millet trapezoid water harvesting techniques may be applied.

3. The best water harvesting techniques for moisture contain depletion is trapezoid compared to other terracing and V- shape, techniques.

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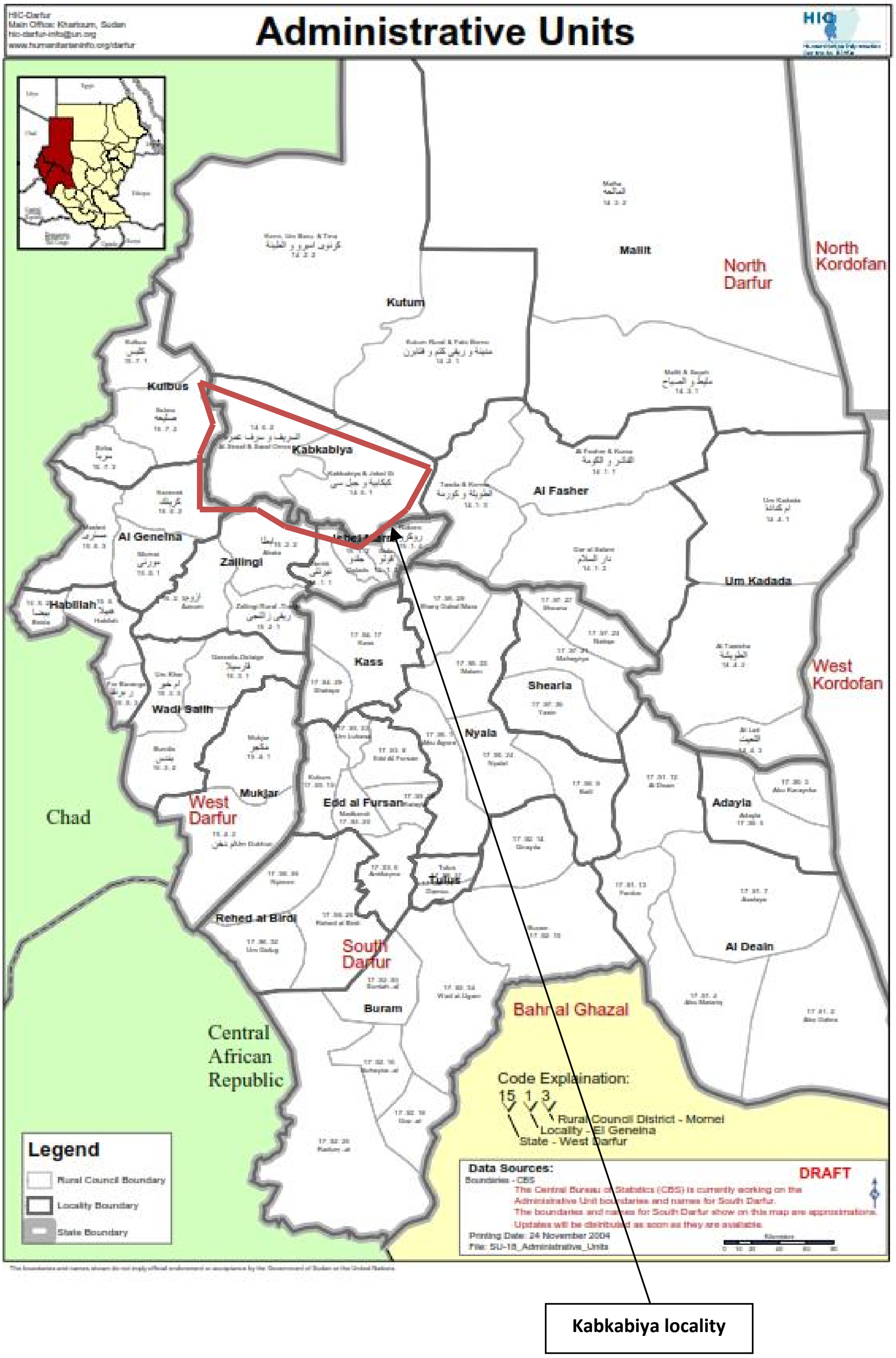
Appendix (1): Sudan Administrative map



Appendix (2). Northern Darfur Administrative Units (Localities)

Appendix (3) Rain Fall Data for Kabkabia Locality for 10 years ago

Year	April	May	June	July	August	September	October	Yearly Rain fall /mm
2003	0	22.2	21	138.2	162.9	34.1	0	378.4
2004	3.5	10	105.5	160.1	0	0	0	279.1
2005	0	0	20.1	319.5	173.8	45.8	0	559.2
2006	0	0	9	72.7	226.5	93.4	21	422.6
2007	0	8.2	85.2	351.4	261.3	134.9	0	841
2008	10.35	0	72.65	186.8	298.75	207.95		776.5
2009	0.8	1	6.75	311.05	269.15	26.9	1.9	617.55
2010	0	0	23.25	373.95	87.85	43.8	27	555.85
2011		2.5	33	131.55	260.25	122.3	0	549.6
2012		29.15	112.05	187.45	252.35	55.25	2.25	638.5
Monthly average	1.465	7.305	48.85	223.27	199.285	76.44	5.215	**561.83**

Appendix (4) layout

Effect of water harvesting technques on growth and yield of pearl millet intercropped with Lubia Abyad

Layout split plot design

R1	MLW2	MLW5	MLW3	MLW1	MLW4	MsW5	MsW3	MsW2	MsW4	MsW1	LsW4	LsW5	LsW3	LsW2	LsW1
R2	MLW5	MLW2	MLW3	MLW1	MLW4	LsW4	LsW2	LsW3	LsW1	LsW5	MsW4	MsW5	MsW3	MsW1	MsW2
R3	LsW3	LsW2	LsW1	LsW4	LsW5	MsW2	MsW5	MsW3	MsW1	MsW4	MLW1	MLW2	MLW4	MLW3	MLW5
R4	LsW2	LsW4	LsW1	LsW3	LsW5	MLW3	MLW2	MLW4	MLW1	MLW5	MsW3	MsW1	MsW5	MsW2	MsW4

Ms= Millet sole
Ls = Lubia sole
ML = Millet + Lubia

Main plot 50 x10 meter

Each sub plot 10 x10 meter

Sub plot

W1 = Terracing
W2 = V - Shape micro catchment
W3 = Contour bunds
W4 = Trapezoid bunds
W5 = Rain fall as control

