EFFECT OF MAGNETIZING IRRIGATION WATERAND SEEDS ON THE PRODUCTION OF OKRA (*Hibiscus esculentus)*

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DEDICATION

This work is dedicated to my family and friends

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First of all, I render my gratitude and praise to the Almighty (Allah).

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ABSTRACT

Very recently special magnetic systems have been used to magnetize water and seeds. Such magnetic treatments were reported to play a great role in increasing the germination rate and improving saline soil, consequently resulting in increasing yield.

An experiment was carried out in the Department of Agricultural Engineering, Faculty of Agriculture, Shambat, during the summer season (April /July) of 2003.

The study aimed to improve crop productivity by using magnetic technologies. A split plot experimental design was used for growing two varieties of okra (Hibiscus esculentus). The treatments were as follows:

(A) Nonmagnetized water + Nonmagnetized seeds.

(B) Nonmagnetized water + Magnetized seeds.

(C) Magnetized water + Nonmagnetized seeds.

(D) Magnetized water + Magnetized seeds.

Each treatment was replicated three times. Variables compared were number of leaves per plant, leaf length, plant length, plant density and yield.

The results of the study showed significant differences ($p \leq 0.05$) in the number of leaves per plant (12.12 leaves /plant), plant density (11.45plants /m^2), leaf length (8.05 cm) and yield (14.8 Kg/ha) when magnetized water was used as compared to nonmagnetized water which gave 7.85 leaves per plant, 8.0 plants per m^2, 6.15cm leaf length and (7.4Kg/ha) for yield.

However there was no significant difference ($p \leq 0.05$) in plant length between magnetized water (43.33 cm) and nonmagnetized water (39.55 cm) with nonmagnetized seeds.

On the other hand there were significant differences ($p \leq 0.05$) in plant density (12.8plant/m^2) and yield (19.4Kg/ha) when magnetized seeds were irrigated by magnetized water as compared to nonmagnetized seeds when irrigated by magnetized water which gave plant density of 11.45 plants per m^2 and (14.8Kg/ha) yield.

The same number of 12.12 leaves per plant was obtained when both magnetized and nonmagnetized seeds were irrigated by magnetized water.

The study showed that when magnetized water was used there were no significant differences ($p \leq 0.05$) in the plant length (48.45 cm) and leaf length (9.05 cm) of magnetized seeds as compared to nonmagnetized seeds which gave 45.77 cm plant length and 8.05cm leaf length.

The results also showed that when nonmagnetized water was used with magnetized seeds there were significant differences ($p \leq 0.05$) in number of leaves per plant (14.97 leaves /plant), plant density (11.48 plants/m^2), leaf length (8.0 cm) and yield (9.0 Kg/ha) as compared to when nonmagnetized seeds were used which gave 7.85 leaves per plant, a plant density of 8.0 plants per m^2, 6.15cm leaf length and yield of 7.4Kg/ha.

When nonmagnetized water was used with magnetized seeds there was no significant difference ($p \leq 0.05$) in plant length (43.33cm) as compared to when nonmagnetized seeds were used (39.55cm).

Furthermore the study results showed that both okra varieties (Kosti and Madani) gave higher values in number of leaves per plant, plant density, plant length, leaf length and yield for the combination of magnetized water and magnetized seeds, they were (17.23 leaves/plant), (14.9 plants/ m^2), 59cm plant length, 9.2 cm leaf length and yield of (25.5 Kg/ha) for the variety Kosti and (12.7 leaves/plant), (13.87 plants/m^2), 57.1 cm plant length, 8.9cm leaf length and a yield of 35.5 Kg/ha for the variety Madani.

Hence it was concluded that magnetizing water would lead to better crop production and further improvement could be attained by magnetizing the seeds.

بسم الله الرحمن الرحيم

الخلاصة

حديثا جدا استخدم نظام المغنطة لمغنطة المياه والبذور. المعالجة بالمغنطة ذكر بانها تلعب دورا عظيما في زيادة معدل الانبات وتحسين حالة التربة مما ينتج عنه زيادة في الانتاجية. اجريت التجربة في قسم الهندسة الزراعية كلية الزراعة (شمبات) جامعة الخرطوم في الموسم الصيفي ابريل / يوليو للعام 2003 .

الدراسة هدفت لتحسين الانتاجية باستخدام تقنية المغنطة. نظام القطع المنفصلة التجريبي استخدم لزراعة عينتين من البامية (Hibiscus esculentus).

المعالجات تمت علي النحو التالي:

(أ) مياه غير ممغنطة + بذور غير ممغنطة.

(ب)مياه غير ممغنطة + بذور ممغنطة

(ت)مياه ممغنطة + بذور غير ممغنطة

(ث)مياه ممغنطة + بذور ممغنطة

اي مـن المعالجـات كـررت ثـلاث مـرات. المتغيـرات التـي قورنـت كانـت عـدد الاوراق لكل نبات، طول الورقة، طول النبات، كثافة النبات، والانتاجية.

اوضـحت نتائج الدراسـة ان هنـاك فرقـا معنويـا عند المستوي ($p\leq$ 0.05) فـي عدد الاوراق للنبات (12.12)، كثافة النبات (11.45 نبات للمتر مربع)، طول الورقـه (8.05 سـم) والانتاجيـة (14.8 كيلـوجرام للهكتـار) عنـدما اسـتخدمت الميـاه الممغنطـة مقارنة بالمياه غير الممغنطة التي اعطت عدد اوراق النبات (7.85)، كثافة النبـات (8.0 نبات للمتر المربع) طول النبات (6.15 سم) و(7.4 كيلوجرام للهكتار) للانتاجية.

من ناحيـة ثانيـة ليس هنـاك فـرق معنـوي عنـد المستوي ($p\leq$ 0.05) فـي طـول النبات بين استخدام الميـاه الممغنطـة (43.33 سم) والميـاه غيـر الممغنطـة (39.55 سم) عند استخدام البذور غير الممغنطة.

من جانب اخر هناك فروقا معنوية عند المستوي ($p\leq$ 0.05) فـي كثافـة النبـات (12.8 نبـات للمتـر المربـع) والانتاجيـة (19.4 كيلـوجرام للهكتـار) عنـد مغنطـة البـذور وريهـا بالميـاه الممغنطـة مقارنـة بالبـذور غيـر الممغنطـة المرويـة بالميـاه الممغنطـة والتـي اعطت (11.45 نبات للمتر المربع) و (14.8 كيلوجرام للهكتار) للانتاجية.

نفـس عـدد الاوراق للنبـات (12.12) متحـصل عليـه عنـدما كـل مـن البـذور الممغنطة والبذور غير الممغنطة تم ريهم بالمياه الممغنطة.

الدراسة اوضحت انه عندما استخدمت المياه الممغنطة ليس هناك فروقا معنوية عند المستوي ($p \leq 0.05$) في طول النبات(48.45 سم) وطول الورقة (9.05 سم) من مغنطة البذور مقارنة بالبذور غير الممغنطة التي اعطت طول نبات (45.77 سم) وطول الورقة (8.05 سم).

النتائج ايضا اوضحت انه عندما استخدمت المياه غير الممغنطة مع البذور الممغنطة ان هناك فروقا معنوية عند المستوي ($p \leq 0.05$) في عدد الاوراق للنبات (14.97)، كثافة النبات (11.48 نبات للمتر المربع)، طول الورقة (8.0 سم) والانتاجية (9.0 كيلوجرام للهكتار) مقارنة باستخدام البذور غير الممغنطة التي اعطت (7.85) عدد اوراق للنبات، (8.0) نبات للمتر المربع، طول الورقة (6.15 سم) وانتاجية (7.4 كيلوجرام للهكتار).

عند استخدام المياه غير الممغنطة مع البذور الممغنطة ليس هناك فرقا معنويا عند المستوي($p \leq 0.05$) في طول النبات (43.33 سم) مقارنة باستخدام البذور غير الممغنطة (39.55سم).

