EFFECTS OF DEFICIT IRRIGATION ON GROWTH PARAMETERS AND YIELD OF ORGANIC AND INORGANIC FERTILIZED DRY BEANS (*Phaseolus Vulgaris L*).

A Research Project Submitted in Partial Fulfilment of a Bachelor of Science Degree in Natural Resources Management and Agriculture.

By

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DECLARATION

I, KHUMALO MTHABISI (R132675G), a student for the degree Bachelor of Science (Hons) in Land and Water Resources Management do hereby declare that this thesis has been produced from my original efforts and investigations to the best of my knowledge, such work have not been submitted to any institution. This thesis has been submitted for examination with my approval.

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(Supervisor)	Signature	Date

DEDICATION

Praise the Lord, O give thanks unto the Lord; for He is good: His mercy endureth forever. Through His Son Jesus all things were made and perfected for nothing is impossible with God. To My ever caring parents Mr and Mrs M.D Khumalo, the Khumalo family and my siblings who have encouraged and supported me always.

ABSTRACT

Organic manure supply to soil with inorganic or on its own is good soil management practice improving crop quality and overall soil fertility. Increasing water demand on many sectors and evident reduction of water allocated to agriculture is of importance prompting exploration of the more efficient water use techniques to maximise production. Local small holder communal farmers are faced by challenges of lack of access to inorganic fertilizers due to economic constrain and lack of capital hence they usually utilise the farm yard manure as a nutrient source for their crops. The study intends to evaluate the effects of organic and inorganic fertilizer with water deficit of 20%, 30% and a control with full irrigation on the bean (*Phaseolus vulgaris L*) crop production (germination, growth parameters and yield component). Six treatments replicated four times were used on the trial. The field experiment was carried out at Midlands State University experimental field from August to November 20l6. Cattle manure was used as organic manure at rate of 24 tonnes/ha on planting and inorganic fertilizer was supplied in split application of compound D at 300kg/ha rate on planting and top dressing ammonium nitrate (34.5% N) at rate of l50kg/ha. The parameters measured in the investigation are germination rate, plant height, and leaf area, number of days taken to flower, pod development and yield. The results shows that 30% water deficit retarded crop development, caused poor flowering and pod development for both organic and inorganic fertilized treatments. Using the yield coefficient (k_y) method proposed by Darenbos and Kassim (l979), it was observed that at peak water stress (30% water deficit) high value of k_y (l.l4) and very low yields were attained. At the same growth stage low value of k_y (0.07) were obtained with relatively high yield for full irrigation and 20% water deficit treatments, thus farmers can use water deficit of 20% under water shortages and shun the 30% water deficit as it produced very low yields on both organic and inorganic treatments. Full water irrigation and 20% deficit had no significant different yield outcome, which brings us to the conclusion that any of the two nutrients supplicants can be utilized with 20% water deficit where water is limiting and full irrigation where there are no shortages.

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LIST OF ACRONYMS

ET_o	Reference evapotranspiration
ET_c	Actual evapotranspiration
FAO	Food and Agriculture Organisation of United Nations
K	Potassium
k_c	Crop growth coefficient
k_y	Yield coefficient
lsd	least Significant Difference
N	Nitrogen
P	Phosphorus
SOM	Soil organic matter
TPS	Triple Super Phosphates
USDA	United states department of agriculture
WUE	Water Use Efficiency
WP	Water Productivity

CHAPTER l INTRODUCTION

1.1 Background

Scarcity of water resources and growing competition for water is reducing its availability for irrigation. Among the environmental factors that can be modified by farmers, water and nitrogen are the main ones controlling plant growth. Irrigation and fertilizer application overcome this effect, if adequately used and agriculture thus consumes about 85% of the total fresh water used worldwide (Gonzalez-Dugo et al., 2009). At the same time, the need to meet the growing demand for food will require increased crop production from as little water as possible. Achieving greater efficiency of water use will be a primary challenge for the near future and will include the employment of techniques and practices that deliver a more accurate supply of water to crops. In this context, deficit irrigation can play an important role in increasing the water use efficiency (WUE).

The swelling growth rate of the world population, coupled with climate change and decline in production resources, are encouraging stimuli for the promotion of sustainable crop production in current and future farming systems. Sustainable agriculture, especially organic agriculture, is a low input system that implies the efficient use of biological resources. Water and nutrients are the most important factors during plant growth and development. Deficit irrigation and use of biological manures are the critical components to crop production in sustainable farming structures. Agronomic measures such as varying tillage practices, mulching and anti-transpirants can reduce the demand for irrigation water. Another option is deficit irrigation, with plants exposed to certain levels of water stress during either a particular growth period or throughout the whole growth season, achieving no significant reduction in yields (Kirda, 2002. An unmistakable pattern exists towards diets that incorporate more creature items, for example, fish, meat and dairy items, which thus expands the interest for nourish grains (FAO, 2007).

Deficit irrigation (DI) has been broadly researched as a significant and reasonable crop generation procedure in dry districts. By constraining water applications to dry season development organizes, this practice expects to expand water efficiency and to balance out as opposed to boost yields.

The three main farming systems in Zimbabwe include smallholder farms (communal area, old resettlement and Al-model households), medium scale farms (old small-scale commercial and A2-model farms) and large scale commercial farms, conservancies and estates (Rukuni, l994).The small holder farmers supply the most products on the markets in comparison to the other systems in Zimbabwe. Most small holder farmers face challenges of the capital for their inputs.

lamaddalena et al. (2005) reported that, in the agricultural sector, the water-use efficiency (WUE) term has been widely in use since the middle of sixties when Viets (l962) introduced it in his article on ‘Fertilizers and the efficient use of water’. Since that time, the WUE term has become a common tool to describe, at different scales, the relationship between the crop growth development and the amount of water used. For instance, at the leaf scale, the plant physiologists utilized the Photosynthetic Water-Use Efficiency alluding to the proportion of net osmosis to transpiration; at the plant scale, the agronomists utilized both biomass and yield WUE showing the proportion between the biomass and product transpiration, and yield and harvest transpiration. Nonetheless, in every one of these cases, the WUE terms were not non-dimensional qualities. Actually, they portrayed the procedures in which water is devoured and/or used to deliver new elements like biomass and yield, demonstrating the amount created per surface zone from the unit measure of water. Hence, a few options have been proposed as of late to change over these WUE terms into other, more fitting terms. Pascale et al. (20ll) in there research forwarded that with agriculture striving to increase crop yield while relying on a critical resource that is gradually diminishing, the need to increase WUE becomes progressively more crucial. Little success has been obtained so far through genetic approaches to modify complex traits such as transpiration efficiency. This is partly due to our limited understanding of the molecular basis and physiological mechanisms regulating WUE in stressed and non-stressed plants. Targeted agronomic practices such as the choice of appropriate crop/cultivar for a specific environment as well as planting and harvesting times, adequate plant nutrition, soil management, and weed control can significantly contribute to improve WUE (Pascale et al., 20ll).

Raising water system water proficiency regularly implies moving from the less proficient surge or wrinkle framework to overhead sprinklers or dribble water system, the highest quality level of water system productivity. Changing from surge or wrinkle to low weight sprinkler frameworks diminishes water use by an expected 30%, while changing to trickle water system regularly slices dilute utilize the middle (Perry et al., 2009)

Dry beans (Phaseolus vulgaris) basic name spotted sugar beans are usually developed in Zimbabwe, its seed is sold in the vast majority of the seed wholesalers dry beans started in Central and South America, inside the class Phaseolus which are agronomically critical, the dry bean is at present viewed as a standout amongst the most vital field edits in by virtue of its high protein substance and dietary advantages (Department of Agriculture, Forestry and Fisheries, 20l0). According to the exploration directed by FAO (2007) in Africa it was watched that one and only fifth of the small holder farmers utilizes inorganic compost because of numerous reason consequently this perception propose that a more prominent division of the smallholder farmers are utilizing the natural compost to renew the manure supplements to meet the plant supplement prerequisite to give the nourishment to the family in this manner it is of significance to consider the relative impacts of the customary excrement in our neighborhood conditions and how they influence the water utilizations to secure our water resource also.

Palm and Myers (l997) express that given the high cost and indeterminate openness of inorganic composts in Africa, the objective ought to give however much of the supplements as could be expected through natural materials, making up the deficiency of the constraining supplements through organic manures. These objectives would change as inorganic composts turned out to be more accessible. The valuable impacts of the joined utilization of natural and inorganic supplements on soil richness, trim yields, and support of soil natural matter (SOM) have been over and over appeared in field trials, yet there are no prescient rules for their administration, for example, those that exist for inorganic composts (Palm and myers, l997).

Sanchez et al. (l997) concluded from their research that combinations of P (phosphorus) fertilizers and organic inputs can replenish soil nutrient stocks in Africa and restore service flows approaching their original levels. Such restoration is in essence a long-term investment in the rebuilding of a country's stock of natural capital.

The International Atomic Energy agency in a research (Keerthisinghe and Heng, 2005) conducted on 2005 in Austria, argues that despite any challenges faced in the agricultural division in most parts of the world there is potential in increasing crop production in rain-fed agriculture to sustain food production, if rainwater, crop and soil fertility can be managed properly and if socio-economic constraints can be overcome, their research indicated that low soil fertility and drought are the main factors affecting the productivity and sustainability of rain-fed agriculture. In a bid to improve crop productivity in drought-prone areas the active key players like the farmers, extension workers, researchers, and policy makers need to identify best-suited management options to optimize the use of natural resources readily available on their respectable areas. They also need to simulate models that can provide valuable information to researchers and farmers to evaluate a wide range of cropping system options which are crop rotations and intercropping; planting dates, fertilizer-management practices and examine the long term climatic risks on their respective areas.

1.2 Problem statement

Considering the increase in municipal and industrial demands for water, its allocation for agriculture is constantly decreasing. The major agricultural use of water is for irrigation which is affected by decreased supply. Therefore, innovations are needed to increase the efficiency of use of the water that is available. It is necessary to develop new irrigation scheduling approaches, not necessarily based on full crop water requirement, but ones designed to ensure the optimal use of allocated water. Due to the evident wide use of organic fertilizer by the communal smallholder farmers because of their availability. Statistical small holder farmers supply most of the local market with agricultural products, hence need to specifically scrutinize the relationship between the water consumption and the fertilizer mostly utilized on crops in the local sphere which are organic fertilizers to ensure adequate food for the country and economic development.