Appendix (5)

Statistix 8.0 Soil moisture first year 6/28/2015, ص09:42:14

Analysis of Variance Table for moisture content Fy First read 20 cm Soil moisture

Source	DF	SS	MS	F
rep	3	90.89	30.2961	1.70
crop	2	44.24	22.1211	1.24
treat	4	149.99	37.4975	2.10*
crop*treat	8	336.54	42.0673	2.36*
Error	42	748.82	17.8290	
Total	59	1370.48		

Grand Mean 10.987   CV 38.43

Analysis of Variance Table for second read 20 cm

Source	DF	SS	MS	F
rep	3	29.528	9.8428	1.36
crop	2	37.046	18.5232	2.56*
treat	4	281.025	70.2563	9.69**
crop*treat	8	115.457	14.4321	1.99*
Error	42	304.449	7.2488	
Total	59	767.506		

Grand Mean 9.4417   CV 28.52

Analysis of Variance Table for third read 20 cm

Source	DF	SS	MS	F
rep	3	3.698	1.2326	0.12
crop	2	26.050	13.0252	1.25
treat	4	82.274	20.5686	1.97
crop*treat	8	128.370	16.0462	1.54
Error	42	437.730	10.4221	
Total	59	678.122		

Grand Mean 4.9883   CV 64.72

Analysis of Variance Table for FY first read 40 cm

Source	DF	SS	MS	F
rep	3	100.294	33.431	2.43
crop	2	32.688	16.344	1.19
treat	4	407.776	101.944	7.42*
crop*treat	8	74.348	9.294	0.68
Error	41	563.140	13.735	
Total	58			

Note: SS are marginal (type III) sums of squares

Grand Mean 10.749   CV 34.48

Analysis of Variance Table for Second read 40 cm

Source	DF	SS	MS	F
rep	3	81.611	27.2037	4.67
crop	2	1.621	0.8105	0.14
treat	4	205.702	51.4254	8.83**
crop*treat	8	36.377	4.5472	0.78
Error	42	244.581	5.8234	
Total	59	569.892		

Grand Mean 9.2750   CV 26.02

Analysis of Variance Table for Fy third read 40 cm

Source	DF	SS	MS	F
rep	3	6.915	2.3049	0.52
crop	2	14.017	7.0087	1.60
treat	4	69.011	17.2527	3.93**
crop*treat	8	26.381	3.2976	0.75
Error	42	184.505	4.3930	
Total	59	300.829		

Grand Mean 5.7867   CV 36.22

Analysis of Variance Table for Fy first read 60 cm

Source	DF	SS	MS	F
rep	3	133.03	44.3433	2.01
crop	2	47.77	23.8832	1.08
treat	4	360.09	90.0223	4.08**
crop*treat	8	26.35	3.2936	0.15
Error	42	925.73	22.0411	
Total	59	1492.96		

Grand Mean 9.8283   CV 47.77

Analysis of Variance Table for second read 60 cm

Source	DF	SS	MS	F
rep	3	131.191	43.7304	5.11
crop	2	1.237	0.6185	0.07
treat	4	138.034	34.5085	4.03**
crop*treat	8	63.103	7.8879	0.92
Error	42	359.709	8.5645	
Total	59	693.274		

Grand Mean 9.6900   CV 30.20

Analysis of Variance Table for third 60cm

Source	DF	SS	MS	F
rep	3	17.943	5.9809	1.07
crop	2	10.932	5.4662	0.98
treat	4	59.571	14.8927	2.66*
crop*treat	8	43.079	5.3849	0.96
Error	42	234.752	5.5893	
Total	59	366.277		

Grand Mean 6.1267   CV 38.59

Statistix 8.0 Soi moisture second year 6/28/2015, 09:46:24 ص

Analysis of Variance Table for Second year first read 20 cm

Source	DF	SS	MS	F
rep	3	116.69	38.8966	2.01
crop	2	141.59	70.7927	3.66*
treat	4	324.24	81.0592	4.19**
crop*treat	8	247.39	30.9239	1.60
Error	42	812.92	19.3553	
Total	59	1642.83		

Grand Mean 9.6583   CV 45.55

Analysis of Variance Table for second year second read 20 cm

Source	DF	SS	MS	F
rep	3	61.133	20.3776	3.60
crop	2	27.610	13.8052	2.44*
treat	4	240.104	60.0261	10.62**
crop*treat	8	55.795	6.9743	1.23
Error	42	237.497	5.6547	
Total	59	622.139		

Grand Mean 8.7367   CV 27.22

Analysis of Variance Table for second year third read 20 cm

Source	DF	SS	MS	F
rep	3	12.185	4.0616	1.83
crop	2	0.021	0.0105	0.00 ns
treat	4	78.218	19.5544	8.81**
crop*treat	8	24.262	3.0328	1.37 ns
Error	42	93.240	2.2200	
Total	59	207.926		

Grand Mean 3.9700   CV 37.53

Analysis of Variance Table for second year first read 40 cm

Source	DF	SS	MS	F
rep	3	341.71	113.902	3.35
crop	2	39.64	19.819	0.58
treat	4	271.03	67.758	1.99
crop*treat	8	384.40	48.050	1.41
Error	42	1430.14	34.051	
Total	59	2466.92		

Grand Mean 10.135   CV 57.58

Analysis of Variance Table for second year second read 40 cm

Source	DF	SS	MS	F
rep	3	76.168	25.389	3.71
crop	2	32.712	16.356	2.39
treat	4	406.807	101.702	14.87**
crop*treat	8	63.008	7.876	1.15
Error	42	287.322	6.841	

Total	59	866.017

Grand Mean 9.8067   CV 26.67

Analysis of Variance Table for second year third read 40 cm

Source	DF	SS	MS	F
rep	3	6.721	2.2404	1.18
crop	2	36.177	18.0887	9.51**
treat	4	33.458	8.3644	4.40**
crop*treat	8	8.184	1.0230	0.54
Error	42	79.909	1.9026	
Total	59	164.449		