علاوة علي ذلك نتائج الدراسة اوضحت انه كل من عينتي الباميا (كوستي ومدني) اعطت اعلي قيم في عدد الاوراق للنبات، كثافة النبات، طول النبات، طول الورقة والانتاجية للمركبة مغنطة المياه ومغنطة البذور وهي (17.23 عدد الاوراق للنبات، (14.9 نبات للمتر المربع)، طول النبات 59 سم، طول الورقة(9.2 سم) وانتاجية(25.5 كيلوجرام للهكتار) للعينة كوستي وعدد اوراق للنبات(12.7)،(13.87 نبات للمتر المربع)، طول نبات (57.1 سم)، طول ورقة (8.9 سم) وانتاجية(35.5 كيلوجرام للهكتار) للعينة مدني.

خلصت الدراسة الي ان استخدام المياه الممغنطة يقود الـي انتاجيـة احسن وزيـادة

في التحسين ممكن التحصل عليه بمغنطة البذور.

CHAPTER ONE

INTRODUCTION

Irrigation has often been defined as the method of applying water to the soil to supplement that from rainfall for maximizing production per unit area.

The growing scarcity and misuse of available water resources particularly in arid and semi arid regions constitute challenges to water demands for various utilities.

Sudan is envisaged to face water shortage very soon. Utilization of water from the river Nile and tributaries is abided by international agreements with neighboring countries. Rainfalls are unpredictable and evaporation losses are high under such arid conditions. Underground water resources need evaluation (quantity and quality wise) and require technically and economically feasible means of extraction.

Agriculture in Sudan is either irrigated or rainfed. Irrigated agriculture in Sudan depends mainly on water from the river Nile and its tributaries.

The utilization of the Nile water is subject to the 1959 Nile water agreement between Egypt and Sudan. Sudan's allotted share is 22.50 milliards m^3 annually (measured at Sennar).

Additional supplies of water can be available through water conservation projects such as Jongli canal which will save about 4 milliards m3 annually shared equally between Sudan and Egypt. The total potentially arable area of the country is estimated as 200 million feddans of which 17 million feddans (1feddan=0.42 ha) are claimed to be under cultivation.

The irrigated sector constitutes about 5 million feddans and contributes about 63 percent of Sudan's exports. The major constraints to produce more food to meet the increasing demands of the world population are land and water. One possible approach to conserve these scarce resources may be through improving the performance of the existing irrigation projects. One way of improving performance may be a technical approach of magnetizing water. Magnetization causes physical and chemical changes of natural water parameters, resulting in improvement of filtration and in an increase of the dissolving properties of water. These changes result in an increased ability of soil to get rid of salts and results in a better assimilation of nutrients and fertilizer in plants during the growing cycle. Plants and trees need mineral salts and trace minerals from the soil for growth and food production. Minerals and nutrients must be well balanced in the soil with an appropriate pH to be utilized by the plants (Busch et al, 1997).

Watering plants with magnetized water dissolves more nutrients because it lowers the surface tension of water. This lets more minerals be suspended in concentration. This buffers the pH and causes more minerals and nutrients to pass through the cell walls of roots. Magnetized water, penetrates the soil faster and deeper, allowing roots to penetrate and grow larger.

Magnetized water dissolves more nutrients into the root zone to become available to stimulate plant growth. These may be the reasons why growth rates are increased. Crop yields are larger in a shorter period of time, and with much less water and fertilizers and pesticides, needs.

This is the reason why magnetic water be used for irrigation. This results in an increased crop production and in an increased quality of agricultural products coupled by savings in labor and money. This is also much better for the environment in many ways-both for land and water and human health especially for need to handle toxic chemicals.

This study has been conducted with a view to evaluate the effect of magnetizing irrigation water and /or seeds on vegetable production under Sudan condition, okra (*Hibiscus esculentus*) have been taken as a case study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Magnets and magnetism:

To many people, magnets are a complete mystery .Vendors of magnets base often uses this ignorance to their own advantage, so a familiarity with the basics of magnetism can aid in the detection of dubious claims. Magnetic fields are produced by the motion of charged particles, for example, electrons flowing in a wire will produce a magnetic field surrounding the wire. The magnetic field generated by moving electrons is used in many household appliances, automobiles, and industrial machines. One basic example is the electromagnet; which is constructed from many coils of wire wrapped around a central iron core. The magnetic field is present only when electrical current is passed through the wire coils (Mike, 1998).

Permanent magnets do not use an applied electrical current. Instead, the magnetic field of a permanent magnet results from the mutual alignment of the very small magnetic fields produced by each of the atoms in the magnet. These atomic level magnetic fields result mostly from the spin and orbital movements of electrons. While many substances under alignment of the atomic level fields in response to an applied magnetic field, only ferromagnetic materials retain the atomic–level alignment when the applied field is removed. Thus, all permanent magnets are composed of ferromagnetic materials. The most commonly used ferromagnetic elements are iron, cobalt, and nickel. The strength of a magnet is given by its magnetic flux density, which is measured in units of gauss. The earth's magnetic field is in the order of 0.5 gauss. Typical household refrigerator magnets have field strengths of about 1000 gauss. The magnets sold for magnetic fuel and water treatment are nothing special, they are just ordinary magnets (Busch et al, 1997).

2.2 Claimed benefits and effects:

The claimed benefits of magnetic water treatment vary depending on the manufacturer. Some claim only that magnetic treatment will prevent and eliminate lime scale in pipe and heating elements, others make additional, more extravagant claims. Some of the additional claims include water softening, improved plant growth, prevention of some diseases in people who consume magnetically treated water. Magnetic water treatment devices consist of one or more magnets, which are clamped onto or installed inside the incoming domestic water supply line.

Magnetic fuel treatment devices are constructed similarly. One or more magnets are clamped around or installed inside an automobile's engine fuel line between the gas tank and the carburetor or (fuel injectors). Claims for these devices include decreased hazardous gas emissions, more complete combustion, improved engine power, longer lasting components and a10 percent to 20 percent increase in gas mileage (Mike, 1998).

The distributors of these devices rarely can cite any documented test results that validate these claims. Instead, they rely on numerous testimonials. Lists of corporations and municipalities that purportedly use the devices, and scientific-sounding explanations of magnetic water and fuel treatment.

However, just because distributors do not cite the literature does not mean that no relevant literature exists. Published test reports and journal articles that investigate magnetic treatment are available (Parsons, 1999).

2.3 Water hardness:

The phrase hard water originated when it was observed that water from some sources requires more laundry soap to produce suds than water from other sources. Waters that required more soap were considered (harder) to use for laundering.

Water hardness is a measure of dissolved mineral content. As water seeps through soil and aquifers, it often contacts minerals such as limestone and dolomite .Under the right conditions, small amounts of these minerals will dissolve in the ground water and the water will become hard. Water hardness is quantified by the concentration of dissolved hardness minerals (Mike, 1998).

The most common hardness minerals are carbonates and sulfates of magnesium and calcium. Water with a total hardness minerals concentration less than about 17 parts per million (ppm) is categorized as (soft). Moderately hard water has a concentration of 60 to 120 ppm. Very hard water exceeds 180 ppm. Hard water is often undesirable because dissolved minerals can form scale. Scale is simply the solid phase of the dissolved minerals. Some hardness minerals become less soluble in water as temperature is increased. These minerals tend to form deposits on the surfaces of water heating, elements, bathtubs, and inside hot water pipes. Scale deposits can shorten the useful life of appliances such as dish washers. Hard water also increases soap consumption and the amount of (soap scum) formed on dishes. (Busch *et al*. 1997)

Many home owners and businesses use water softeners to avoid the problems that result from hard water .Most water softeners remove problematic dissolved magnesium and calcium by passing water through a bed of "ion-exchange" beads. The beads are initially contacted with a concentrated salt (sodium chloride) solution to saturate bead exchange site with sodium ions. These ion exchange sites have a greater affinity for calcium and magnesium, so when hard water is passed through the beads the calcium and magnesium ions are captured and sodium is released. The end result is that the calcium and magnesium ions in the hard water are replaced by sodium ions. Sodium salts do not readily form scale or soap scum, so the problems associated with hard water are avoided. (Mike, 1998).