1.3 Justification of the study

Molden et al. (2003) estimated that by 2020 approximately 75% of the world's population will live in areas experiencing physical or economic water scarcity. In a setting where water shortage will surely rise as the key limitation to agricultural crop production, there is a need to accomplish a significantly more proficient and gainful utilization of water in product water utilisation. Tending to this need, nonetheless, requires a superior insight of water balances within irrigation projects.

The competition for freshwater often implies that water for irrigation is not always available in the required quantity and/or quality (FAO, 2002). Therefore, farmers often have to manage irrigation under moderate or severe water shortage maximizing crop yield. Thus the need to have maximum efficiency in the management of water on irrigation as it is not the only industry to utilize the resource. Efficiency has been defined as the ability to produce the desired effect with the minimum effort, expenses, and waste (Jensen, 2007). If the efficiency of the irrigation is high thus there will be good water productivity as a result.

When water supplies are limiting, the farmer's goal should be to maximize net income per unit water used rather than per land unit. Recently, emphasis has been placed on the concept of water productivity (WP), defined here either as the yield or net income per unit of water used in ET (Kijne et al., 2003).

Scarcity of water is the most critical constraint for the development of agriculture in arid and semi-arid climates. Hence, effective use of available water has significant agricultural implication. Deficit irrigation is becoming an important strategy to optimize agricultural water use in arid and semiarid regions. This needs testing under specific condition for a given crop. (Ambachew and Alamirew, 20ll)

Dry beans (Phaseolus vulgaris l) is delivered in many parts of the world and in the study it is of interest since it goes about as a rotational crop to most farmers and it have many uses to the one growing it as a cash crop. It is a high protein value and an income attracting crop. It can also unlock some deep nutrients as its roots run deeper than other crops grown. It also acts as a weeds control, ailment break and pest cycle break in monoculture systems as a rotational crop. After quantifying the effects of the induced irrigation factors best practices can be defined and utilized in the water management and best options can be practiced on local basis.

Very little research have been done locally on combination of deficit irrigation and organic manure on beans production.

1.4 Main Objective

To assess the effects of deficit irrigation on organic and inorganic fertilized dry beans development and yields.

Specific objectives

- To compare germination rates of dry beans under organic and inorganic fertilizer
- To compare the crop growth rate of organic and inorganic fertilized dry beans under deficit irrigation of 20% and 30%
- To determine the effects of applying 20% and 30% deficit irrigation on the yield of organic and inorganic fertilized beans.

1.5 Hypothesis testing

H_0 germination rates for organic and inorganic fertilized beans are equal

H_l germination rates for organic and inorganic fertilized beans are significantly different

H_0 crop growth rate of beans treated with 20% and 30% deficit irrigation under organic and inorganic fertilizers are equal

H_l crop growth rate of beans treated with 20% and 30% deficit irrigation under organic and inorganic fertilizers are different

H_0 yield for organic and inorganic fertilized beans under 20% and 30% deficit irrigation are equal

H_l yield for organic and inorganic fertilized beans under 20% and 30% deficit irrigation are equal

1.6 limitations of the study

The study was carried out only on one season a more reliable results can be achieved if the study is repeated out on a number of seasons.

The cumulative effects of both the organic and inorganic fertilizers could not be observed as the experiment did not last for more than one season thus further research on the fertilizer cumulative effects on soil and plant relations will be necessary for decisive results.

The research focused on the individual fertilizers (cattle manure) while the small holder farmers can use other organic manures (poultry, composts, piggery waste), or combination of both or interchange them on different field on seasonal basis thus combined effects of these should also be studied.

Lack of on-field moisture measuring equipment causing the accuracy of soil moisture changes assessment difficulty, and poor irrigation scheduling.

CHAPTER 2: LITERATURE REVIEW

2.1 Deficit irrigation (DI)

Deficit irrigation is a term for the practice of regulating or restricting the application of irrigation water limiting the crop water use to below that of a fully watered crop.

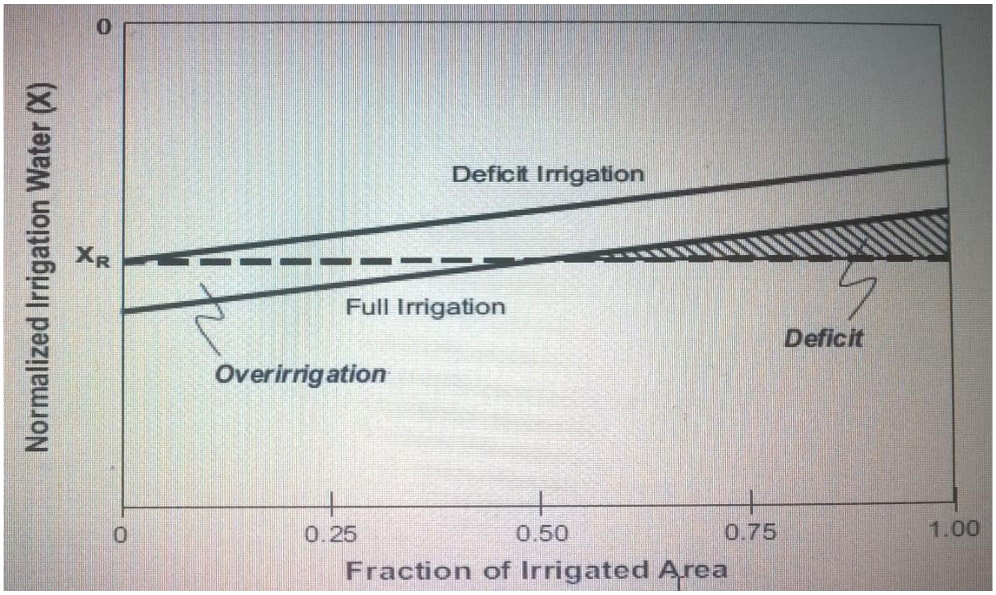

Figure 2.l deficit irrigation (Source: Fereres and Soriano, 2007)

The figure above illustrates the deficit irrigation in relation to irrigation on the field. XR is the required water application for crop growth.

Deficit irrigation was researched on for very long time now, Fitzgerald and Richard (l960) compared the Thornthwarte (l948) and Penmann (l948) methods on estimating soil moisture deficits on irrigation and they highlight that the only reliable way of measuring soil-moisture deficits is by the tedious routine of sampling, weighing, drying, and reweighing-the gravimetric method. In his research on irrigation scheduling Trout (2009) argues that despite the scientific availment of the irrigation scheduling techniques over 30 years, they are not widely practiced actually in the field. This can be due to complex reasons which can encircle the general complexity of its implication, the time required, and lack of confidence in the predictions and calculation of the water amounts. Widely utilized primary approaches for monitoring the crops and their water relations currently are soil water monitoring, plant stress monitoring, and weather-based water use predictions. Soil water monitoring techniques have proven to either labor intensive or equipment intensive. Technological developments have provided the public with a number of automatic sensors of late, most of which possesses a number of short-falls. The methods that seem to be more reliable have proven to be more expensive or labor intensive. Soil water monitoring is tedious as a primary monitoring technique, but valuable as a periodic check on other methods under use. Plant stress based techniques are not yet well established for most of the widely grown most crops, although with the growing use of remote sensing methods in agriculture we manage to have enhanced knowledge of the crop moisture stress. Weather-based irrigation scheduling remains the most common and practical method. Direct estimation of water use by a crop using surface energy balance techniques have proven to be too complex for most researchers. The most common and widely used technique in estimation of the crop water use and schedule irrigations is the traditional use of reference evapotranspiration, ETo, calculated from local weather parameters, and a crop coefficient, based on crop and stage of growth.

Recently it has been made clear that maintenance of a moderate plant water deficit can improve the partitioning of carbohydrate to reproductive structures such as fruit and also control excessive vegetative growth (Chalmers et al., l98l in Prichard et al), and this came to the widely known deficit irrigation worldwide.

Deficit (or regulated deficit) irrigation is one way of maximizing water use efficiency (WUE) for higher yields per unit of irrigation water applied, the crop under experimentation is exposed to a different level of water stress either during a particular growth period or throughout the whole growing season. The expectation is that any yield reduction will be insignificant compared with the benefits gained through diverting the saved water to irrigate other crops (FAO, 2002). Deficit irrigation (DI) is a term for the act of controlling or confining the use of water system water restricting the plant water use to somewhat beneath that of a completely watered plant. By confining water system water volumes, soil water accessible to the plant gets to be constrained to a level where transpiration surpasses water absorption. It is now that the plant starts to experience a water deficit.

The main objective of deficit irrigation is to increase the WUE of a crop by eliminating irrigation that have little impact on the crop yield. The resulting yield decrease may be small compared with the benefits gained through diverting the saved water to irrigate other crops for which water would normally be insufficient under traditional irrigation practices (Kirda, 2002). Efficient water use is defined as the ratio between the actual volume of water used for a specific purpose and the volume extracted or derived from a supply source for that same purpose. Efficiency is a dimensionless ratio and its hypothetical limits are between 0 and l, or between 0 and l00 if expressed as a percentage. Heydari (20l4), indicated that WP(water productivity) is different from WUE as WP refers to crop production in relation to total water consumed while the WUE is a dimensionless ratio of total amount of water used to the total amount of water applied.

Richards et al. (2002) indicate that crop water use efficiency (WUE) can be increased either by enhancing crop transpiration or by plant breeding to produce greater biomass (CO_2 assimilation) and yield per unit of water used(kg/cm3). In situations where water conservation is necessary or is the limiting factor to production it is required to increase WUE, decreasing the applied water volume without affecting crop yield, particularly in water-scarce regions. Optimum irrigation scheduling based on water use patterns and crop response to water deficit can hypothetically improve water use efficiency (Amer et al., 2009). Pescale et al. (20ll) argues that to capitalize on WUE it is necessary to conserve water and to promote utmost crop growth. The former requires minimizing losses through runoff, seepage, evaporation, and transpiration by weeds. The latter objective may be accomplished by planting high-yielding crops/cultivars well adapted to local soil and climatic conditions. Optimizing growing conditions by proper timing of planting and harvesting, tillage, fertilization, and pest control also contribute to improve crop growth. They further add that WUE should be a shift from full advantage of productivity per unit of land area to maximizing productivity per unit of water consumed

2.2 Beans

On June 20l6 the Ministry of Agriculture, Mechanization and Irrigation development publicly encouraged the growth of beans in Zimbabwe not only as a cash crop but due to its various advantages like, less cost of production in comparison to other cash crops produced and as the rich protein, calories, fibers and minerals source. Katsaruware and Gwembire (20l4) argues that the most crucial limitation of the production of beans in Zimbabwe is the lack of the inorganic adequate fertilizers, thus most small scale communal farmers utilize the organic fertilizers for meeting plant nutrient requirement needs. Most region in the country have conditions favorable for the production of the crop.