Grand Mean 5.8467   CV 23.59

Analysis of Variance Table for second year first read 60 cm

Source	DF	SS	MS	F
rep	3	300.29	100.098	5.19
crop	2	7.19	3.593	0.19
treat	4	339.80	84.949	4.40**
crop*treat	8	162.49	20.312	1.05
Error	42	810.80	19.305	
Total	59	1620.57		

Grand Mean 9.9317   CV 44.24

Analysis of Variance Table for second year second read 60 cm

Source	DF	SS	MS	F
rep	3	29.695	9.8984	1.20
crop	2	17.826	8.9132	1.08
treat	4	239.442	59.8604	7.28**
crop*treat	8	57.955	7.2444	0.88
Error	42	345.207	8.2192	
Total	59	690.126		

Grand Mean 9.1083   CV 31.48

Analysis of Variance Table for second year third read 60 cm

Source	DF	SS	MS	F
rep	3	0.221	0.0738	0.02
crop	2	17.913	8.9565	1.83
treat	4	57.616	14.4040	2.94*
crop*treat	8	60.482	7.5603	1.54
Error	42	205.624	4.8958	
Total	59	341.856		

Grand Mean 6.4800   CV 34.15

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Analysis of Variance Table for first year (FY) Plant High first read

Source	DF	SS	MS	F
rep	3	139.981	46.6603	3.24
crop	1	4.556	4.5562	0.32
treat	4	146.712	36.6779	2.54*
crop*treat	4	21.237	5.3094	0.37
Error	27	389.342	14.4201	
Total	39	701.828		

Grand Mean 18.808 CV 20.19

Analysis of Variance Table for first year Plant High second read PH2

Source	DF	SS	MS	F
rep	3	921.89	307.30	1.09
crop	1	9.61	9.61	0.03
treat	4	7723.59	1930.90	6.88**
crop*treat	4	1671.79	417.95	1.49
Error	26	7299.20	280.74	
Total	38			

Note: SS are marginal (type III) sums of squares

Grand Mean 164.24 CV 10.20

Analysis of Variance Table for Analysis of Variance Table for first year Plan High third read PH3

Source	DF	SS	MS	F
rep	3	1377.2	459.06	1.01
crop	1	39.8	39.84	0.09
treat	4	10198.2	2549.56	5.59**
crop*treat	4	1705.2	426.30	0.93
Error	27	12322.5	456.39	
Total	39	25643.0		

Grand Mean 160.38 CV 13.32

Analysis of Variance Table for Number of leaves first read NL1

Source	DF	SS	MS	F
rep	3	1.2750	0.42500	1.44
crop	1	2.0250	2.02500	6.86*
treat	4	7.1000	1.77500	6.01**
crop*treat	4	1.6000	0.40000	1.35
Error	27	7.9750	0.29537	
Total	39	19.9750		

Grand Mean 6.4750 CV 8.39

Analysis of Variance Table for Analysis of Variance Table for Number of leaves second read NL2

Source	DF	SS	MS	F
rep	3	174.275	58.0917	19.02
crop	1	42.025	42.0250	13.76**

treat	4	5.400	1.3500	0.44
crop*treat	4	6.600	1.6500	0.54
Error	27	82.475	3.0546	
Total	39	310.775		

Grand Mean 9.6750   CV 18.06

Analysis of Variance Table for Analysis of Variance Table for Number of leaves Third read   LN3

Source	**DF**	**SS**	**MS**	**F**
rep	3	1.2750	0.42500	0.50
crop	1	0.6250	0.62500	0.73
treat	4	5.8500	1.46250	1.72
crop*treat	4	1.2500	0.31250	0.37
Error	27	22.9750	0.85093	
Total	39	31.9750		

Grand Mean 7.5250   CV 12.26

Analysis of Variance Table for leave area first read LA1

Source	**DF**	**SS**	**MS**	**F**
rep	3	2459.6	819.88	1.19
crop	1	1822.7	1822.71	2.66
treat	4	8736.4	2184.09	3.18*
crop*treat	4	5626.2	1406.55	2.05
Error	26	17841.6	686.22	
Total	38			

Note: SS are marginal (type III) sums of squares

Grand Mean 142.01   CV 18.45

Analysis of Variance Table for leave area second read LA1   LA2

Source	**DF**	**SS**	**MS**	**F**
rep	3	13484.0	4494.7	4.79
crop	1	12110.4	12110.4	12.91**
treat	4	18840.6	4710.2	5.02**
crop*treat	4	2751.4	687.8	0.73
Error	27	25322.0	937.9	
Total	39	72508.4		

Grand Mean 248.80   CV 12.31

Analysis of Variance Table for leave area thrid read LA1 LA3

Source	**DF**	**SS**	**MS**	**F**
rep	3	14531.2	4843.74	7.23
crop	1	2438.3	2438.28	3.64*
treat	4	17357.5	4339.36	6.48**
crop*treat	4	4074.6	1018.66	1.52
Error	27	18087.8	669.92	
Total	39	56489.4		

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Analysis of Variance Table for first year stem diameter first reading SD1

Source	DF	SS	MS	F
rep	3	0.13275	0.04425	2.87
crop	1	0.04489	0.04489	2.92^{*}
treat	4	0.10156	0.02539	1.65
crop*treat	4	0.05336	0.01334	0.87
Error	27	0.41575	0.01540	
Total	39	0.74831		

Grand Mean 0.6635 CV 18.70

Analysis of Variance Table for first year stem diameter second read SD2

Source	DF	SS	MS	F
rep	3	0.04322	0.01441	0.39
crop	1	0.01444	0.01444	0.39
treat	4	0.30177	0.07544	2.03
crop*treat	4	0.09438	0.02360	0.63
Error	27	1.00503	0.03722	
Total	39	1.45884		

Grand Mean 1.2970 CV 14.88

Analysis of Variance Table for first year stem diameter third reading SD3

Source	DF	SS	MS	F
rep	3	0.04941	0.01647	1.92
crop	1	0.01600	0.01600	1.87
treat	4	0.47732	0.11933	13.94^{**}
crop*treat	4	0.06617	0.01654	1.93
Error	27	0.23109	0.00856	
Total	39	0.83999		