A1960 survey of municipal water supplies in one hundred U.S cities revealed that water hardness ranged from 0 to 738 ppm with a medium of 90 ppm. Ion-exchange water softeners are capable of reducing the hardness of the incoming water supply to between 0 and 2 ppm, which is well below the levels where scale and soap precipitation are significant.

One of the principal draw backs of ions–exchange water softeners is the need to periodically recharge the ion exchange beads with sodium ions. Rock salt is added to a reservoir in the softener for this purpose (Liburkin *et al*, 1986).

2.4 Some results of applying of magnetized water for soil desalination:

It stands to reason that soil desalination is a crucial problem nowadays. It is noteworthy that the possibility of using magnetized water to desalinate the soil accounts for its enhanced dissolving capacity which has been registered repeatedly.

Soviet scientists staged myriad trials on the soil of experimental drainage grounds. They came to establish that the density of magnetized water which had penetrated the soil layer was 0.1 g/cm more than that of unmagnetized water. It was noted that filtration rate had been doubled. In the case with magnetized water every 100 g of soil had salts removed by 10g more. Once a5% water solution of technical green vitriol was exposed to magnetic treatment it yielded ameliorant which brought out of the soil by 20g of salts more per every 100g as opposed to regular water. Thereafter these findings were corroborated repeatedly both on testing grounds and industrial premises in of the world (Tkatchenko, 1997).

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The tests have been implemented on the soil that contained the following indicators (%):

Table (2-1) Soil indicators content (%)

CO_3	0.019	Ca	0.082
HCO_3	0.066	Mg	0.006
CL	0.572	Na +K	1.072
SO_4	1.663		

The dry sediments were 3.46 mg/l. magnetic treatment was applied to the water which contained (mg eqv. /l):

HCO_3^- -1.94; Cl^- -0.79; Ca^{2+} -1.16; Mg^{2+} -0.76.

The dry sediments were 372 mg/l. It was found that with optimized mode of magnetic treatment the magnetized water will wash salts out by 5 times more efficiently than usual water (Tkatchenko, 1997).

2.5 Magnetic water treatment:

A wide variety of magnetic water treatment devices are available, and most consist of one or more permanent magnets affixed either inside or to the exterior surface of the incoming water pipe. The water is exposed to the magnetic field as it flows through the pipe between the magnets. An alternative approach is to use electrical current flowing through coils of wire wrapped around the water pipe to generate the magnetic field (Mike, 1998).

Purveyors of magnetic water treatment devices claim that exposing water to a magnetic field will decrease the waters (effective) hardness. Typical claims include the elimination of scale deposits, lower water–heating bills, extended life of water heaters and household appliances, and more efficient use of soaps and detergents. Thus, it is claimed, magnetic water treatment gives all the benefits of water softened by ion exchange without the expense and hassle of rock–salt additions (Kronenberg, 1985).

Hardness is claimed to be reduced through magnetic treatment, magnesium or calcium is removed from the water by magnetic treatment, instead the claim is that the magnetic field decreases the tendency of the dissolved minerals to form scale. Even though the dissolved mineral concentration indicates the water is still hard, magnetically treated water supposedly behaves.

According to some vendors, magnetically softened water is healthier than water softened by exchange. Ion-exchange softener increases the water sodium concentration, and hence claimed unhealthy for people with high blood pressure. There is apparently no consensus among magnet vendors regarding the mechanisms by which magnetic water treatment occurs.

Clearly magnetic water treatment has received some attention from the scientific community. The reported effects of magnetic water treatment however are varied and often contradictory.

In many cases researchers report findings with no significant magnetic treatment effects. In other cases, however reasonable evidence for an effect is provided.

Liburkin *et al* (1986) found that magnetic treatment affected the structure of gypsum (calcium sulfate). Gypsum particles formed in magnetically treated water were found to be larger and more regularly oriented) than those formed in ordinary water. Similarly Kronenberg (1985) reported that magnetic treatment changed the mode of calcium carbonate precipitation such that circular disc-shaped particles are formed rather than the dendretic (branching or tree –like) particles observed in non treated water.

Others (e.g. Chechel and Annekova 1972, Martynova *et al.*, 1967) also have found that magnetic treatment affects the structure of subsequently precipitated solids. Because scale formation involves precipitation and crystallization, these studies imply that magnetic water treatment is likely to have an effect on the formation of scale.

Some researchers hypothesize that magnetic treatment affects the nature of hydrogen bonds between water molecules. They report changes in water properties such as light absorbance, surface tension, and pH (e.g Joshi and Kamat 1966, Bruns *et al* 1966, Klassen 1981). However, these effects have not always been found by later investigators (Mirumyants *et al*. 1972) Duffy (1977) provides experimental evidence that scale suppression in magnetic water treatment devices is due not to magnetic effects on the fluid, but to the dissolution amount of iron.

Iron ions can suppress the rate of scale formation and encourage the growth of a softer scale deposit. Busch *et al*. (1986) measured the voltages produced by fluids flowing through a commercial magnetic treatment device. Their data support the hypothesis that a chemical reaction driven by the induced electrical currents may be responsible for generating the iron ions shown by Duffy to affect scale formation .Among those who report some type of direct magnetic water treatment effect, a consensus seems to be emerging that the effect results from the interaction of the applied magnetic field with surface charges of suspended particles.

Whether or not some magnetic water treatment effect actually exists, the further question, and the most important for consumers, is whether the magnetic water treatment devices perform as advertised.

Numerous accounts of the successes and failures of magnetic water treatment devices can be found in the literature Lin and Yotvat 1989, Raisen 1984, Wilkes and Baum 1979, Welder and Partridge 1954. However, because of the varied conditions under which these field trials are conducted it is unclear whether the positive reports are due to magnetic treatment or to other conditions that were not controlled during the trial. Some commercial devices have been subjected to test under controlled conditions. Unfortunately, the results are mixed. Duffy (1977) tested a commercial device with an internal magnet and found that it had no significant effect on the precipitation of calcium carbonate scale in a heat exchanger.

According to lipus *et al*. (1994), however, the scale prevention capability of their ELMAG device is proven, although they do not supply much supporting data. Busch *et al.,* (1997) measured the scale formed by the distillation of hard water with and without magnetic treatment; using laboratory–prepared hard water a22 percent reduction in scale formation was observed when the magnetic treatment device was used instead of a straight pipe section. However, a17 percent reduction in scaling was found when an unmagnetized, but otherwise identical, device was installed. Busch *et al*. (1997) speculated that fluid turbulence inside the device may be the cause of the 17 percent reduction, with the magnetic field effect responsible for the additional 5percent.River water was subjected to similar tests, but no difference in scale formation was found with and without the magnetic treatment device installed. An explanation for the negative result was not found. Another study of a commercial magnetic water treatment device was conducted by Hasson and Bramson (1985). Under the technical supervision of the device supplier, they tested the device to determine its ability to prevent the accumulation of calcium carbonate scale in a pipe. Very hard water(300 to 340 ppm) was pumped through a cast–iron pipe, and the rate of scale accumulation inside the pipe was determined by periodically inspecting the pipes interior. Magnetic exposure was found to have no effect on either the rate of scale accumulation or on the adhesive nature of the scale deposits.

The general principle operation for magnetic technology is a result of the physics of interaction between a magnetic field and fluid. The magnetic field exerts a force on the charged species in the fluid and redirects the orientation of the charged species, which produces physicochemical changes in the fluid. Mechanisms of action have been proposed, but not proven.

Parsons (1999) summarized proposed mechanisms for the magnetic treatment of hard water. Micro contaminations, which affect crystal nucleation growth rates, may play a key role. The magnetic field may affect crystalline growth by acting either directly on the solid crystal or at the solid liquid interface, leading to changes in nucleation and crystal size. The magnetic field may cause structural changes in the aqueous solutions, which deforms the hydration sphere around ions or affects the average cluster size in water.

The magnetic core is a single or multiple bars multi-field, multi–pole cobalt alloy permanent magnet.

The fluid velocity in the magnetic chamber is critical and varies with the spacing of the poles, the contact time of the fluid within each poles flux path is 0.1 second.