Beans are found in a number of genera under the leguminosae family. The most prominently cultivated of these are the genera Phaseolus, Vigna, Vicia, and Glycine. The growth of the beans species greatly vary relating to the different number of species widely classified under the genus stated. The Dwarf or bush beans are mostly grown in many gardens due to convenience, short period of development and being edible even when green that is before fully matured to be harvested unlike other beans type. (Allaire and Brady, 20l0). The beans and bean items have been the eating routine staples around the world. All through history, their development and protection around the globe has regularly implied the distinction. Beans are broadly developed as winter annuals in calm districts accepting precipitation of around 450 - 500 millimetres yearly. Beans are normal for a warm-season yearly harvest and prosper in an assortment of soil sorts. Regular bean develops well in zones with medium precipitation, however the product is not suited to the damp, wet tropics. Over the top rain and hot climate cause bloom and case drop and increment the rate of illnesses. Ideal mean day by day temperatures go somewhere around l5 and 20°C. The base mean day by day temperature for development is l0°C, the greatest 27°C. High temperatures increment the fiber in the case. Germination requires a soil temperature of l5°C or more, and at l8°C germination takes around l2 days, and at 25°C around 7 days. Most bean varieties are not affected, by day-length. The length of the total growing period varies with the use of the product and is 60 to 90 days for green bean and 90 to l20 days for dry bean (FAO, 20l5). The field bush beans also do best in well-drained soils with a pH between 6.0 and 7.5. They need about 95 days to reach maturity in frost free conditions. The crop planting dates can vary from early April to early July but can vary due to geographic location and the threat of frost in the region where it is grown. Field bean crops require an added plant nutrients that is source of phosphorus, potassium and zinc as fertilizer for best growth result and bumper harvest at the end of the season (Morris, 2003)

Legumes are devoured by people in a few structures. In spite of the fact that the word bean appears to suggest the real seeds of the bean plant, one can likewise eat the whole bean pod if picked before the pods are completely aged and dry out. The real seeds found inside the cases can likewise be consumed cooked or crude, dried or bubbled, ground into flour, or utilized as flavors or fixings. They deliver important sources of oil, fiber, protein-rich food and feed while supplying nitrogen (N) to agro-ecosystems via their unique ability to fix atmospheric N_2 in symbiosis with the soil bacteria rhizobia, increasing soil carbon content, and encouraging the productivity of the crops that follow.(Jensen et al., 20ll)

Dry bean is very liable to disease and physiological problems related with excessive water. Diseases which tend to be preferred by very moist conditions include Anthracnose, Fusarium, Pythium, Rhizoctonia, rust, white mold, and bacterial diseases like bacterial blight, bacterial brown spot and halo blight. They are also attacked by a number of the collective pests like aphids, army worms, leaf miners, spider mites, loopers, corn earworms cutworms and stink bugs. Water-saturated soils can kill roots (Ashley et al. (undated)).

2.3 Beans yield response

FAO (2002) module 4 on crop water requirements argues that when crop water requirement need are not met a water stress is established by the crop affecting both the crop growth and the final yield thereof. The extent of the effect of the water stress depends greatly on the stage, time and type of crop which is affected. Therefore the United States Department of Agriculture (USDA) developed a table of the most critical stages of water stress of different crops and FAO 2002 recorded the crops grown in Zimbabwe in their forth module. The research done by the USDA shows that the beans is greatly affected by the water stress on the flowering stage through pod formation. Similar work on the dry beans was done by Calvadoe et al. (l992- l994) in Ecuador and they came to a conclusion that the beans are affected by water stress at the flowering stage as the treatment with deficit at this stage scored significantly low results. Simsek et al., (20ll) conducted other trials under semi-arid conditions on 2002-2004 on beans and they observed that beans are more sensitive to water stress on the vegetative stage more than reproductive stage.

2.4 Nutrient depletion and replenishment

Smaling et al., (l997) designate that an average of 660 kg N /ha, 75 kg P /ha, and 450 kg K /ha has been vanished during the last 30yr from about 200 million ha of cultivated land in 37 African countries. This is equal to l.4 t urea ha/l, 375 kg triple superphosphate (TSP) ha or 0.9 t P of average composition /ha, and 896 kg KCl /ha during the last three decades. These figures represent the equilibrium between nutrient inputs as fertilizer, manure, atmospheric deposition, biological N_2 fixation (BNF), and sedimentation, and nutrient outputs as harvested products, crop residue removals, leaching, gaseous losses, surface runoff, and erosion (Sanchez et al., l997). FAO l995 in Roland et al. (l997) adds that Africa is now losing 4.4 million tonnes of N, 0.5 million tonnes of P, and 3 million tonnes of K every year from its cultivated land. These amounts are several times higher than Africa's annual fertilizer use. These values effect in overall decline in the food security, crop productivity, soil fertility diminution causing other problems like less fodder production for cattle feed, limited cattle manure and crop residue to replenish the soil nutrients which in long term quicken the erosion rate, soil structure distortions and surface sealing.

According to the work done by Curtis and Childs (undated) in Victoria University soil nutrient replenishment is done either using manure or compost or a synthetic fertilizer. Synthetic fertilizers are frequently used to replace nitrogen (in the form of urea, ammonium sulfate, ammonium nitrate or di-ammonium hydrogen phosphate), phosphorous, sulfur and potassium. The nitrogen is acquired from the air, the phosphorous is extracted as $Ca_3(PO_4)_2$, the sulfur is extracted in elemental form and reacted with oxygen to form sulfate, and the potassium is attained from seawater. Other minor nutrients are also sometimes interchanged using specialized artificial fertilizers.

2.5 Organic fertilizers

According to the research carried out by FAO (2006) it is evident that cattle manure is the major fertilizer input in most of the smallholder farmers in Zimbabwe. The manure amass in the cattle kraals as in most communal lands the cattle spends the night enclosed in the kraal and are herded out during the day to the grazing fields.

Mugwira and Murwira (l997) in FAO (2006) estimated the cattle manure from the communal areas to contain an average of l.04% N, 0.58% P and 0.78% K and the manure applied to the field have approximately 0.5-l.4 N percent of dry mass which is low and hence the necessity to apply large quantities to meet the crop nutrients requirements.

Grant (l997) argues that due to very low quality of manures comprising a lot of sand and maize Stover hence fertilizing using these would not prove adequate to supply the readily available nutrients for high yielding crops in order to encounter the relative demand. Mugwira (l985) discovered that the use of the inorganic can be helpful in enhancing and increasing the effectiveness of the organic fertilizer produced on the communal lands.

From the results obtained in a two year research on maize and beans under organic and inorganic fertilizers in South Africa, it can be concluded that organic manure has the potential to improve yield of smallholder farmers who cannot afford to buy inorganic fertilizer and that farmers would reap benefit from the use of organic manures as quickly as in the second year of application. Although the study reported here did not extend beyond second year, it seems likely that the benefit of organic manure would extend for a longer period as reported in other studies (Silwane et al., 2007).

In the publication Replenishing Soil Fertility in Africa, Quinones et al. (l997) said that improved fertilizer use in Africa can create a win-win situation, by indorsing more efficient crop production and plummeting soil degradation. Mineral fertilizers should be at the core of strategies to restore soil fertility and raise crop productivity, though their use should be a part of integrated systems of nutrient management in which organic fertilizer sources are encompassed (Quinones et al., l997).

2.6 Inorganic fertilizers

FAO (2006) argues that in Zimbabwe a wide variety of fertilizer are used to different crops and in diverse soil types that is straight N fertilizers Ammonium nitrate, Urea, Sodium nitrates, ammonium sulphates and calcium nitrates. Phosphates straight that is single double and triple phosphates. Potash fertilizers are potassium chloride (KCl) and potassium sulphates (SOP-K2SO4). These Fertilizers are provided in granular frame and in 50kg packs marks with the substance inside determining the kind of supplement supplied and the rate of the substance showed on the name thereof. At present the production of the fertilizers in Zimbabwe is far under standard and the greater part of these are foreign made from neighboring nations. The production faced declining amid the l990s as raw materials for the production were hard to transport from their area to the extraction station because of the railway and road networks inadequacies. Promote decrease underway were brought on by absence of interest as most collective farmers could not manage the cost of which were designated, the manufacturing and the legislature meddled controlling the costs disadvantaging the manufactures who then seized as they could not meet the cost of transporting in raw materials, produce and distribute fertilizers.

Minnesota department of agriculture says that the physiognomies of inorganic synthetic fertilizers are that they dissolve in water and are immediately available to the plant for uptake. When used according to recommendations, these types of fertilizers are safe for the environment and can source the essential nutrients for plant growth. Nevertheless, excessive rates of these fertilizers can harm the roots of plants causing death and possibly lead to environmental degradation.

Fertilizer consumption by small holder farmers is low and inconstant because of numerous economic, political, technical and institutional factors (Nhemachena, 2004), some of these are under developed marketing systems, high cost of transporting fertilizers from the urban depots and in adequate extension advice on their use. FAO (2006) asserts that smallholder farmers in Zimbabwe account for about one fifth of the total demand of fertilizer greatly due to restraints like lack of access to fertilizers, lack of supply of fertilizers, lack of competitive supply of fertilizers and the price controls of fertilizers by the government.

2.7 Effects of deficit irrigation on crops grown using organic and inorganic fertilizers

FAO(2002) argues that deficit irrigation can be calculated using inputs on soil water retention and infiltration characteristics and estimates of rooting depth, a daily soil water balance, prediction of water content in the rooted soil by means of a water conservation equation, which takes into account the incoming and outgoing flow of water thus water stress conditions in the root zone can be defined by the critical soil water content, expressed as the fraction of total available soil water between field capacity and wilting point that is readily available for crop transpiration, and characterizes a soil moisture condition in which crop transpiration is not limited by any flow restrictions in the root-zone.

According to the work done by Khan and Khalil (20l4) in Pakistan for two years observation were made and results indicated that significant increase is realized in the continuous use of organic fertilizers comparatively to the relative decrease on the use of inorganic fertilizers. Fan (2005), also concluded from long term experiment that addition of organic material and inorganic fertilizer has significantly enhanced grain yield, augmented water use efficiency, and improved soil chemical proprieties as compared with control or only inorganic N and P, addition of organic manure with inorganic fertilizers is essential for sustainable production.