Grand Mean 1.0605 CV 8.72

Analysis of Variance Table for first year Plant densty first readyD1

Source	DF	SS	MS	F
rep	3	44.600	14.867	8.38
crop	1	160.000	160.000	90.19^{**}
treat	4	47.250	11.812	6.66^{**}
crop*treat	4	6.250	1.562	0.88
Error	27	47.900	1.774	
Total	39	306.000		

Grand Mean 8.0000 CV 16.65

Analysis of Variance Table for first year Plant density second ready PD2

Source	DF	SS	MS	F
rep	3	44.600	14.867	8.38
crop	1	160.000	160.000	90.19^{**}
treat	4	47.250	11.812	6.66^{**}
crop*treat	4	6.250	1.562	0.88
Error	27	47.900	1.774	
Total	39	306.000		

Grand Mean 8.0000 CV 16.65

Analysis of Variance Table for first year Plant density third read PD3

Source	DF	SS	MS	F	P
rep	3	44.600	14.867	8.38	
crop	1	160.000	160.000	90.19**	
treat	4	47.250	11.812	6.66**	
crop*treat	4	6.250	1.562	0.88	
Error	27	47.900	1.774		
Total	39	306.000			

Grand Mean 8.0000 CV 16.65

Analysis of Variance Table for first year Day50

Source	DF	SS	MS	F
rep	3	2.700	0.9000	0.25
crop	1	2.500	2.5000	0.69
treat	4	179.850	44.9625	12.41**
crop*treat	4	34.250	8.5625	2.36*
Error	27	97.800	3.6222	
Total	39	317.100		

Grand Mean 54.150 CV 3.51

Analysis of Variance Table for first year maturity

Source	DF	SS	MS	F
rep	3	56.90	18.967	2.94
crop	1	3.60	3.600	0.56*
treat	4	778.85	194.713	30.20*
crop*treat	4	13.65	3.413	0.53
Error	27	174.10	6.448	
Total	39	1027.10		

Grand Mean 87.350 CV 2.91

Analysis of Variance Table for first year panicle length

Source	DF	SS	MS	F
rep	3	10.186	3.3953	0.82
crop	1	7.056	7.0560	1.70
treat	4	74.932	18.7329	4.50**
crop*treat	4	12.831	3.2079	0.77
Error	27	112.339	4.1607	
Total	39	217.344		

Grand Mean 21.280 CV 9.59

Analysis of Variance Table for 1000-seed weight first season

Source	DF	SS	MS	F
rep	3	6.410	2.1367	1.60
crop	1	4.900	4.9000	3.67*
treat	4	77.627	19.4066	14.53**
crop*treat	4	4.363	1.0906	0.82
Error	27	36.065	1.3357	
Total	39	129.364		

Grand Mean 9.0800 CV 12.73

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Analysis of Variance Table for first year total grain yield

Source	DF	SS	MS	F
rep	3	310370	103457	3.42
crop	1	65610	65610	2.17
treat	4	2817960	704490	23.29**
crop*treat	4	84440	21110	0.70
Error	27	816730	30249	
Total	39	4095110		

Grand Mean 913.50   CV 19.04

Analysis of Variance Table for first year straw yield Kg

Source	**DF**	**SS**	**MS**	**F**
rep	3	3831460	1277153	18.43
crop	1	196000	196000	2.83
treat	4	1.725E+07	4312863	62.24**
crop*treat	4	75950.0	18988	0.27
Error	27	1870940	69294	
Total	39	2.323E+07		

Grand Mean 2925.0   CV 9.00

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Analysis of Variance Table for second year plant high first read millet PH1

Source	**DF**	**SS**	**MS**	**F**
rep	3	348.59	116.198	5.14
crop	1	138.01	138.012	6.11*
treat	4	161.22	40.305	1.78
crop*treat	4	74.01	18.502	0.82
Error	27	609.96	22.591	
Total	39	1331.80		

Grand Mean 22.273   CV 21.34

Analysis of Variance Table for second year plant high read PH2 millet

Source	**DF**	**SS**	**MS**	**F**	**P**
rep	3	1892.6	630.87	0.81	
crop	1	2079.4	2079.36	2.65	
treat	4	12847.6	3211.91	4.10*	
crop*treat	4	1236.8	309.19	0.39	
Error	27	21153.8	783.48		
Total	39	39210.2			

Grand Mean 163.37   CV 17.13

Analysis of Variance Table for second year plant high third read PH3 millet

Source	**DF**	**SS**	**MS**	**F**
rep	3	3018.0	1006.01	2.75
crop	1	479.6	479.56	1.31
treat	4	10947.9	2736.96	7.48**
crop*treat	4	2249.8	562.45	1.54
Error	27	9873.5	365.69	

Total	39	26568.8

Grand Mean 195.22   CV 9.80

Analysis of Variance Table for second year number of leave of millet first read NL1

Source	DF	SS	MS	F
rep	3	12.1000	4.03333	6.85
crop	1	1.6000	1.60000	2.72
treat	4	2.6500	0.66250	1.12
crop*treat	4	1.6500	0.41250	0.70
Error	27	15.9000	0.58889	
Total	39	33.9000		

Grand Mean 8.4500   CV 9.08

Analysis of Variance Table for second year number of leave of millet second read NL2

Source	DF	SS	MS	F
rep	3	4.4750	1.49167	2.09
crop	1	2.0250	2.02500	2.84
treat	4	6.3500	1.58750	2.22*
crop*treat	4	1.8500	0.46250	0.65
Error	27	19.2750	0.71389	
Total	39	33.9750		

Grand Mean 8.7250   CV 9.68**Analysis of Variance Table forsecond year number of leave of millet third read N3**

Source	DF	SS	MS	F	P
rep	3	4.30000	1.43333	3.46	
crop	1	4.77	4.777	11.00*	
treat	4	9.85000	2.46250	5.94**	
crop*treat	4	1.75000	0.43750	1.05	
Error	27	11.2000	0.41481		
Total	39	27.1000			

Grand Mean 8.8500   CV 7.28

Analysis of Variance Table for second year Stem diameter first read SD1

Source	DF	SS	MS	F
rep	3	0.26831	0.08944	1.39
crop	1	0.25760	0.25760	4.00*
treat	4	0.41701	0.10425	1.62
crop*treat	4	0.22921	0.05730	0.89
Error	27	1.73987	0.06444	
Total	39	2.91200		