The magnetic associated with each of poles varies, depending on the fluid flow gap. Because there are no moving parts, the magnetic unit is low maintenance and does not use energy to produce the treatment. The manufactured units have a capacity ranges from 1gph up to 50.000 gph of water conditioning. The natural gas application ranges from 0.25 inch up to 20 inch diameter pipe.

Proper installation of the unit is critical. Parameters of interest to the manufacturer include fluid flow rate, proximity to electromagnetic fields, and in the case of water applications, water quality parameters such as hardness, iron, silica, and alkalinity.

2.6 Natural gas combustion:

The combustion of natural gas generates carbon monoxide, carbon dioxide and other pollutants that contribute to air pollution and global warming. Innovations that reduce natural gas consumption will extend this resource, improve our nations energy independence, produce economic benefits industrial users, reduce air pollution and improve public health, reduce health care costs, and reduce global warming (Kronenberg, 1985).

2.7 Golf course irrigation:

Irrigation and agriculture are important users of water resources and chemical, including pesticides, fertilizers, and wetting agents to improve penetration (Mike, 1998).

Resulting environmental issues include chemical contamination of surface and ground water and water usage. According to Tkatchenko, (1997) primary reason for investing in magnetic technology was to obtain better infiltration of water and thereby reduce water and chemical usage. Tkatchenko, (1997) noted that the magnetic technology, which effectively lowers the surface tension of the water, has dramatically improved the infiltration distribution of the water, substantially eliminating both wet and dry areas.

Prior to installation of the unit, approximately 80 labor hours per week were spent on hand watering, even with the Toro system, and the golf course still had uneven infiltration of water. Since the installation of the magnetic unit, uniformity distribution problems have reduced dramatically. It is now unusual to allocate more than 10 labor hours spent roping off wet areas and repairing cart damage have been eliminated. The data from the Brick yard golf course show a71%reduction in the use of wetting agents and fertilizers and a related cost savings of 62%after the installation of the magnetic unit. The pay back time for its water, is about 4.5 years based only on the wetting agent and fertilizers usage. Anecdote report from a facility in hot weather region suggests a pay back time of less than one year for facilities that pay for water (Tkatchenko, 1997).

2.8 Pre-sowing magnetic treatment of seeds:

The potential energy of self–preservation in seeds differs at different stages of development. During the harvest collection, seeds also contain different energy levels and not all planted seeds will grow. That is the reason for an increase of the sowing norm, which is taken to the maximum amount of grown seeds for a hectare. Therefore, it results in the excess of costly seed material being used. Magnetic treatment of seeds before sowing not only allows spending 30-50% less on the sowing material but also provides earlier ripping of the harvest. Seeds which were treated using magnetic field, grow faster (Kronenberg, 1985).

Also the property of magnetic field to activate the process speeds up protein formation, providing for the growth of roots and activating processes in weak seeds. As the experiments have shown, it is important to note that the vital element while magnetizing seeds is to choose the right lunar phase, and to magnetize seeds affected by fungous diseases during the first half of the day.

For example, it is better to magnetize wheat seeds during the new moon, cucumber–during the last quarter of the lunar phase, tomato-in full moon; carrot–in the first quarter of the lunar phase, In addition magnetization of seeds can be done as 5 months before sowing as on the same day.

Application of the above mentioned technology in Russia, Ukraine, Byelorussia, Uzbekistan, UAE, Malaysia, Indonesia and Egypt, with a considerable decrease in the riping time and an increase in the quality of vegetable, fruits and cereals, allowed for an increase of harvest by 12-36 %and in some cases up to 100%and more (Tkatchenko, 1997).

2.8.1 Magnetic treatment of seeds:

Seeds are resting systems of organs of a future plant what the plant will be and what results are obtained will depend upon the quality of this system. Magnetic treatment of seeds is necessary while using the non-standard seeds, for the improvement of seeds quantity, their germination properties and for the stimulation of seeds growth during vegetation period .The seeds should be treated directly before sowing (Tkatchenko, 1997).

2.8.2 Preparation of seeds for magnetization:

Seeds prepared for the treatment before sowing must be from one group with controlled seeds .Identical by lineage, reproduction and conditions of storing .Seeds from different layers should be thoroughly mixed and humidity should not be more than 14% multiplicity of the treatment is not important.

The physiological method of definition of magnetized seeds, productivity is in measuring the length of the embryonic root. It was experimentally proved that plants with good speed of growth of the embryonic root during transition from heterotrophic to autotrophic type of nourishment are more productive and create more developed root system.

Magnetic treatment of seeds can be applied at both methods of sowing:

1. Sowing with soaked seeds.
2. Sowing with un soaked seeds.

2.8.3 Sowing with soaked seeds:

The seeds were magnetized by pouring water on them through a magnetic funnel. They were left for about 30 minutes. Then they were poured again through the magnetic funnel where they become ready for immediate or late sowing as recommended by Mike (1998).

2.8.4 Sowing with un soaked seeds:

This method of magnetic treatment of seeds is used for sowing on large industrial areas (grain, wheat, maize, barley, millet, buck wheat, etc).

When seeds soaking is difficult due to large quantities. In this case, it is enough to pass seeds through a magnetic funnel. The results of both methods will be much better if after magnetic treatment of seeds; magnetic water is used for irrigation (Mike, 1998).

Below follows an outline of specific practical applications of magnetic systems in the economy of diverse regions of the former Soviet Union.

In 1980-1984 collective farms of Leningrad region saw experiment on pre-sowing magnetization of potato tubers on a total area of more than 3000 hectares. An average increase of the yield made up 4.18tons per hectare or 23.8% and, in some cases, 35%

Agroindustrial tests on pre-sowing seed magnetization of carrots, radish, cabbage, Swede, cotton, sugar beets and other crops were carried out in 1980-1984. The relevant analysis showed a30% harvest growth with significant reduction of vegetative period and quality improvement (Tkatchenko, 1997).

Experts from Azerbaijani Scientific Research Institute of Water Machinery and Land improvement irrigated plots of land by magnetized sea water (salt content -14mg/l). The level of tomato productivity and sorghum verdure increased by 44.6% and 19.45%, respectively. Fresh magnetized water applied for irrigation did not produce impressive effects although they were quite visible. The yield supplement of tomatoes and sorghum constituted 11.4% and 10.4%, respectively.

Don experimental station of oil crops at Soviet Union held tests on pre-sowing treatment of sunflower seeds in a magnetic system in 1984. The additional harvest ran up to 430 Kg per hectare.

Field research on irrigation of tomatoes by magnetized water was run at Novocherkask mechanical engineering institute in 1984. Magnetic systems were mounted on water sprinkler. The tomato yield swelled by 570 Kg per hectare. Likewise, the number of green and ripe fruits per one bush built up by 2and 31pieces, respectively (Tkatchenko, 1997).

CHAPTER THREE

Material and methods

3.1 Experimental sites and layout:

The experiment was conducted in the Demonstration farm of Faculty of Agriculture Shambat, University of Khartoum. Shambat lies at latitude 15° 40′ N, and longitude 32° 32′ E.

The study was carried out during 2003 summer season. The experimental period extended over April –July .The climate of the area is tropical semi-arid, characterized by low relative humidity with mean daily maximum and minimum temperatures of about 36° C and 21° C. respectively (Oliver, 1965). The annual rainfall is about 158 mm mainly during July, August and September (Sudan Metrological Department 1951-1980).

During the experimental period of 2003 no rainfall was recorded during April –June while it was 2.9 mm in July.

The soil in the experimental field is heavy clay with percentages ranging between 65% in the top 15 cm and 55% in the 100-140 cm depth .The soil reaction is moderately alkaline with a pH ranging from 7 to 8 (Saeed, 1968).The infiltration rate is low, and has been estimated to be about 20 mm/hr in the first two hours and 5mm/hr after 10 hours (Ferguson, 1970).

An area of 170 m^2 was planted with two varieties of okra (Madni and Kosti) divided into two sections. One section was irrigated by sowing with magnetic water .The magnetic device (plate 3-1) was attached at the end of the line so as to magnetize the water that passes through it to the field and the field was divided in 12 plots.