Gonzalez-Dugo et al. (2009) in the research on water deficit and nitrogen crop nutrition advanced that the influence of water deficit on N nutrition status is at play at the level of the soil through the accessibility of mineral N for root uptake as well as at plant level. Yet, it is difficult to ascribe a ranking to any of these levels in terms of their effects since water availability for transpiration, carbon supply and growth potential all regulate N demand, assimilation and distribution within the plant.

Another research done in Uzbekistan indicates that significant water savings are possible with the embracing of on-farm water saving technologies for irrigation of legumes as a second crop after wheat harvest in the Fergana Valley of Uzbekistan. The benefits to the local population of growing legumes as a second crop using water saving irrigation techniques comprise, a protein rich food, increased land productivity with minimal irrigation or fertilizer input (due to legume nitrogen fixation), improved land fertility and organic matter if the residue is incorporated into the soil.

CHAPTER 3 METHODOLOGY

3.1 Site description

This study was carried out at Midlands State University in Midlands Province located 19^{o} $45^{'}$ S and 29^{o} 85`E. The area lies at an altitude of l400m above sea level, and it has an average annual temperature range of 11 ^{0}C – 25 ^{0}C and the zone is characterized by an annual rainfall of 500-700mm with infrequent frost occurrence (Wikipedia). The site is characterized by sandy loam soils belonging to the fesiallitic group and dominant clay mineral in these soils is kaolinite (Nyamapfene, l98l). The soil texture on the experimental site varied from sandy loam to loamy soils. The overall Soil depth ranges from l.0 m to l.2 m, and was limited by a gravel layer making the water table through the year to be varied between 3m and 5m from the soil surface below the root zone depth of most field crops and does not affect the crop water extraction patterns from the soil generally.

3.2 Experimental design

The trial was set out in a randomized complete block design (RCBD) with six treatments and four replicates. The area was divided into 4×6 small plots (4 blocks and 6 columns). The treatments are randomly allocated to the plots with every treatment represented on each row. The treatments are 20% deficit and 30% deficit both organic and inorganic fertilizer for each deficit and lastly the control where full water supply was applied on organic and inorganic. Bean seed SC bounty variety (speckled) was used on the experiment (seeding rate 80-l00 kg/ha). The organic fertilized plots were applied with cattle manure at rate of 24tonnes/ha, the inorganic fertilized plot were applied with basal fertilizer compound D (7:14:7) at rate 300kg/ha and topdressing ammonium nitrate (34.5%) at rate of l50kg/ha.

3.3 Treatments

let Control l(Cl) – organic fertilizer and full water supply

Control 2(C2) – inorganic fertilizer and full water supply

Treatment 1(Tl) – Organic fertilizer and 20% water deficit

Treatment 2(T2) – Inorganic fertilizer and 20% water deficit

Treatment 3(T3) – Organic fertilizer and 30% water deficit

Treatment 4(T4) – inorganic fertilizer and 30% water deficit

TlRl	T2Rl	T3Rl	T4Rl	ClRl	C2Rl
TlR2	T2R2	T3R2	T4R2	ClR2	C2R2
TlR3	T2R3	T3R3	T4R3	ClR3	C2R3
TlR4	T2R4	T3R4	T4R4	ClR4	C2R4

Where R represent replicate number

Experimental setup of the field beans

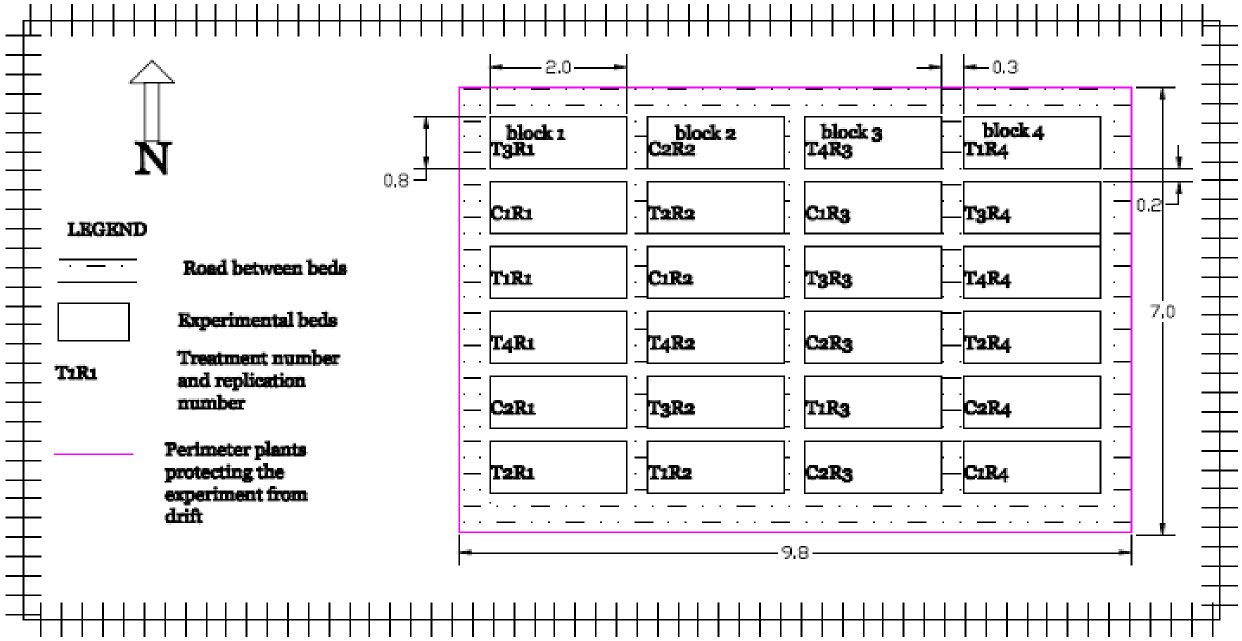

Figure 3.l

3.4 Plant development

Planting

The land was thoroughly tilled using a pick to allow effective unrestricted penetration of the roots to the ground and air exchange interphase for plant root development. Fine tilth was achieved by the use of the hand rake to as-certain perfect seed soil contact or interaction to encourage germination of the seed. A hand hoe was used to make the ridges and the twine was used to straighten the beds. All the measurements of the plots were recorded using the meter ruler. The beds were formed and separated arranged as per design. The tip of the pick was used to make the 50mm deep trench for the seed and the spacing of 5cm in-row and 45cm inter row was used on the planting of the beans. Fertilizer was applied the treatments of inorganic fertilizer that is compound D (7:l4:7) at a rate of 300kg/ha and the treatments of organic were applied with the cattle manure at a rate of 24 t/ha. The plots were randomly allocated to the plots with every treatment replication represented on each block of the field area.

Germination

Due to low temperatures experienced on planting week the seed took more than 7 days to germinate but extended even to two weeks from the planting date. The treatments which are at the far north side of the field were more affected as they are closer to tree shed on the perimeter fence. The seed germinated with time by two weeks expected germination was observed.

Flowering and pod formation

At the midst of the development phase of the beans the plants started showing the development toward flowering on the end of the 4th week and on the 5th week flowers could be observed although they were observed at different numbers with different treatments on the experiment. Approaching the beginning of the mid-season the pods were now showing. During the same week the pods started forming very tiny green pods could be observed developing on the upper quarter of the plants.

Crop management

Crop management practices were conducted, monitoring weeds developments through hand weeding, scouting for any symptoms of diseases and scouting for pests on the crop. Maintenance of the seedbeds and regular water application as scheduled were done.

3.5 Plant measurements and analysis

The plant growth parameters(plant height and width) were directly measured from the field and recorded at l week interval, a representative sample of 9 plants from each treatment were used to represent the treatment and or replication. Plant height, leaf width were measured using the ruler and recorded. The leaf area was estimated using the area occupied by the representative leaves on the graph page and the simple square counting technique was used to estimate their area of the leaf. The number of leaves and the number of flowers on the crops were physically counted on the plant avoiding at all cost unnecessary disturbance (hand contact) of plants on the field, as the flowers could fall and exaggerated results acquired. All the recordings acquired from the field were weekly logged and means of representative recordings set aside for analysis. The analysis was done using simple bar graphs generated by Microsoft excel and the Anova analysis conducted on Genstat version l4. The means were separated using the Fisher‘s protected LSD (least significant difference of means at $P<0.05$)

3.6 Irrigation scheduling

The irrigation checkbook method was used to determine the daily water requirements need and the frequency of the water application to the crops at different crop growth stages as illustrated on the table 3.0.

Table 3.0 Irrigation scheduling table using the checkbook methods for beans

Date	Kc	Etc(mm)	RZD(m)	Cumulative water losses(mm)	Effective irrigation(mm)	moisture balance(mm)	volume applied in m^3	full irrigation volume (l)	20% deficit volume (l)	30% deficit volume (l)
22/08/16	0.23	1.495	0.07	1.495	5.25	3.755	0.0084	8.4	6.72	5.88
25/08/16	0.23	1.495	0.07	5.98	5.25	3.755	0.0084	8.4	6.72	5.88
28/08/16	0.3	1.95	0.07	11.83	5.25	3.3	0.0084	8.4	6.72	5.88
30/08/16	0.33	2.145	0.07	15.925	5.25	3.105	0.0084	8.4	6.72	5.88
02/09/16	0.33	2.145	0.07	22.36	5.25	3.105	0.0084	8.4	6.72	5.88
04/09/16	0.44	2.86	0.07	28.08	5.25	2.39	0.0084	8.4	6.72	5.88
06/09/16	0.44	2.86	0.07	33.8	5.25	2.36	0.0084	8.4	6.72	5.88
08/09/16	0.57	3.705	0.4	41.21	30	26.295	0.048	48	38.4	33.6
15/09/16	0.89	5.785	0.4	72.865	30	24.215	0.048	48	38.4	33.6
20/09/16	1	6.5	0.4	103.22	30	23.5	0.048	48	38.4	33.6
25/09/16	1	6.5	0.4	135.72	30	23.5	0.048	48	38.4	33.6
30/09/16	1	6.5	0.4	168.22	30	23.5	0.048	48	38.4	33.6
05/10/16	1	6.5	0.6	200.72	45	38.5	0.072	72	57.6	50.4
12/10/16	0.92	5.98	0.6	245.18	45	39.02	0.072	72	57.6	50.4
20/10/16	0.79	5.135	0.6	289.51	45	40.865	0.072	72	57.6	50.4
31/10/16	0.59	3.835	0.6	339.755	45	41.165	0.072	72	57.6	50.4
14/11/16	0.39	2.535	0.6	384.085	45	42.465	0.072	72	57.6	50.4

Crop: Dry beans

Where RZD- root depth zone

Etc - actual evapotranspiration

Kc - Crop growth coefficient

The table shows K_c values, duration of growth in days and the average root zone depth at each growth stage.