Grand Mean 0.9127   CV 27.81

Analysis of Variance Table for second year Stem diametersecond read SD2

Source	DF	SS	MS	F
rep	3	0.24397	0.08132	5.53
crop	1	0.09025	0.09025	6.13*
treat	4	0.14388	0.03597	2.44*
crop*treat	4	0.00883	0.00221	0.15
Error	27	0.39738	0.01472	
Total	39	0.88431		

Grand Mean 1.1965   CV 10.14

Analysis of Variance Table for second year Stem diameter third read SD3

Source	DF	SS	MS	F
rep	3	0.34413	0.11471	8.92
crop	1	0.16256	0.16256	12.64**
treat	4	0.17234	0.04309	3.35*
crop*treat	4	0.03880	0.00970	0.75
Error	27	0.34735	0.01286	
Total	39	1.06518		

Grand Mean 1.1557   CV 9.81

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Analysis of Variance Table for second year Leave area first read LA1

Source	DF	SS	MS	F
rep	3	3635.5	1211.82	1.31
crop	1	4227.3	4227.34	4.57*
treat	4	12679.4	3169.85	3.43*
crop*treat	4	6392.1	1598.02	1.73
Error	27	24970.8	924.84	
Total	39	51905.1		

Grand Mean 147.20   CV 20.66

Analysis of Variance Table for second year Leave area second read LA2

Source	DF	SS	MS	F
rep	3	13484.0	4494.7	4.79
crop	1	12110.4	12110.4	12.91**
treat	4	18840.6	4710.2	5.02**
crop*treat	4	2751.4	687.8	0.73
Error	27	25322.0	937.9	
Total	39	72508.4		

Grand Mean 248.80   CV 12.31

Analysis of Variance Table for second year Leave area third read LA3

Source	DF	SS	MS	F
rep	3	7460.6	2486.86	5.86
crop	1	5.1	5.11	0.01
treat	4	12446.3	3111.59	7.33**
crop*treat	4	2907.1	726.77	1.71
Error	27	11458.9	424.40	
Total	39	34278.1		

Grand Mean 132.55   CV 15.54

Analysis of Variance Table for second year plant density first readmPD1

Source	DF	SS	MS	F
rep	3	21.300	7.100	5.86
crop	1	129.600	129.600	107.01**
treat	4	22.650	5.663	4.68**
crop*treat	4	11.650	2.913	2.40*
Error	27	32.700	1.211	
Total	39	217.900		

Grand Mean 7.9500 CV 13.84

Analysis of Variance Table for second year plant density second D2

Source	DF	SS	MS	F
rep	3	21.200	7.067	5.82
crop	1	122.500	122.500	100.84**
treat	4	27.850	6.963	5.73**
crop*treat	4	13.250	3.312	2.73*
Error	27	32.800	1.215	
Total	39	217.600		

Grand Mean 7.9000 CV 13.95

Analysis of Variance Table for second year plant density third read PD3

Source	DF	SS	MS	F
rep	3	21.200	7.067	5.82
crop	1	122.500	122.500	100.84**
treat	4	27.850	6.963	5.73**
crop*treat	4	13.250	3.312	2.73*
Error	27	32.800	1.215	
Total	39	217.600		

Grand Mean 7.9000 CV 13.95

Analysis of Variance Table for second year Day50

Source	DF	SS	MS	F
rep	3	2.100	0.7000	0.12
crop	1	14.400	14.4000	2.53
treat	4	68.100	17.0250	2.99*
crop*treat	4	12.600	3.1500	0.55
Error	27	153.900	5.7000	
Total	39	251.100		

Grand Mean 55.350 CV 4.31

Analysis of Variance Table for second year day maturity

Source	DF	SS	MS	F
rep	3	56.90	18.967	2.94
crop	1	3.60	3.600	0.56
treat	4	778.85	194.713	30.20**
crop*treat	4	13.65	3.413	0.53
Error	27	174.10	6.448	
Total	39	1027.10		

Grand Mean 87.350 CV 2.91

Analysis of Variance Table for second year panicle length

Source	DF	SS	MS	F
rep	3	4.915	1.6382	0.74
crop	1	10.920	10.9203	4.97*
treat	4	47.889	11.9721	5.44**
crop*treat	4	7.899	1.9746	0.90
Error	27	59.378	2.1992	
Total	39	131.000		

Grand Mean 21.473 CV 6.91

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Analysis of Variance Table for 1000 seed second year

Source	DF	SS	MS	F
A	3	13.385	4.4616	1.61
crop	1	0.342	0.3422	0.12
treat	4	78.895	19.7238	7.10**
crop*treat	4	27.329	6.8323	2.46*
Error	27	74.973	2.7768	
Total	39	194.924		

Grand Mean 9.3125   CV 17.89

Analysis of Variance Table for Second year Total grain yield

Source	**DF**	**SS**	**MS**	**F**
rep	3	33388	11129	0.40
crop	1	244923	244923	8.81**
treat	4	3940390	985098	35.44**
crop*treat	4	81890	20473	0.74
Error	27	750588	27800	
Total	39	5051178		

Grand Mean 1011.8   CV 16.48

Analysis of Variance Table for second year straw yield Millet

Source	DF	SS	MS	F
rep	3	809210	269737	16.33
crop	1	533610	533610	32.30**
treat	4	8846210	2211553	133.89**
crop*treat	4	29890.0	7473	0.45
Error	27	445990	16518	
Total	39	1.066E+07		

Grand Mean 2931.5   CV 4.38

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Analysis of Variance Table for Phosphorus Millet

Source	**DF**	**SS**	**MS**	**F**
rep	3	67.68	22.5601	0.75
Crop	1	99.04	99.0361	3.30*
treatment	4	208.68	52.1699	1.74
Crop*treatment	4	135.80	33.9504	1.13
Error	27	809.98	29.9993	
Total	39	1321.18		

Grand Mean 24.944   CV 21.96

Analysis of Variance Table for calcium

Source	**DF**	**SS**	**MS**	**F**
rep	3	153.900	51.3000	4.63
Crop	1	52.900	52.9000	4.78*
treatment	4	17.000	4.2500	0.38