The treatments were arranged in a split plot design, and each treatment was replicated three times.

Magnetic treatment of seeds was applied at both methods of sowing:

1- Sowing with soaked seeds.

2- Sowing with un soaked seeds.

3.2 Sowing with soaked seeds:

A magnetic funnel and a container were taken to soak seeds in, the required amount of water was poured through magnetic funnel into the container; the seeds were passed through the magnetic funnel into the container with magnetic water.

The seeds were left in the magnetic water for about 30 minutes and then the water was poured out of the container and the seeds were passed through the magnetic funnel again, the seeds are now ready for sowing (Mike, 1998).

In this experiment seeds were treated by passing them through a magnetic funnel which consists of magnetic plates fixed inside it.

The other section was irrigated by natural water (control).It was also divided into 12 plots.

3.3 Land preparation:

The land preparation of the experimental area included:

a) Ploughing with standard integral mounted disc plough at a depth of about 0.25 m .The land was then left for two weeks before it received its subsequent operations mainly to control the weeds.

b) Leveling was done with a general purpose blade.

c) Ridging was done at a spacing of 0.7 m with a general purpose ridger.

3.4 Crops planting:

The Okra seeds were sown at a seed rate of about 7.5 Kg per feddan. The sowing date was 28^{th} April 2003.

Two to three seeds were planted manually in rows on the east side of the ridge at a spacing of 70 cm between ridges and 30 cm between plants.

3.5 Irrigation system description:

a) Pump unit:

An Indian electric motor was used to draw irrigation water by a centrifugal pump from the main domestic supply system (plate 3—2).

b) Control unit:

Two valves were fixed, one before the pump unit and the other after it to control discharge and pressure in the entire system.

c) The main pipe line:

The main pipe line was made of polyvinyl chloride (PVC) of 50 mm diameter which was buried under ground at a depth of 50 cm (plate 3—3).

Water was drawn from the pump to supply the field and one valve fixed to control irrigation water.

Predetermined amounts of water were gives at 7 days irrigation interval.

3.6 Data collection:

The plant growth parameters measured are as follows:

a) Number of leaves per plant:

Nine plants were taken at random from each three ridges so as to count the number of leaves per plant, and then the mean number of leaves was recorded.

b) Density of plant:

Number of plants for each three ridges was counted then the mean density was recorded.

c) Plant height:

Eight weeks from sowing, plants height was measured by a wooden ruler from the base of the stem to the tip of youngest leaf.9 plants were taken at random from each three ridges, and then the mean height of the 9 plants was recorded.

d) Length of leaves:

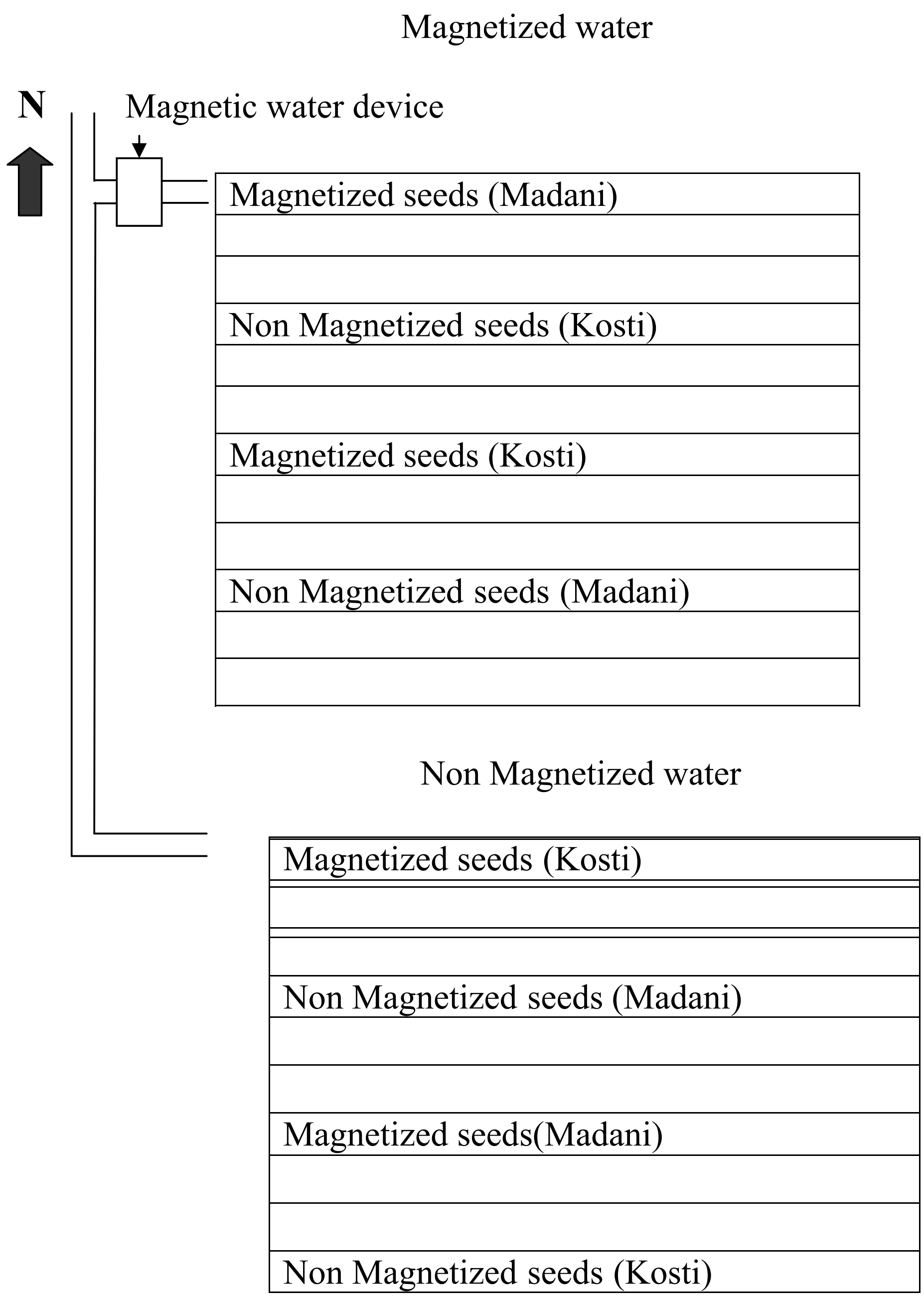
Nine plants were randomly selected from each three ridges, then using a wooden ruler the length of the leaves was measured, and the mean of length of the leaves was recorded.

e) The yield: A sensitive balance was used to weigh the end product.

Plate (3.1): The Magnetic water device

Plate (3.2): The pump unit

Plat (3-3) Irrigation pipe connection



Magnetized water
N
Magnetic water device
Magnetized seeds (Madani)
Non Magnetized seeds (Kosti)
Magnetized seeds (Kosti)
Non Magnetized seeds (Madani)
Non Magnetized water
Magnetized seeds (Kosti)
Non Magnetized seeds (Madani)
Magnetized seeds(Madani)
Non Magnetized seeds (Kosti)

Fig 3.1 Plan of split plot design

CHAPTER FOUR

RESULT AND DISCUSSION

The experimental results as presented in Tables (4-1), (4-2) and Appendix A are as follows:

4.1 Number of leaves per plant:

As shown in Table (4-1) it can well be observed that there was a significant difference ($p \leq 0.05$) in the number of leaves per plant when magnetized water was used (12.12 leaves /Plant) as compared to nonmagnetized water (7.85 leaves /Plant).

The same number of leaves per plant (12.12 leaves /Plant) was obtained when both magnetized and nonmagnetized seeds were irrigated by magnetized water.

From Table (4-1) it can also be observed that when nonmagnetized water was used there was a significant difference ($p \leq 0.05$) in the number of leaves per plant with magnetized seeds (14.97 leaves /plant) as compared to nonmagnetized seeds (7.85 leaves /plant).