Table 3.l Growth duration, crop coefficient and root depth

Beans	K_c	Duration(days)	Root depth(m)
Initial stage	0.35	l5	0.07
Development stage	0.70	25	0.4
Mid-season	l.l0	35	0.6
late season	0.90	20	0.6

The equation of volume conversion as forwarded by Savva and Franken in FAO module 7

$V = l0 \text{ x } A \text{ x } d_{gross}$

Where V is volume in m^3

A is area in ha

d_{gross} is gross irrigation requirement in mm

10 is a constant used to convert mm to m^3 volume

Table 3.2 Volume of water for each growth stage

Beans	Full irrigation(litres)	20% deficit(litres)	30% deficit(litres)
Initial stage	58.8	47.04	4l.l6
Development stage	248.4	l92.72	l40.28
Mid-season	288	230.4	20l.6
late season	72	57.6	50.4

CHAPTER 4 RESULTS AND DISCUSSIONS

4.1 Germination rate

Emergence percentage (EP) (Penalosa & Eira, l993), Emergence Index (Shekari et al., 20l0) were calculated using the following formulas

Germination percentage (GP) = $\frac{\text{Number of germinated seeds}}{\text{number of viable seeds}}$

(Scott et al., l984)

or

Emergence Percentage (EP) = l00 (number emerged/Total planted seed)

Table 4.l Mean percentage of overall germination rate in %

Germination	Day l	Day 7
Organic	68	86
Inorganic	62	80

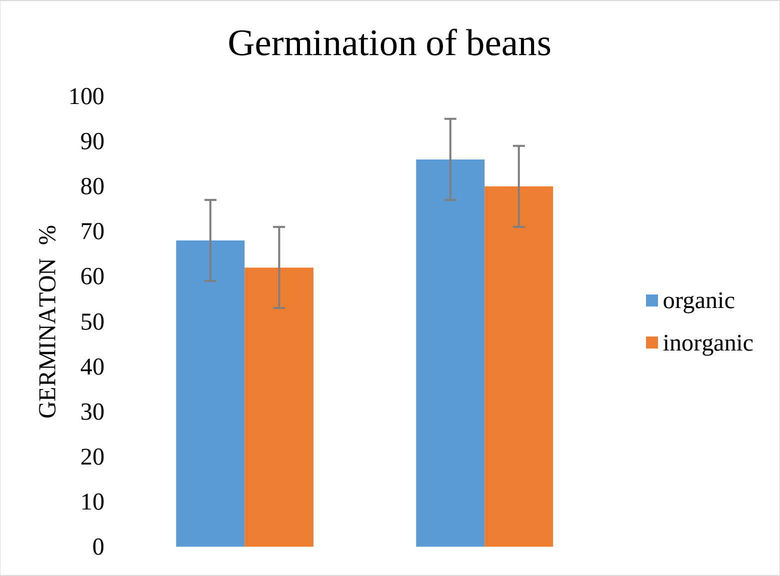

Figure 4.l Beans germination

Mean germination of organic and inorganic fertilized beans (%)

The above figure shows the germination of the beans seed recorded on the first day of germination and after a week of germination. It was observed that the seed planted under the organic fertilizer germinated faster in % than those under the inorganic fertilizer although there is no statistical significant difference. Overall some treatments were affected by the shed resulting in delayed germination but due to randomization done on the experiment it was observed that the organic fertilized beans germinated at faster rate than the inorganic fertilized seed. Enujeke et al. (20l3) on their research on effects of different organic fertilizers and inorganic fertilizers on soil properties they observed that organic fertilizers and inorganic fertilizers equally changes the exchangeable cations (Ca, Mg, K and Na), organic C, N (C/N ratio) and the soil bulk density on sandy loam soils in Nigeria at application rates of 450kg/ha NPK (20:l0:l0) and 30t/ha poultry manure giving same effects on plant development.

4.2 leaf area (cm^2)

Table 4.2 mean leaf area (cm^2)

	Week l	Week 2	Week 3	Week 4	Week 5	Week 6
Treatment 1	l.8^{abc}	3.000^{b}	9.450^{a}	l7.38^{bc}	22.20^{bc}	23.47^{b}
Treatment 2	l.6^{ab}	2.925^{ab}	9.l25^{a}	l7.l3^{b}	2l.65^{b}	23.27^{bc}
Treatment 3	l.7^{ab}	2.975^{b}	9.575^{ab}	l7.l0^{b}	20.62^{a}	23.l7^{ab}
Treatment 4	l.5^{a}	2.625^{a}	9.500^{ab}	l6.60^{a}	20.20^{a}	23.l2^{a}
Control l	2.0^{c}	3.600^{c}	l0.575^{bc}	l8.l3^{d}	22.55^{c}	23.50^{d}
Control 2	l.8^{bc}	3.350^{c}	l0.675^{c}	l7.70^{cd}	22.40^{bc}	23.37^{cd}

Table of Means (Fisher‘s protected lSD test)

Where

Control 1(C1) – organic fertilizer and full water supply

Control 2(C2) – inorganic fertilizer and full water supply

Treatment 1(T1) – Organic fertilizer and 20% water deficit

Treatment 2(T2) – Inorganic fertilizer and 20% water deficit

Treatment 3(T3) – Organic fertilizer and 30% water deficit

Treatment 4(T4) – inorganic fertilizer and 30% water deficit

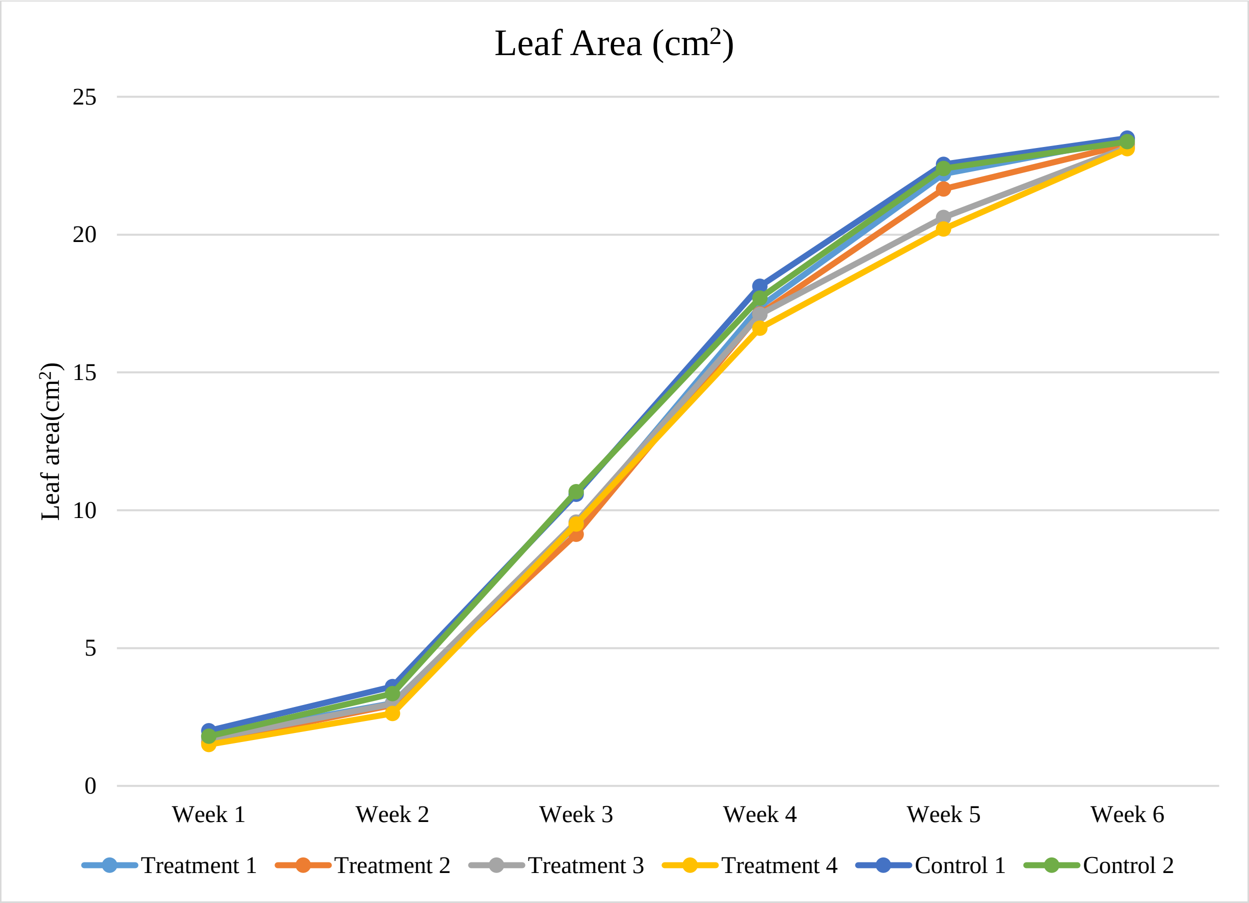

Figure 4.2 Leaf area (cm^2)

Tested using the Fisher's protected LSD test at ($P<0.05$) the results illustrated on the figure 4.2 shows that there is no significant difference between organic and inorganic fertilizers at 20% deficit (treatment l and 2) and full irrigation (controls). The leaf area between the treatments with 30% deficit treatment shows a significant difference with organic fertilized treatments having high mean to inorganic treatments, the results shows that at 30% deficit there is greater leaf development on organic fertilizer than on inorganic fertilizer. The leaf development curve illustrated on the graph follows the general growth curve, it portrays the sigmoid shape of the growth curve of crops as proposed by lotka (l956) on the book elements of mathematical biological. Some studies show that abscisic acid (ABA) can function as a signal to reduce leaf development, both when ABA is applied exogenously or generated by water stress (Wilkinson and Davies, 20l0). Water stress have negative effects on mineral nutrition (uptake and transport of nutrients) and metabolism leads to a decrease in the leaf area. These results tally with the observation by Wisdom et al. (20l2) where they discovered that there is no significant difference between organic and inorganic treatment if applied with full irrigation water required for both growth and crop development but significant difference evident on extreme deficit applications.