Crop*treatment	4	34.600	8.6500	0.78
Error	27	299.100	11.0778	
Total	39	557.500		

Grand Mean 12.750   CV 26.10

Analysis of Variance Table for Crude Protein

Source	DF	SS	MS	F
rep	3	36.103	12.0345	2.80
Crop	1	1.271	1.2709	0.30
treatment	4	11.559	2.8898	0.67
Crop*treatment	4	4.921	1.2302	0.29
Error	27	115.936	4.2939	
Total	39	169.790		

Grand Mean 17.249   CV 12.01

Analysis of Variance Table for potassium

Source	DF	SS	MS	F
rep	3	9.6065	3.20216	3.03
Crop	1	1.0530	1.05300	1.00
treatment	4	10.7769	2.69422	2.55*
Crop*treatment	4	16.6826	4.17066	3.95
Error	27	28.5350	1.05685	
Total	39	66.6540		

Grand Mean 5.7072   CV 18.01

Analysis of Variance Table for Ash

Source	DF	SS	MS	F
rep	3	10.885	3.6285	0.38
Crop	1	69.406	69.4059	7.35*
treatment	4	43.596	10.8990	1.15
Crop*treatment	4	3.013	0.7531	0.08
Error	27	254.842	9.4386	
Total	39	381.741		

Grand Mean 5.0777   CV 60.50

Analysis of Variance Table for Magnesium

Source	DF	SS	MS	F
rep	3	127.30	42.4333	1.35
Crop	1	4.90	4.9000	0.16
treatment	4	143.25	35.8125	1.14
Crop*treatment	4	99.85	24.9625	0.79
Error	27	848.20	31.4148	
Total	39	1223.50		

Grand Mean 11.250   CV 49.82

Lobia analysis

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Analysis of Variance Table for first year labia plant height first read PH1

Source	DF	SS	MS	F
rep	3	58.481	19.4937	5.01
crop	1	0.676	0.6760	0.17
treat	4	12.499	3.1246	0.80
crop*treat	4	33.992	8.4979	2.18^{*}
Error	27	105.124	3.8935	
Total	39	210.771		

Grand Mean 8.5650 CV 23.04

Analysis of Variance Table for first year plant height second read PH2

Source	DF	SS	MS	F
rep	3	3131.3	1043.77	1.04
crop	1	1680.9	1680.91	1.67
treat	4	27486.8	6871.70	6.83^{**}
crop*treat	4	9059.8	2264.95	2.25^{*}
Error	27	27157.5	1005.83	
Total	39	68516.3		

Grand Mean 159.56 CV 19.88

Analysis of Variance Table for first year plant height third read PH3

Source	DF	SS	MS	F
rep	3	4391.8	1463.95	1.37
crop	1	54.3	54.29	0.05
treat	4	31938.7	7984.68	7.45^{**}
crop*treat	4	3556.8	889.19	0.83
Error	27	28940.9	1071.88	
Total	39	68882.5		

Grand Mean 178.06 CV 18.39

Analysis of Variance Table for first year Number of leave first read NL1

Source	DF	SS	MS	F
rep	3	9.9000	3.30000	3.23
crop	1	3.6000	3.60000	3.52^{*}
treat	4	3.8500	0.96250	0.94
crop*treat	4	2.1500	0.53750	0.53
Error	27	27.6000	1.02222	
Total	39	47.1000		

Grand Mean 5.8500 CV 17.28

Analysis of Variance Table for Analysis of Variance Table for first year Number of leave second read NL2

Source	DF	SS	MS	F
rep	3	369.675	123.225	8.42
crop	1	27.225	27.225	1.86
treat	4	135.750	33.938	2.32^{*}
crop*treat	4	60.650	15.163	1.04
Error	27	395.075	14.632	
Total	39	988.375		

Grand Mean 15.125 CV 25.29

Analysis of Variance Table for first year Number of leave third read lobia LN3

Source	DF	SS	MS	F	P
rep	3	20.075	6.6917	0.73	0.5425
crop	1	3.025	3.0250	0.33	0.5702
treat	4	179.150	44.7875	4.89**	0.0042
crop*treat	4	45.350	11.3375	1.24	0.3182
Error	27	247.175	9.1546		
Total	39	494.775			

Grand Mean 16.325   CV 18.53

Analysis of Variance Table for first year stem diameter first read SD1

Source	DF	SS	MS	F
rep	3	0.04125	0.01375	3.28
crop	1	0.00552	0.00552	1.32
treat	4	0.00921	0.00230	0.55
crop*treat	4	0.01129	0.00282	0.67
Error	27	0.11323	0.00419	
Total	39	0.18050		

Grand Mean 0.4622   CV 14.01

Analysis of Variance Table for first year stem diameter secon read SD2

Source	DF	SS	MS	F
rep	3	0.07105	0.02368	1.53
crop	1	0.00625	0.00625	0.40
treat	4	0.21831	0.05458	3.52*
crop*treat	4	0.25525	0.06381	4.11**
Error	27	0.41905	0.01552	
Total	39	0.96991		

Grand Mean 1.1685   CV 10.66

Analysis of Variance Table for first year stem diameter third read SD3

Source	DF	SS	MS	F
rep	3	0.08650	0.02883	1.80
crop	1	0.10816	0.10816	6.75*
treat	4	0.45906	0.11477	7.16**
crop*treat	4	0.28534	0.07133	4.45**
Error	27	0.43290	0.01603	
Total	39	1.37196		

Grand Mean 1.2510   CV 10.12

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Analysis of Variance Table for first season plant density first read PD1

Source	DF	SS	MS	F
rep	3	1.2750	0.4250	1.21
crop	1	15.6250	15.6250	44.53**
treat	4	7.1500	1.7875	5.09**
crop*treat	4	7.2500	1.8125	5.16**
Error	27	9.4750	0.3509	
Total	39	40.7750		

Grand Mean 4.9250   CV 12.03

Analysis of Variance Table for first season plant density second read PD2

Source	DF	SS	MS	F
rep	3	1.2750	0.4250	1.21
crop	1	15.6250	15.6250	44.53**
treat	4	7.1500	1.7875	5.09**
crop*treat	4	7.2500	1.8125	5.16**
Error	27	9.4750	0.3509	
Total	39	40.7750		