Both okra varieties (Kosti and Madani) gave higher values of number of leaves per plant for the combination magnetized water and magnetized seeds, which are respectively (17.23 leaves /plant), (12.7 leaves /plant) as exhibited in Table (4-2).

4.2 Plant density:

The data given in Table (4-1) reflect a significant difference ($p \leq 0.05$) in plant density per m^2 for magnetized water (11.45 plants /m^2) as compared to 8 plants /m^2 for nonmagnetized water.

There is a significant difference ($p \leq 0.05$) in the plant density per m^2 when magnetized seeds were irrigated by magnetized water (12.8 plants /m^2) as compared to 11.45 plants/m^2 for nonmagnetized seeds when irrigated by magnetized water this is given in Table (4-1).

The data of Table (4-1) also reflect that when nonmagnetized water was used there was a significant difference ($p \leq 0.05$) in plant density per m^2 for magnetized seeds (11.48 plants /m^2) as compared to 8 plants/ m^2 for nonmagnetized seeds.

The combination of magnetized water and magnetized seeds gave higher plant density per m^2 for both okra varieties, they are (14.9 plants /m^2) for Kosti and (13.87 plants/m^2) for Madani (Table 4-2).

4.3 Plant length:

With reference to Table (4.1) it is noticeable that no significant difference ($p \leq 0.05$) in plant length when magnetized water was used (43.33 cm) as compared to nonmagnetized water (39.55cm).

Also it was found that when magnetized water was used there was no significant difference ($p \leq 0.05$) in plant length in magnetized seeds (48.45cm) as compared to nonmagnetized seeds (45.77cm) (Table 4-1).

Referring to Table (4-1) it was noticeable that when nonmagnetized water was used there was no significant difference ($p \leq 0.05$) in plant length in magnetized seeds (43.33 cm) as compared to none magnetized seeds (39.55 cm).

Furthermore, it was found that both okra varieties (Kosti and Madani) gave higher values of plant length for the combination magnetized water and magnetized seeds; they are (59cm) for Kosti and (57.1 cm) for Madani (Table 4-2).

4.4 Leaves length:

A significant difference ($p \leq 0.05$) in leaf length was obtained from magnetized water (8.05cm) as compared to (6.15cm) when nonmagnetized water was used (Table 4-1)

It was found that when magnetized water was used there was no significant difference ($p \leq 0.05$) in the leaf length of magnetized seeds (9.05cm) as compared to nonmagnetized seeds (8.05cm) (Table 4-1).

Referring to Table (4-1) it was a noticeable that when nonmagnetized water was used there was a significant difference ($p \leq 0.05$) in the leaf length of magnetized seeds (8.0 cm) as compared to nonmagnetized seeds (6.15 cm).

The combination of magnetized water and magnetized seeds gave in higher leaf length for both okra varieties, they are (9.2 cm) for Kosti and (8.9cm) for Madani (Table 4-2).

4.5 Yield:

There was a significant difference ($p \leq 0.05$) in yield when irrigated by magnetized water (14.8 Kg/ha) as compared to nonmagnetized water (7.4 Kg/ha).

A significant difference ($p \leq 0.05$) was also obtained when magnetized water was used with magnetized seeds (19.4Kg/ha) as compared to when magnetized water was used with nonmagnetized seeds (14.8 Kg/ha) (Table 4-1).

Table (4-1) also shows that nonmagnetized water gave a significant difference in the yield of magnetized seeds (9.0 Kg/ha) as compared to nonmagnetized seeds (7.4 Kg/ha).

The combination of magnetized water and magnetized seeds gave higher yield for both okra varieties, which are (25.5 Kg/ha) for Kosti and (35.5 Kg/ha) for Madani (Table 4-2).

Table 4.1 Analysis of the effects of magnetized and nonmagnetized water and seeds on crop production:

parameters	magnetized water		Nonmagnetized water		
	Mag. seeds	Nonmag. seeds	Mag. seeds	Nonmag. seeds	LSD
Numberof leaves/plant	a 12.12	a 12.12	a 14.97	b 7.85	2.88
Plant density (plants/m^2)	a 12.8	ab 11.45	ab 11.48	b 8.0	3.70
Plant height (cm)	a 48.45	a 45.77	a 43.33	a 39.55	12.07
Leaf length (cm)	a 9.05	a 8.05	a 8.0	b 6.15	1.49
Yield (Kg/ha)	a 19.4	b 14.8	c 9.0	d 7.4	1.38

Table 4.2 Mean comparison test:

CHAPTER FIVE

	magnetized water				Nonmagnetized water				
	Kosti		Madani		Kosti		Madani		
Parameters	Mag. seeds	Nonmag. seeds	Mag. seeds	Nonmag. seeds	Mag. Seeds	Nonmag. seeds	Mag. seeds	None mag. seed	LSD
Number of leaves/plant	a 17.23	bc 12.43	bc 12.7	de 9.9	b 14.33	ef 8.9	cd 11.8	f 6.8	2.14
Plant density (plants/m^2)	a 14.9	b 8.0	a 13.87	b 9.1	a 13.6	b 8.0	a 12.0	b 8.0	2.75
Plant length (cm)	a 59	d 37.9	ab 57.1	cd 39.8	ab 53.63	bc 47.9	de 31.2	e 27.67	8.97
Leaf length (cm)	a 9.2	bc 7.8	ab 8.9	c 7.1	ab 8.9	c 6.9	ab 8.3	d 5.4	1.11
Yield (Kg/ha)	b 25.5	e 4.3	a 35.5	c 13.9	e 4.2	f 2.5	d 10.6	ef 3.4	1.02

CONCLUSION AND RECOMMENDATIONS

From the results of this study the following conclusion and recommendations can be made:

- Magnetizing irrigation water can lead to better crop production and further improvement may be attained by magnetizing the seeds.

- The major problem associated with magnetization technology may be the high initial cost for the device and its requirement for special connecting accessories.

- Since the technology of magnetization has been newly introduced and it proves to have good potentialities in agricultural production further research studies are highly recommended in this area.

REFERENCES

Baker,J.S and. S.J Judd. (1996) Review paper, magnetic Amelioration of scale formation "water research, vol 30, No.2, PP247- 260.

Busch, K. W., M. A. Busch, R. E. Darling, S. Maggard, and S. W Kubala. (1997). Design of a test loop for the evaluation of magnetic water treatment devices. Process Safety and

Environmental Protection. Transactions of the Institution of Chemical Engineers 75 (Part B): 105-114. Russian

Bruns, S. A., V. I. Klassen, and A. K. Konshina. (1966). Change in the extinction of light by water after treatment in a magnetic field. Kolloidn. Zh. 28: 153-155.

Busch, K. W., M. A. Busch, D. H. Parker, R. E. Darling, and J. L. McAtee, Jr. (1986). Studies of a water treatment device that uses magnetic fields.Corrosion 42 (4): 211-221.

Chechel, P.S ., and G.V. Annenkova. (1972) Influence of magnetic treatment on solubility of calcium sulphate. coke chem... USSR, 8:60—61

Duffy, E. A. (1977). Investigation of Magnetic Water Treatment Devices. Ph. D. dissertation, Clemson University, Clemson, S.C.

ElNadi A. H, and E. M. Kheir. (1969). An appraisal of the meteorological approach for assessing evaporation under tropical conditions. Sudan Agric. J.4(2) : 38-47.

Ferguson, J. (1970). The rate of natural evaporation from shallow ponds. Aust. J. Sci. Res. (5) : 315—330.

Hasson, D., and D. Bramson. (1985). Effectiveness of magnetic water treatment in suppressing CaCO3 scale deposition. Ind. Eng. Chem. Process Des. Dev. 24: 588-592.

Joshi, K. M., and P. V. Kamat. (1966). Effect of magnetic field on the physical properties of water. J. Ind. Chem.Soc. 43: 620-622

Klassen, V. I. (1981). Magnetic treatment of water in mineral processing. In Developments in Mineral Processing, Part B, Mineral Processing. Elsevier, N.Y., pp. 1077-1097.