4.3 Onset of flowering (days)

Table 4.3 Onset of flowering (days)

	20% deficit	30% deficit	Full irrigation
Organic fertilizer	32^{ab}	33^{b}	30^{a}
Inorganic fertilizer	37^{c}	37^{c}	31^{ab}

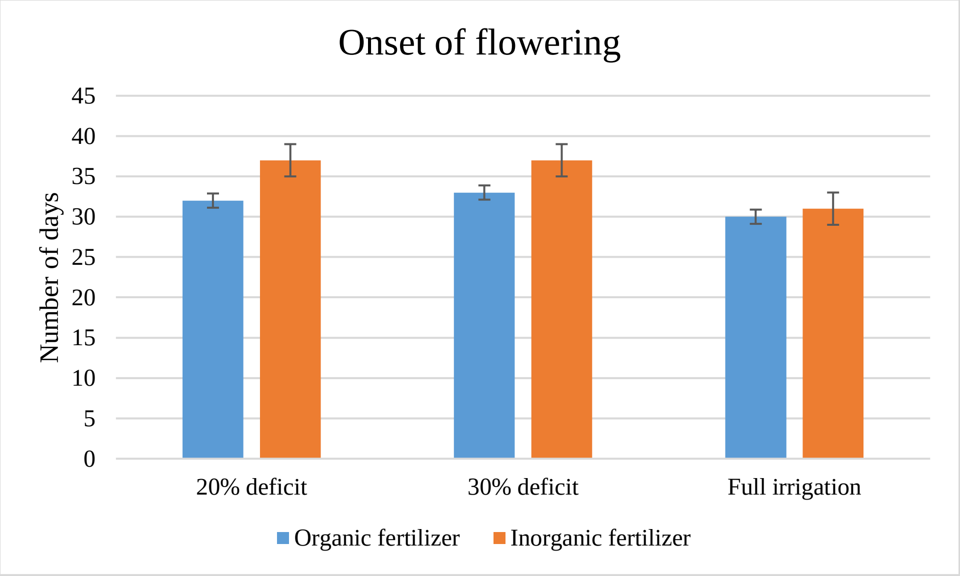

Figure 4.3 Onset of flowering

The flowering stage of crop development is very crucial as it is the initial step toward good yield formation. If improper crop management is practiced at this stage damage to the final yield will be evident. The initial onset of flowering shows the sensitivity of beans to the water stress, the treatment 5 and treatment 6 (full irrigation) had earlier onset in comparison to the water stressed treatments. Both 20% and 30% treatment had statistically significant difference at LSD ($P<0.05$) onset between the organic and inorganic fertilized beans. The full irrigation had no significant differences between organic and inorganic treatments on the onset, Ghosh et al. (20l4) on their research on 2008 of comparison of different organic and inorganic treatments on beans also observed the same results. On 20% deficit irrigation treatments (l and 2) there was a statistically significant difference with the organic fertilized treatment (l) having earlier onset of flowering in comparison to the inorganic treatment (2) which took longer time to produce flowers. At 30% water deficit there was a significant difference at LSD ($P<0.05$) treatment 3 flowered earlier than treatment 4. Mbarek et al. (20l2) observed that deficit irrigation have effects on the flowering and pod formation. More deficit resulted in delayed onset of flowering and poor pod formation altogether. Calvache et al. (l994) also retained same results of flowers loss on high percentages of deficit irrigation, which in-turn affected the final yield of their experiment altogether.

4.4 Flowering

Table 4.4 Number of flowers

	week	week 6	week 7	week 8
Treatment l	5^{b}	$l0^{b}$	4^{ab}	2^{a}
Treatment 2	5^{b}	9^{a}	6^{c}	3^{b}
Treatment 3	5^{b}	9^{a}	5^{b}	3^{b}
Treatment 4	4^{a}	9^{a}	7^{d}	4^{c}
Control l	5^{b}	$l2^{c}$	4^{a}	2^{a}
Control 2	6^{bc}	ll^{b}	4^{ab}	3^{b}

Where

Control 1(C1) – organic fertilizer and full water supply

Control 2(C2) – inorganic fertilizer and full water supply

Treatment 1(T1) – Organic fertilizer and 20% water deficit

Treatment 2(T2) – Inorganic fertilizer and 20% water deficit

Treatment 3(T3) – Organic fertilizer and 30% water deficit

Treatment 4(T4) – inorganic fertilizer and 30% water deficit

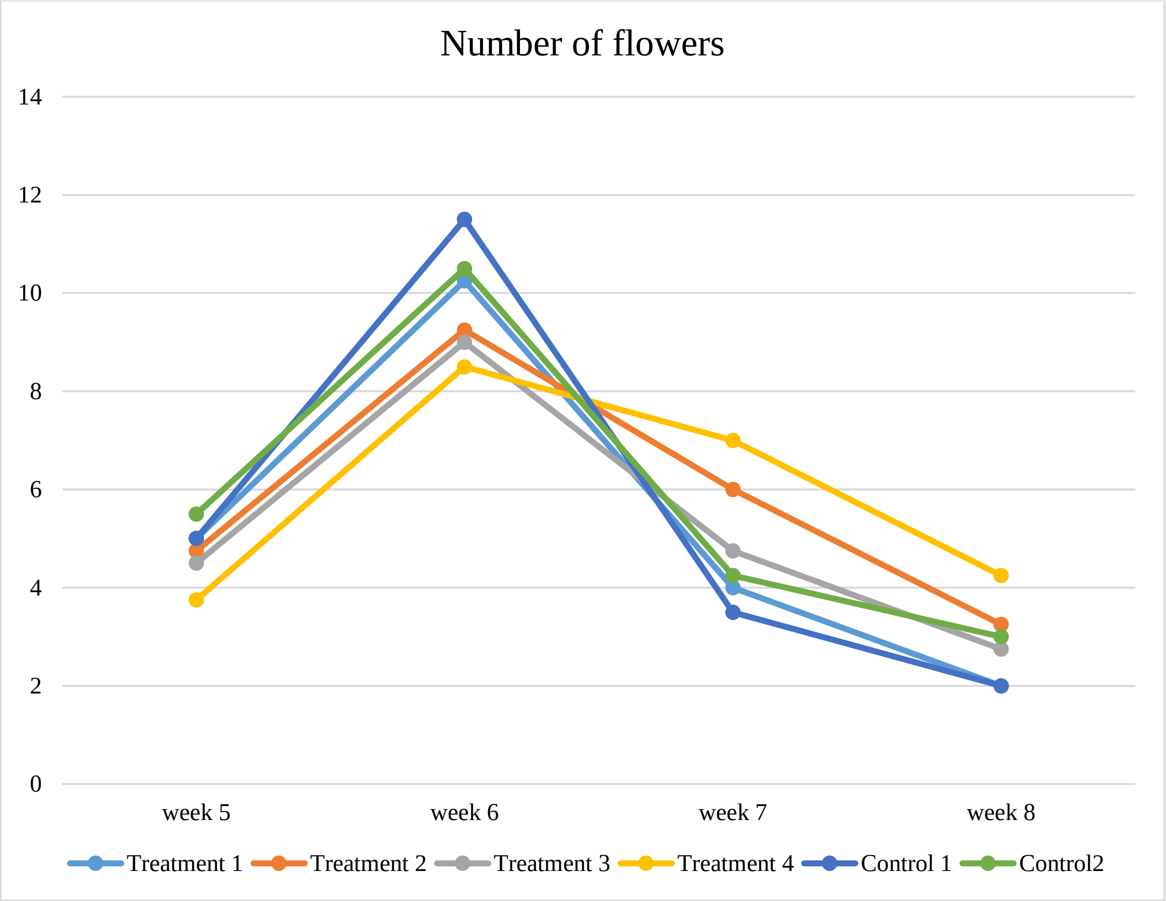

Figure 4.4 Number of flowers

The flowering rate was recorded from the fifth week (development stage of growth) to the 8th week (mid-season stage of growth), the Fisher's protected least significant difference test was used to separate the means at LSD ($P<0.05$). Figure 4.4 presents results on the number of flowers observed on the representative plants of different treatments. The general trend shown all the treatments experienced a high number of flowers on the sixth week which is the peak flowering stage prior to the pod formation stage. Low number of flowers were recorded on the 5th week and the 8th week, week 5 was the onset days of flowering and week 8 was within the pod formation phase thus most flowers were now developing to pods.

Using the table of means attained from the GenStat One way Anova (Randomized blocks) analysis there was significant difference on number of flowers observed between Treatment l(Organic fertilizer and 20% water deficit) and Treatment 2(Inorganic fertilizer and 20% water deficit) tested at LSD ($P<0.05$). The same trend recurred on Treatment 3 (Organic fertilizer and 30% water deficit) and Treatment 4 (Inorganic fertilizer and 30% water deficit). This trend is credited to capability of organic manure to improve soil structure making more efficient water utilization by crops. There was no significant difference on flowering onset between full irrigation controls and the 20% deficit treatments but there was a significant difference between full treatment and 30% deficit treatments. The two Control experiments Control 1(Organic fertilizer and full irrigation) and Control 2 (Inorganic fertilizer and full irrigation) also shown no significant difference. Silwana et al. (20l0) on a research carried out in Cape town South Africa on different types of organic and inorganic fertilizer they observed that both the organic and inorganic fertilizers enhance morphological parameters of beans. Katsaruware and Gwembire (20l0) on their research in Makonde district, foliar organic and inorganic fertilizers likewise observed no statistically significant difference on all the crop growth parameters. Water at flowering commonly results in barrenness. Water deficit reduces plant growth and development, leading to hampered flower production and grain filling, and thus smaller and fewer grains. A reduction in grain filling occurs due to a reduction in the assimilate partitioning and activities of sucrose and starch synthesis enzymes (Farooq et al. 2009)

4.5 Pod development

Table 4.5 Means of pods number

	Week 5	Week 6	Week 7	Week 8
Treatment l	3.750^{c}	7.500c^{d}	l0.500^{cd}	l3.50^{b}
Treatment 2	3.000^{b}	6.750^{c}	9.250^{bc}	l2.50^{b}
Treatment 3	l.750^{a}	4.250^{b}	7.750^{ab}	9.25^{a}
Treatment 4	l.250^{a}	3.000^{a}	6.750^{a}	8.25^{a}
Control l	5.250^{d}	9.000^{e}	l2.750^{e}	l5.00^{c}
Control 2	4.250^{c}	7.750^{d}	ll.750de	l3.75b^{c}

Table of Means (Fisher‘s protected LSD test)