Grand Mean 4.9250   CV 12.03

Analysis of Variance Table for first season plant density third read PD3

Source	DF	SS	MS	F
rep	3	0.9000	0.3000	0.73
crop	1	36.1000	36.1000	87.81**
treat	4	4.0000	1.0000	2.43*
crop*treat	4	1.4000	0.3500	0.85
Error	27	11.1000	0.4111	
Total	39	53.5000		

Grand Mean 4.7500   CV 13.50

Analysis of Variance Table for first season lobia Day50

Source	DF	SS	MS	F
rep	3	34.875	11.6250	2.46
crop	1	0.225	0.2250	0.05
treat	4	191.400	47.8500	10.14**
crop*treat	4	18.900	4.7250	1.00
Error	27	127.375	4.7176	
Total	39	372.775		

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Analysis of Variance Table for first year lobia maturity

Source	DF	SS	MS	F
rep	3	2.90	0.967	0.20
crop	1	52.90	52.900	11.15**
treat	4	894.00	223.500	47.11**
crop*treat	4	37.60	9.400	1.98
Error	27	128.10	4.744	
Total	39	1115.50		

Grand Mean 87.250   CV 2.50

Analysis of Variance Table for firs year number of flower/raceme Nflowerac

Source	DF	SS	MS	F
rep	3	31.4750	10.4917	6.86
crop	1	0.0250	0.0250	0.02
treat	4	11.2500	2.8125	1.84
crop*treat	4	15.3500	3.8375	2.51*
Error	27	41.2750	1.5287	
Total	39	99.3750		

Grand Mean 11.375   CV 10.87

Analysis of Variance Table for firs year number of pod/flower Npodsflow

Source	DF	SS	MS	F
rep	3	2.9000	0.96667	2.07

crop	1	0.1000	0.10000	0.21
treat	4	16.2500	4.06250	8.71**
crop*treat	4	3.6500	0.91250	1.96
Error	27	12.6000	0.46667	
Total	39	35.5000		

Grand Mean 2.7500   CV 24.84

Analysis of Variance Table for firs year number of seeds/pod

Source	**DF**	**SS**	**MS**	**F**
rep	3	3.3000	1.1000	1.02
crop	1	25.6000	25.6000	23.67**
treat	4	23.6000	5.9000	5.46**
crop*treat	4	9.4000	2.3500	2.17
Error	27	29.2000	1.0815	
Total	39	91.1000		

Grand Mean 13.850   CV 7.51

Analysis of Variance Table for first year 100 seed weight lobia

Source	**DF**	**SS**	**MS**	**F**
rep	3	9.349	3.1162	1.06
crop	1	0.371	0.3706	0.13
treat	4	65.578	16.3946	5.60**
crop*treat	4	39.521	9.8803	3.38*
Error	27	79.028	2.9270	
Total	39	193.847		

Grand Mean 20.466   CV 8.36

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Analysis of Variance Table for first year total grain yield lobia

Source	**DF**	**SS**	**MS**	**F**
rep	3	278648	92883	19.76
crop	1	15602	15602	3.32*
treat	4	844460	211115	44.91**
crop*treat	4	1460	365	0.08
Error	27	126927	4701	
Total	39	1267098		

Grand Mean 587.75   CV 11.67

Analysis of Variance Table for first year total straw yield lobia

Source	**DF**	**SS**	**MS**	**F**
rep	3	667610	222537	51.45
crop	1	77440	77440	17.90**
treat	4	1409415	352354	81.46**
crop*treat	4	7135	1784	0.41
Error	27	116790	4326	
Total	39	2278390		

Grand Mean 940.50   CV 6.99

Analysis of Variance Table for lobia second year first read plant height PH1

Source	DF	SS	MS	F
rep	3	1129.74	376.581	10.16
crop	1	121.45	121.452	3.28*
treat	4	482.10	120.525	3.25*
crop*treat	4	30.63	7.657	0.21
Error	27	1001.02	37.075	
Total	39	2764.95		

Grand Mean 19.133   CV 31.83

Analysis of Variance Table for lobia second year second read plant height PH2

Source	DF	SS	MS	F
rep	3	2895.3	965.10	1.13
crop	1	5764.8	5764.80	6.74*
treat	4	25185.0	6296.25	7.36**
crop*treat	4	4791.2	1197.80	1.40
Error	27	23104.3	855.71	
Total	39	61740.6		

Grand Mean 154.25   CV 18.97

Analysis of Variance Table for lobia **second year third read plant heigh PH3**

Source	DF	SS	MS	F
rep	3	5024.6	1674.9	1.58
crop	1	531.4	531.4	0.50
treat	4	40682.7	10170.7	9.62**
crop*treat	4	5150.1	1287.5	1.22
Error	27	28548.1	1057.3	
Total	39	79936.9		

Grand Mean 181.25   CV 17.94

Analysis of Variance Table for lobia second year first read number of leave NL1

Source	DF	SS	MS	F
rep	3	7.5000	2.50000	1.17
crop	1	0.9000	0.90000	0.42
treat	4	26.1000	6.52500	3.06*
crop*treat	4	1.1000	0.27500	0.13
Error	27	57.5000	2.12963	
Total	39	93.1000		

Grand Mean 9.3500   CV 15.61

Analysis of Variance Table for lobia second year second read number of leave NL2

Source	DF	SS	MS	F
rep	3	13.475	4.4917	1.84
crop	1	5.625	5.6250	2.31

treat	4	135.150	33.7875	13.87**
crop*treat	4	2.750	0.6875	0.28
Error	27	65.775	2.4361	
Total	39	222.775		

Grand Mean 14.675   CV 10.64

Analysis of Variance Table for lobia second year third read number of leave   LN3

Source	DF	SS	MS	F
rep	3	66.500	22.1667	2.51
crop	1	19.600	19.6000	2.22
treat	4	324.900	81.2250	9.20**
crop*treat	4	22.400	5.6000	0.63
Error	27	238.500	8.8333	
Total	39	671.900		

Grand Mean 16.950   CV 17.53

Analysis of Variance Table for lobia second year stem diameter first read SD1

Source	DF	SS	MS	F
rep	3	125.44	41.8138	0.97
crop	1	37.38	37.3842	0.87
treat	4	173.48	43.3699	1.01
crop*treat	4	173.44	43.3600	1.01
Error	27	1163.86	43.1060	
Total	39	1673.61		