Kronenberg, K.J.1985.Experimental evidenece for effects of magnetic fields on moving water.IEEE Trans. on magnetics, Vol. mag-21, no 5: 2059-2061.

Liburkin, V.G.B. S. Kondrateve, and T.S. Pavlyukova.(1986).Action magnetic treatment of water on the structure formation of gypsum. glass and ceramics (English translation of steklo Ikeramika) 1:101-105, Russian.

Lin, I., and Y. Yotvat. (1989). Electro-magnetic treatment of drinking Water on the structure formation of gypsum. Glass and Ceramics (English translation of steklo Ikeramika) 1: 101-105 Russian.

Lipus, L., J. Krope, and L. Garbai. (1994). Magnetic water treatment for scale prevention. Hungarian J. Ind. Chem. 22: 239-242.

Martynova, O.I., E. F. Tebenekhin, and B.T. Gusev.(1967).Conditions and mechanism of deposition of the solid calcium carbonate phase from Aqueous(sic) solutions under the influence of a magnetic field. Colloid J.USSR 29:512-514.

Mike R. P. (1998) Magnetic Water and Fuel Treatment : Myth, Magic or Mainstream Science?. Skeptical Inquirer Magazine.

Mirumyants, S. O., E. A. Vandyukov, and R. S. Tukhvatullin (1972). The effect of a constant magnetic field on the infrared absorption spectrum of liquid water. Russ. J. Phys. Chem. 46: 124.

Oliver, J. (1965). The climate of Khartoum province Sudan Notes and Records. 46: 90- 129.

Parsons, S. (1999).Overview of Recent Magnetic Treatment esearch at Cranfield University," in MAG3, 3rd Symposiuon Anti- Scale Magnetic Water and physical Conditioning The School of water Sciences, Cranfield University, ranfield Bedford shire, UK.

Raisen, E. (1984). The control of scale and corrosion in water systems using magnetic fields.Corrosion 84.Conference proceedings, Nat. Assoc. of Corrosion Engineers, Houston, paper no. 117.

Saeed, A. M. (1968). Some physical and chemical properties of Certain Shambat soil. Unpublished M.Sc. Thesis University, of Khartoum.

Sudan Metrological Department (1980). Annual Report (1951-1980) Shambat Metrological station, Sudan.

Tkatchenko, Y . P. (1997). Practical magnetic technologies in agriculture-Dubai, U.A.E

Welder, B. Q., and E. P. Partridge. (1954). Practical performance of

Water-conditioning gadgets. Ind. Eng. Chem. 46: 954-960. Russian.

Wilkes, J. F., and R. Baum. (1979). Water conditioning devices - an update. Int. Water Conf.: 40th Annual Meeting, paper no. IWC-79-20. Russian.

APENDEX 1

```
    Data file:  _AWAD_
      Title:      mag
      Function: FACTOR

      Experiment Model Number 5:
           Completely Randomized Design for
Factors A and B, Factor
           C is a Split Plot on A and B
      Data case no. 1 to 24.

      Factorial ANOVA for the factors:
           Replication (Var 7: rep) with values
from 1 to 3
           Factor A (Var 1: w1) with values from 1
to 2
           Factor B (Var 3: v1) with values from 1
to 2
           Factor C (Var 2: wm) with values from 1
to 2

      Variable 8: le/h
```

Grand Mean = 7.813   Grand Sum = 187.500
Total Count = 24

ANALYSIS OF VARIANCE TABLE

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	1	1.084	1.084	0.8920	
4	Factor B	1	13.054	13.054	10.7438	0.0112
6	AB	1	12.184	12.184	10.0278	0.0133
-7	Error	8	9.720	1.215		
8	Factor C	1	3.604	3.604	10.6778	0.0114
10	AC	1	0.094	0.094	0.2778	
12	BC	1	4.594	4.594	13.6111	0.0061
14	ABC	1	0.454	0.454	1.3444	0.2797
-15	Error	8	2.700	0.338		
	Total	23	47.486			

Coefficient of Variation: 7.44%

Variable 9: pl/h

Grand Mean = 44.275   Grand Sum = 1062.600
Total Count = 24

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	1	192.667	192.667	5.4386	0.0480
4	Factor B	1	62.727	62.727	1.7706	0.2200
6	AB	1	1.815	1.815	0.0512	
-7	Error	8	283.407	35.426		
8	Factor C	1	2464.427	2464.427	114.2613	0.0000
10	AC	1	84.375	84.375	3.9120	0.0833
12	BC	1	98.415	98.415	4.5629	0.0652
14	ABC	1	64.027	64.027	2.9686	0.1232
-15	Error	8	172.547	21.568		
	Total	23	3424.405			

Coefficient of Variation: 10.49%

==

Variable 10: pl/h

Grand Mean = 10.933   Grand Sum = 262.400   Total Count = 24

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	1	6.827	6.827	2.4487	0.1563
4	Factor B	1	35.042	35.042	12.5691	0.0076
6	AB	1	34.082	34.082	12.2248	0.0081
-7	Error	8	22.303	2.788		
8	Factor C	1	5.227	5.227	2.5774	0.1471
10	AC	1	0.107	0.107	0.0526	
12	BC	1	38.002	38.002	18.7393	0.0025
14	ABC	1	66.002	66.002	32.5465	0.0005
-15	Error	8	16.223	2.028		
	Total	23	223.813			

Coefficient of Variation: 13.02%

Variable 11: pl/d

Grand Mean = 215.058 Grand Sum = 5161.400 Total Count = 24

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob

```
-------------------------------------------------
---------------------------
  2     Factor A         1    140301.043
140301.043    833.1166   0.0000
  4     Factor B         1      3896.402
3896.402     23.1371   0.0013
  6     AB               1     16632.135
16632.135     98.7627   0.0000
 -7     Error            8      1347.240
168.405
  8     Factor C         1    579642.006
579642.006   7062.1985   0.0000
 10     AC               1    125368.219
125368.219   1527.4518   0.0000
 12     BC               1      2064.615
2064.615     25.1547   0.0010
 14     ABC              1     32017.816
32017.816    390.0963   0.0000
-15     Error            8       656.614
82.077
-------------------------------------------------
---------------------------
        Total           23    901926.091
-------------------------------------------------
---------------------------
     Coefficient of Variation: 4.21%
=================================================
============================
     Variable 13: le/N

     Grand Mean = 11.762   Grand Sum = 282.300
Total Count = 24
          A N A L Y S I S   O F   V A R I A N C E
T A B L E

  K                 Degrees of   Sum of
Mean          F
Value    Source       Freedom    Squares
Square       Value     Prob
-------------------------------------------------
---------------------------
  2     Factor A         1         3.010
3.010      1.2589   0.2944
```

```
  4     Factor B          1        75.970
75.970     31.7702   0.0005
  6     AB                1        75.970
75.970     31.7702   0.0005
 -7     Error             8        19.130
2.391
  8     Factor C          1        51.334
51.334     41.6924   0.0002
 10     AC                1         0.920
0.920      0.7475
 12     BC                1        14.570
14.570     11.8338   0.0088
 14     ABC               1         0.700
0.700      0.5689
-15     Error             8         9.850
1.231
-------------------------------------------------
----------------------------
        Total            23       251.456
-------------------------------------------------
----------------------------
     Coefficient of Variation: 9.43%

_Data File : _AWAD_
Title : mag
Case Range : 33 - 36
Variable 8 : le/h
Function : _RANGE_
Error Mean Square = 0.3300
Error Degrees of Freedom = 3
No. of observations to calculate a mean = 3

Duncan's Multiple Range Test
LSD value = 1.493
s_ = 0.3317     at alpha = 0.050
 x
_
     Original Order               Ranked Order

 Mean    1 =    9.050  A     Mean    1 =    9.050
A
 Mean    2 =    6.150   B    Mean    3 =    8.050
A
```

Mean 3 = 8.050 A Mean 4 = 8.000
A
Mean 4 = 8.000 A Mean 2 = 6.150
B

Data File : _AWAD_
Title : mag
Case Range : 55 - 62
Variable 8 : le/h
Function : _RANGE_
Error Mean Square = 0.3300
Error Degrees of Freedom = 7
No. of observations to calculate a mean = 3