Where

Control 1(C1) – organic fertilizer and full water supply

Control 2(C2) – inorganic fertilizer and full water supply

Treatment 1(T1) – Organic fertilizer and 20% water deficit

Treatment 2(T2) – Inorganic fertilizer and 20% water deficit

Treatment 3(T3) – Organic fertilizer and 30% water deficit

Treatment 4(T4) – inorganic fertilizer and 30% water deficit

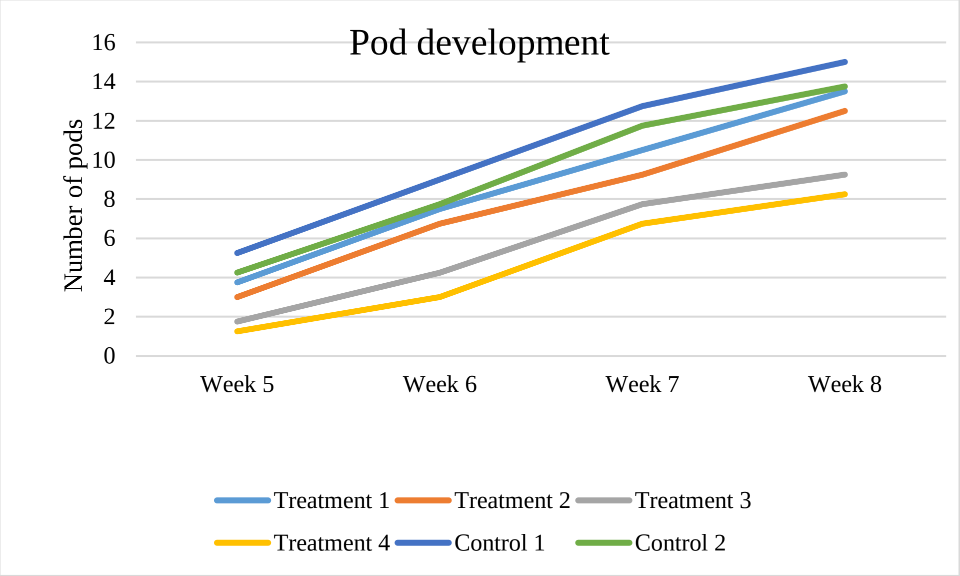

Figure 4.5 Pod development

From the results recorded on flowering was observed that the treatments under 30% deficit recorded low number of flowers, this resulted on the poor pod formation. Tested at LSD ($P<0.05$) there is a statistically significant difference between (30% deficit treatments) treatment 3 and treatment 4 with the other treatments(treatment l and 2) which further suggests that water deficit at flowering and pod development growth phase causes severe loses on the yield development or pod formation. The most crucial stage of yield production on the bean crop is the flowering and pod formation. Nayyar et al., (2006) stated that the flowering and pod setting stages seem to be the utmost sensitive stages to water stress. Earlier studies indicated that water deficit during the vegetative growth stage had little effect on yield, whereas it increased the flower and pod abortion during the early reproductive stage (Frederick et al., l99l; Demirtas et al., 20l0).

4.6 Plant height (cm)

Table 4.6 mean plant height

	Weekl	Week2	Week3	Week4	Week5	Week6	Week7	Week8	Week9	Weekl0
Treatmentl	2.944^{bc}	5.667^{c}	8.525^{bc}	l2.22^{c}	l6.73^{bc}	l9.l7^{b}	2l.57^{bc}	23.85^{c}	26.33^{c}	28.367
Treatment2	l.972^{a}	4.694^{ab}	7.025^{a}	9.90^{abc}	l5.90^{abc}	l8.77^{ab}	l9.27^{a}	22.40^{ab}	25.l3^{b}	28.553
Treatment3	2.778^{b}	5056^{abc}	7.875^{ab}	ll.60^{bc}	l5.95^{abc}	l9.00^{ab}	20.47^{ab}	22.77^{bc}	24.73^{a}	28.433
Treatment4	l.9l7^{a}	4.36l^{a}	6.850^{a}	8.47^{a}	l4.68^{a}	l7.52^{a}	l9.47^{a}	2l.47^{a}	24.93^{ab}	28.533
Control l	3.333^{c}	5.583^{bc}	9.l25^{c}	ll.92^{bc}	l7.50^{c}	20.37^{bc}	23.37^{d}	25.52^{d}	27.57^{e}	28.667
Control 2	2.556^{bc}	4.583^{a}	7.950^{ab}	9.57^{ab}	l5.43^{ab}	2l.32^{c}	22.l0^{cd}	23.95^{c}	27.l0^{d}	28.700

Note the week l0 is not significant thus the values are means are not from the fisher’s table of means like other weeks

Where

Control 1(C1) – organic fertilizer and full water supply

Control 2(C2) – inorganic fertilizer and full water supply

Treatment 1(T1) – Organic fertilizer and 20% water deficit

Treatment 2(T2) – Inorganic fertilizer and 20% water deficit

Treatment 3(T3) – Organic fertilizer and 30% water deficit

Treatment 4(T4) – inorganic fertilizer and 30% water deficit

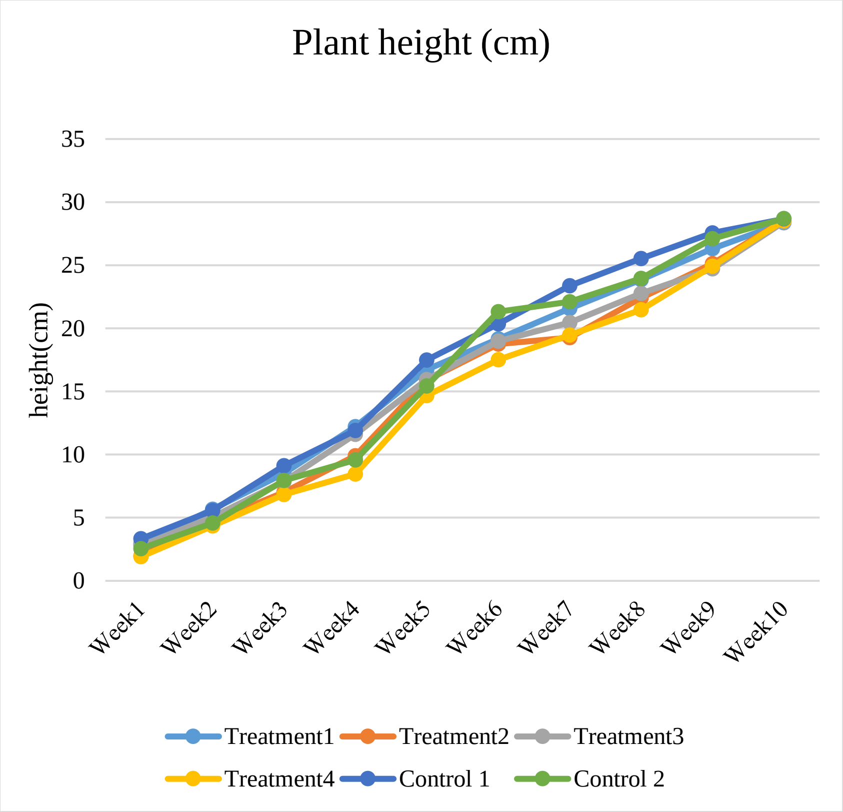

Figure 4.6 Plant height (cm)

Tested at LSD (P<0.05) using the Fisher's protected LSD test there is no significant difference between the treatments of 20% deficit (treatment l and 2) and the controls with full irrigation at each week, a significant difference is observed between the control treatments and 30% deficit treatments (3 and 4). The organic and inorganic treatments at deficit level 20% and controls shows no statistical difference on plant height, while 30% deficit treatments (3 and 4) shows difference. The general trend of all the treatments follows the growth curve characteristics as proposed by lotka (l956). These results are similar findings to those of Molnar (20l4) that at about 50% deficit there is a significant difference on plant height between full water treatments and water deficits. Comlekcioglu and Simsek (20ll) observed same results on plant height and attributed the difference to decrease in the formation of node on the main stem due to water stress throughout the plant growth period. Reduced cell enlargement reduces the leaf expansion as explained on leaf area development, reduces the leaf expansion the leaves become smaller and therefore transpire less, and these have been found to decrease the stem length.

4.7 Yield response factor

$$[l - \frac{Y_a}{Y_m}] = k_y [l - \frac{ET_a}{ET_m}]$$

Y_a, Y_m, ET_a and ET_m are actual yield, maximum yield, actual evapotranspiration and maximum evapotranspiration respectively.

The k_y values for the three different water deficits as limiting factor on crop development show same trend as the values proposed by FAO (l986) in FAO (2002) table of various crop yield coefficients ranging from zero to l.2 for field beans.

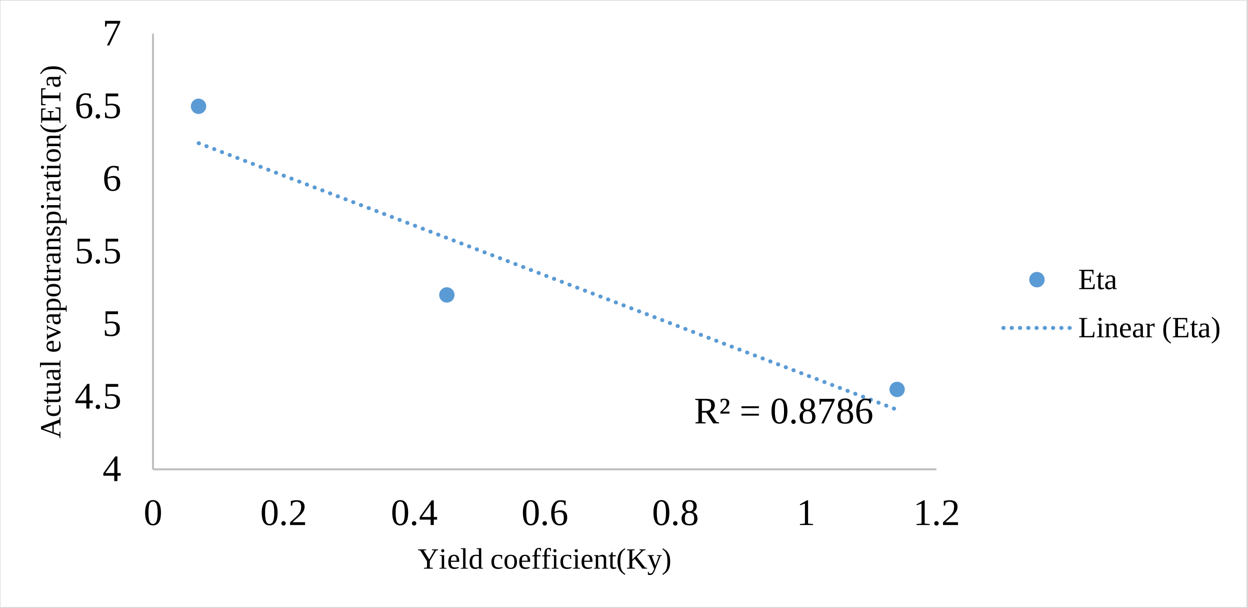

Figure 4.7

The figure 4.7 demonstrate the relationship between yield coeffient and evapotranspiration and it was observed that at almost field capacity or soil saturation low yield coefficient values (0.07 and 0.45) are recorded that is higher yield on the control treatments with full irrigation compared 30% water deficit treatments. At very severe water stress that is treatment with 30% water deficit there was low evapotranspiration that is higher yield coefficient value (l.l4) relative to other treatments with poor yield harvested. The coefficient of determination (R^2) on the linear graph shows strong (87.86%) relationship between ET_a and k_y as suggested by (Doorenbos and Kassim, l979). In order to minimize the negative effects of water stress the plants respond by changing their growth pattern, producing stress proteins and chaperones, up-regulation of anti-oxidants, accumulation of compatible solutes, increasing the amount of transporters involved in water and ion uptake and transport and by closing the stomata (Aeve et al. 20ll). Plants responds differently to certain amounts of water stresses depending on their variety and the climate they are subjected to, beans on the experiment shown adverse effects of water stress on 30% water deficit resulting in greatly reduced yield.