Grand Mean 1.6228   CV 404.59

Analysis of Variance Table for lobia second year stem diameter second read SD2

Source	DF	SS	MS	F
rep	3	0.03697	0.01232	0.54
crop	1	0.05112	0.05112	2.22
treat	4	0.16256	0.04064	1.77
crop*treat	4	0.07389	0.01847	0.80
Error	27	0.62046	0.02298	
Total	39	0.94500		

Grand Mean 1.0373   CV 14.61

Analysis of Variance Table for lobia second year stem diameter third readSD3

Source	DF	SS	MS	F
rep	3	0.05291	0.01764	0.72
crop	1	0.01056	0.01056	0.43
treat	4	0.99592	0.24898	10.23**
crop*treat	4	0.08357	0.02089	0.86
Error	27	0.65702	0.02433	
Total	39	1.79998		

Grand Mean 1.2982   CV 12.02

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Analysis of Variance Table for loba second year plant density first read PD1

Source	DF	SS	MS	F
rep	3	5.2750	1.7583	3.40
crop	1	24.0250	24.0250	46.42**
treat	4	4.9000	1.2250	2.37*
crop*treat	4	2.6000	0.6500	1.26
Error	27	13.9750	0.5176	
Total	39	50.7750		

Grand Mean 4.9250   CV 14.61

Analysis of Variance Table for loba second year plant density secoread PD2

Source	DF	SS	MS	F
rep	3	5.2750	1.7583	3.40
crop	1	24.0250	24.0250	46.42**
treat	4	4.9000	1.2250	2.37*
crop*treat	4	2.6000	0.6500	1.26
Error	27	13.9750	0.5176	
Total	39	50.7750		

Grand Mean 4.9250   CV 14.61

Analysis of Variance Table for loba second year plant density third read PD3

Source	DF	SS	MS	F
rep	3	5.2750	1.7583	3.40
crop	1	24.0250	24.0250	46.42**
treat	4	4.9000	1.2250	2.37*
crop*treat	4	2.6000	0.6500	1.26
Error	27	13.9750	0.5176	
Total	39	50.7750		

Grand Mean 4.9250   CV 14.61

Analysis of Variance Table for loba second year Day50

Source	DF	SS	MS	F
rep	3	53.000	17.6667	8.75
crop	1	4.900	4.9000	2.43
treat	4	137.850	34.4625	17.07**
crop*treat	4	3.350	0.8375	0.41
Error	27	54.500	2.0185	
Total	39	253.600		

Grand Mean 55.400   CV 2.56

Analysis of Variance Table for loba second year maturity

Source	DF	SS	MS	F
rep	3	4.28	1.425	0.26
crop	1	38.02	38.025	7.06
treat	4	931.90	232.975	43.24**
crop*treat	4	27.10	6.775	1.26
Error	27	145.47	5.388	
Total	39	1146.78		

Grand Mean 87.075   CV 2.67

Analysis of Variance Table for lobia second year number of flower/ raceme

Source	DF	SS	MS	F
rep	3	7.475	2.4917	1.01
crop	1	0.225	0.2250	0.09
treat	4	71.500	17.8750	7.23**
crop*treat	4	6.400	1.6000	0.65
Error	27	66.775	2.4731	
Total	39	152.375		

Grand Mean 11.875 CV 13.24

Analysis of Variance Table for lobia second year number of pods/plant

Source	DF	SS	MS	F
rep	3	24.900	8.3000	0.79
crop	1	14.400	14.4000	1.37
treat	4	68.150	17.0375	1.62
crop*treat	4	48.350	12.0875	1.15
Error	27	284.100	10.5222	
Total	39	439.900		

Grand Mean 3.4500 CV 94.02

Analysis of Variance Table for lobia second year number of seed/pod Nseedpod

Source	DF	SS	MS	F
rep	3	0.2750	0.09167	0.12
crop	1	7.2250	7.22500	9.53**
treat	4	8.6500	2.16250	2.85*
crop*treat	4	8.1500	2.03750	2.69*
Error	27	20.4750	0.75833	
Total	39	44.7750		

Grand Mean 13.325 CV 6.54

Analysis of Variance Table for second season lobia100 seed weight

Source	DF	SS	MS	F
rep	3	4.634	1.5447	0.47
crop	1	1.743	1.7431	0.53
treat	4	52.903	13.2257	3.99*
crop*treat	4	20.275	5.0687	1.53
Error	27	89.533	3.3160	
Total	39	169.087		

Grand Mean 20.551 CV 8.86

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Analysis of Variance Table for second season lobia total grain yield

Source	DF	SS	MS	F
rep	3	80288	26763	12.25
crop	1	30802	30802	14.10**
treat	4	1029160	257290	117.77**
crop*treat	4	4260	1065	0.49
Error	27	58988	2185	
Total	39	1203498		

Grand Mean 549.75 CV 8.50

Analysis of Variance Table for second season lobia total straw yield (kg)

Source	DF	SS	MS	F
rep	3	448888	149629	38.05
crop	1	101002	101002	25.68**
treat	4	1848250	462062	117.49**
crop*treat	4	1610	403	0.10
Error	27	106187	3933	
Total	39	2505938		

Grand Mean 956.25 CV 6.56

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Analysis of Variance Table for Phosphorus cowpea

Source	DF	SS	MS	F
rep	3	535.50	178.499	2.37
crop	1	55.70	55.696	0.74
treat	4	157.68	39.419	0.52
crop*treat	4	55.69	13.921	0.18
Error	27	2033.06	75.298	
Total	39	2837.61		

Grand Mean 27.879 CV 31.12

Analysis of Variance Table for Crude Fiber

Source	DF	SS	MS	F
rep	3	5.669	1.8898	0.48
crop	1	17.716	17.7156	4.54*
treat	4	13.796	3.4490	0.88
crop*treat	4	2.817	0.7042	0.18
Error	27	105.404	3.9039	
Total	39	145.402		

Grand Mean 9.3085 CV 21.23

Analysis of Variance Table for Crude Protein

Source	DF	SS	MS	F
rep	3	21.400	7.1333	1.07
crop	1	13.712	13.7124	2.06
treat	4	110.354	27.5885	4.14**
crop*treat	4	19.412	4.8529	0.73
Error	27	180.120	6.6711	
Total	39	344.998		

Grand Mean 26.078 CV 9.90