Duncan's Multiple Range Test
LSD value = 1.109
s_ = 0.3317 at alpha = 0.050
x
_

Original Order			Ranked Order		
Mean 1 =	8.900	AB	Mean 2 =	9.200	A
Mean 2 =	9.200	A	Mean 1 =	8.900	AB
Mean 3 =	5.400	D	Mean 8 =	8.900	AB
Mean 4 =	6.900	C	Mean 5 =	8.300	AB
Mean 5 =	8.300	AB	Mean 6 =	7.800	BC
Mean 6 =	7.800	BC	Mean 7 =	7.100	C
Mean 7 =	7.100	C	Mean 4 =	6.900	C
Mean 8 =	8.900	AB	Mean 3 =	5.400	D

__
Data File : _AWAD_
Title : mag
Case Range : 33 - 36
Variable 9 : pl/h
Function : _RANGE_
Error Mean Square = 21.56

Error Degrees of Freedom = 3
No. of observations to calculate a mean = 3

Duncan's Multiple Range Test
LSD value = 12.07
s_ = 2.681 at alpha = 0.050
x
_
Original Order Ranked Order

Mean 1 = 43.33 A Mean 3 = 48.45
A
Mean 2 = 39.55 A Mean 4 = 45.77
A
Mean 3 = 48.45 A Mean 1 = 43.33
A
Mean 4 = 45.77 A Mean 2 = 39.55
A
__
Data File : _AWAD_
Title : mag
Case Range : 55 - 62
Variable 9 : pl/h
Function : _RANGE_
Error Mean Square = 21.56
Error Degrees of Freedom = 7
No. of observations to calculate a mean = 3

Duncan's Multiple Range Test
LSD value = 8.965
s_ = 2.681 at alpha = 0.050
x
_
Original Order Ranked
Order

Mean 1 = 27.67 E Mean 2 =
59.00 A
Mean 2 = 59.00 A Mean 6 =
57.10 AB
Mean 3 = 31.20 DE Mean 8 =
53.63 AB
Mean 4 = 47.90 BC Mean 4 =
47.90 BC

Mean 5 = 39.80 CD Mean 5 =
39.80 CD
Mean 6 = 57.10 AB Mean 7 =
37.90 D
Mean 7 = 37.90 D Mean 3 =
31.20 DE
Mean 8 = 53.63 AB Mean 1 =
27.67 E

__
Data File : _AWAD_
Title : mag
Case Range : 33 - 36
Variable 10 : pl/h
Function : _RANGE_
Error Mean Square = 2.028
Error Degrees of Freedom = 3
No. of observations to calculate a mean = 3

Duncan's Multiple Range Test
LSD value = 3.700
s_ = 0.8222 at alpha = 0.050
x
_
Original Order Ranked Order

Mean 1 = 12.80 A Mean 1 = 12.80
A
Mean 2 = 8.000 B Mean 3 = 11.48
AB
Mean 3 = 11.48 AB Mean 4 = 11.45
AB
Mean 4 = 11.45 AB Mean 2 = 8.000
B

__
Data File : _AWAD_
Title : mag
Case Range : 55 - 62
Variable 10 : pl/h
Function : _RANGE_
Error Mean Square = 2.028
Error Degrees of Freedom = 7
No. of observations to calculate a mean = 3
Duncan's Multiple Range Test
LSD value = 2.749

```
s_ = 0.8222     at alpha = 0.050
 x
_
     Original Order                Ranked Order

 Mean    1 =    12.00  A     Mean    8 =    14.90
A
 Mean    2 =    13.60  A     Mean    5 =    13.87
A
 Mean    3 =    8.000   B    Mean    2 =    13.60
A
 Mean    4 =    8.000   B    Mean    1 =    12.00
A
 Mean    5 =    13.87  A     Mean    6 =    9.100
B
 Mean    6 =    9.100   B    Mean    3 =    8.000
B
 Mean    7 =    8.000   B    Mean    7 =    8.000
B
 Mean    8 =    14.90  A     Mean    4 =    8.000
B
__
Data File : _AWAD_
Title : mag
Case Range : 33 - 36
Variable 11 : pl/d
Function : _RANGE_
Error Mean Square = 82.08
Error Degrees of Freedom = 3
No. of observations to calculate a mean = 3
Duncan's Multiple Range Test
LSD value = 23.54
s_ = 5.231      at alpha = 0.050
 x
_
      Original Order                Ranked Order

 Mean    1 =    125.0     D    Mean    3 =
330.6  A
 Mean    2 =    152.2    C     Mean    4 =
252.4   B
 Mean    3 =    330.6  A       Mean    2 =
152.2    C
```

Mean 4 = 252.4 B Mean 1 =
125.0 D
__
Data File : _AWAD_
Title : mag
Case Range : 55 - 62
Variable 11 : pl/d
Function : _RANGE_
Error Mean Square = 82.08
Error Degrees of Freedom = 7
No. of observations to calculate a mean = 3

Duncan's Multiple Range Test
LSD value = 17.49
s_ = 5.231 at alpha = 0.050
x
_
Original Order Ranked
Order

Mean 1 = 180.9 D Mean 5 =
604.1 A
Mean 2 = 69.13 E Mean 7 =
434.3 B
Mean 3 = 262.6 C Mean 3 =
262.6 C
Mean 4 = 41.80 F Mean 1 =
180.9 D
Mean 5 = 604.1 A Mean 8 =
70.57 E
Mean 6 = 57.10 EF Mean 2 =
69.13 E
Mean 7 = 434.3 B Mean 6 =
57.10 EF
Mean 8 = 70.57 E Mean 4 =
41.80 F
__
Data File : _AWAD_
Title : mag
Case Range : 80 - 83
Variable 13 : le/N
Function : _RANGE_
Error Mean Square = 1.231
Error Degrees of Freedom = 3

```
No. of observations to calculate a mean = 3
Duncan's Multiple Range Test
LSD value = 2.883
s_ = 0.6406     at alpha = 0.050
 x
_
     Original Order               Ranked Order

 Mean    1 =    14.97  A     Mean    1 =    14.97
A
 Mean    2 =    7.850   B    Mean    4 =    12.12
A
 Mean    3 =    12.12  A     Mean    3 =    12.12
A
 Mean    4 =    12.12  A     Mean    2 =    7.850
B
__
Data File : _AWAD_
Title : mag
Case Range : 102 - 109
Variable 13 : le/N
Function : _RANGE_
Error Mean Square = 1.231
Error Degrees of Freedom = 7
No. of observations to calculate a mean = 3
Duncan's Multiple Range Test
LSD value = 2.142
s_ = 0.6406     at alpha = 0.050
 x
_
       Original Order                 Ranked
Order

 Mean    1 =    12.70   BC       Mean    2 =
17.23  A
 Mean    2 =    17.23  A         Mean    6 =
14.33   B
 Mean    3 =    6.800       F    Mean    1 =
12.70   BC
 Mean    4 =    8.900      EF    Mean    8 =
12.43   BC
 Mean    5 =    9.900     DE     Mean    7 =
11.80    CD
```

Mean 6 = 14.33 B Mean 5 = 9.900 DE
Mean 7 = 11.80 CD Mean 4 = 8.900 EF
Mean 8 = 12.43 BC Mean 3 = 6.800 F

Data file : _AWAD_
Title : mag
Function : STAT
Data case no. 1 to 24

Variable Number	No. of Cases	Minimum	Maximum	Sum
le/h 8	24	5.000	11.200	187.500
pl/h 9	24	25.200	62.900	1062.600
pl/h 10	24	7.000	16.900	262.400
pl/d 11	24	37.600	609.500	5161.400
le/N 13	24	5.400	19.000	282.300

Variable Number	Mean	Variance	Standard Deviation	Standard Error

8	7.813	2.065	1.437	0.293
9	44.275	148.887	12.202	2.491
10	10.933	9.731	3.119	0.637
11	215.058	39214.178	198.026	40.422
13	11.762	10.933	3.306	0.675