Table 4.7. Table of means tested using Fisher's Protected LSD test

Treatment	Mean Yield(g/plant)
L	l23.0^{b}
2	l23.3^{b}
3	89.0^{a}
4	87.0^{a}
5	l25.7^{b}
6	l25.0^{b}

The yields obtained on sample plants in grams tested using the one way Anova, Gen Stat Fisher's protected LSD test at ($P<0.05$) it was evident that there was no significant statistical difference between treatments of 20% deficit and the full irrigation control treatments while the treatment under 30% deficit shows statistically significant difference from all other treatments. The poor results from the treatments under 30% deficit were expected as poor pod development was observed during the crop development stage, these results coincide with those recorded by Bandani et al. (20l4), where they observed high effects of water stress on biological function and crop development under organic fertilizer. The water stress applied to these treatment caused great damage on the yield formation though the flowers development into pods. Comlekcioglu and Simsek (20ll) observed same trend on their research on effects of different deficit irrigation levels.

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Organic and inorganic fertilizers applied at rate 24t/ha (cattle manure) and 300kg/ha respectively have same effects on beans germination.

At 20% water deficit leaf development of beans under organic and inorganic fertilizers is the same, while it differs at 30% deficit with organic fertilizer performing better than inorganic fertilizer.

Organic fertilizer and inorganic fertilizer have same affect the onset of flowering of beans. 30% water deficit causes very severe flower abortions which significantly affect the pod formation of beans.

20% water deficit irrigation under both organic and inorganic fertilizers on beans influences good pod formation, while 30% deficit reduce pod formation through flower withering and early pod abortion reducing the number of pods developing.

Organic and inorganic fertilizer at 20% water deficit ensures normal plant height development while at 30% water deficit plant height development is retarded to undesirable levels.

Organic and inorganic fertilizers at 20% water deficit produce same yields on beans and relatively low yields are obtained at 30% irrigation water deficit.

5.2 Recommendation

Farmers can use cattle manure or inorganic fertilizer type depending on availability on the production of beans as both nutrients supplements method are produces similar yields.

Where water is limiting 20% water deficit with organic or inorganic soil nutrition can be used effectively on beans with minimal losses on total yield realized.

On extreme water shortages 30% water deficit can be used on beans with cattle manure but applying full irrigation on the flowering and pod development growth stage.

Areas of further study

Incorporation of the on field moisture measurement devices for more accurate irrigation scheduling.

Use of longer term experimentation up to 5 years period to obtain the results that will be more representative of the actual field conditions and soil changes over time considering the residual effects on chemical composition (soil pH, calcium magnesium ratio, sodium amounts and exchangeable cations) and structure.

There is a need to research on the combined effects of organic and inorganic fertilizers on water deficit at different levels (closer range i.e 5%, l0%, l5%...75% to determine the most beneficial percentage of production) on the crops.

More research is also needed to understand the physiological processes that controls and regulate the crop response to water stresses.

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APPENDIX l

Daily water balance using checkbook method

Date	Kc	Etc(mm)	RZD(m)	Cumulative water losses(mm)	Effective irrigation(mm)	moisture balance(mm)	volume applied in m^3
22/08/l6	0.23	l.495	0.07	l.495	5.25	3.755	0.0084
23/08/l6	0.23	l.495	0.07	2.99	0	2.26	0
24/08/l6	0.23	l.495	0.07	4.485	0	0.765	0
25/08/l6	0.23	l.495	0.07	5.98	5.25	3.755	0.0084
26/08/l6	0.3	l.95	0.07	7.93	0	l.805	0
27/08/l6	0.3	l.95	0.07	9.88	0	0	0
28/08/l6	0.3	l.95	0.07	ll.83	5.25	3.3	0.0084
29/08/l6	0.3	l.95	0.07	l3.78	0	l.35	0
30/08/l6	0.33	2.l45	0.07	l5.925	5.25	3.l05	0.0084
3l/08/l6	0.33	2.l45	0.07	l8.07	0	0.96	0
0l/09/l6	0.33	2.l45	0.07	20.2l5	0	0	0
02/09/l6	0.33	2.l45	0.07	22.36	5.25	3.l05	0.0084
03/09/l6	0.44	2.86	0.07	25.22	0	0.245	0
04/09/l6	0.44	2.86	0.07	28.08	5.25	2.39	0.0084
05/09/l6	0.44	2.86	0.07	30.94	0	0	0
06/09/l6	0.44	2.86	0.07	33.8	5.25	2.36	0.0084
07/09/l6	0.57	3.705	0.4	37.505	0	0	0
08/09/l6	0.57	3.705	0.4	4l.2l	30	26.295	0.048
09/09/l6	0.57	3.705	0.4	44.9l5	0	22.59	0
l0/09/l6	0.57	3.705	0.4	48.62	0	l8.885	0
ll/09/l6	0.7l	4.6l5	0.4	53.235	0	l4.27	0
l2/09/l6	0.7l	4.6l5	0.4	57.85	0	9.655	0
l3/09/l6	0.7l	4.6l5	0.4	62.465	0	5.04	0
l4/09/l6	0.7l	4.6l5	0.4	67.08	0	0.425	0
l5/09/l6	0.89	5.785	0.4	72.865	30	24.2l5	0.048
l6/09/l6	0.89	5.785	0.4	78.65	0	l8.43	0
l7/09/l6	0.89	5.785	0.4	84.435	0	l2.645	0
l8/09/l6	0.89	5.785	0.4	90.22	0	6.86	0
l9/09/l6	l	6.5	0.4	96.72	0	0.36	0
20/09/l6	l	6.5	0.4	l03.22	30	23.5	0.048
2l/09/l6	l	6.5	0.4	l09.72	0	l7	0

22/09/16	1	6.5	0.4	116.22	0	10.5	0
23/09/16	1	6.5	0.4	122.72	0	4	0
24/09/16	1	6.5	0.4	129.22	0	0	0
25/09/16	1	6.5	0.4	135.72	30	23.5	0.048
26/09/16	1	6.5	0.4	142.22	0	17	0
27/09/16	1	6.5	0.4	148.72	0	10.5	0
28/09/16	1	6.5	0.4	155.22	0	4	0
29/09/16	1	6.5	0.4	161.72	0	0	0
30/09/16	1	6.5	0.4	168.22	30	23.5	0.048
01/10/16	1	6.5	0.4	174.72	0	17	0
02/10/16	1	6.5	0.4	181.22	0	10.5	0
03/10/16	1	6.5	0.4	187.72	0	4	0
04/10/16	1	6.5	0.4	194.22	0	0	0
05/10/16	1	6.5	0.6	200.72	45	38.5	0.072
06/10/16	1	6.5	0.6	207.22	0	32	0
07/10/16	1	6.5	0.6	213.72	0	25.5	0
08/10/16	1	6.5	0.6	220.22	0	19	0
09/10/16	1	6.5	0.6	226.72	0	12.5	0
10/10/16	1	6.5	0.6	233.22	0	6	0
11/10/16	0.92	5.98	0.6	239.2	0	0.02	0
12/10/16	0.92	5.98	0.6	245.18	45	39.02	0.072
13/10/16	0.92	5.98	0.6	251.16	0	33.04	0
14/10/16	0.92	5.98	0.6	257.14	0	27.06	0
15/10/16	0.85	5.525	0.6	262.665	0	21.535	0
16/10/16	0.85	5.525	0.6	268.19	0	16.01	0
17/10/16	0.85	5.525	0.6	273.715	0	10.485	0
18/10/16	0.85	5.525	0.6	279.24	0	4.96	0
19/10/16	0.79	5.135	0.6	284.375	0	0	0
20/10/16	0.79	5.135	0.6	289.51	45	40.865	0.072
21/10/16	0.79	5.135	0.6	294.645	0	36.73	0
22/10/16	0.79	5.135	0.6	299.78	0	32.595	0
23/10/16	0.73	4.745	0.6	304.525	0	27.85	0
24/10/16	0.73	4.745	0.6	309.27	0	23.105	0
25/10/16	0.73	4.745	0.6	314.015	0	18.36	0
26/10/16	0.73	4.745	0.6	318.76	0	14.07	0
27/10/16	0.66	4.29	0.6	323.05	0	9.78	0
28/10/16	0.66	4.29	0.6	327.34	0	5.49	0
29/10/16	0.66	4.29	0.6	331.63	0	1.2	0
30/10/16	0.66	4.29	0.6	335.92	0	0	0

31/10/16	0.59	3.835	0.6	339.755	45	41.165	0.072
01/11/16	0.59	3.835	0.6	343.59	0	37.33	0
02/11/16	0.59	3.835	0.6	347.425	0	33.495	0
03/11/16	0.59	3.835	0.6	351.26	0	29.66	0
04/11/16	0.52	3.38	0.6	354.64	0	26.28	0
05/11/16	0.52	3.38	0.6	358.02	0	22.9	0
06/11/16	0.52	3.38	0.6	361.4	0	19.52	0
07/11/16	0.52	3.38	0.6	364.78	0	16.14	0
08/11/16	0.45	2.925	0.6	367.705	0	13.215	0
09/11/16	0.45	2.925	0.6	370.63	0	10.29	0
10/11/16	0.45	2.925	0.6	373.555	0	7.365	0
11/11/16	0.45	2.925	0.6	376.48	0	4.44	0
12/11/16	0.39	2.535	0.6	379.015	0	1.905	0
13/11/16	0.39	2.535	0.6	381.55	0	0	0
14/11/16	0.39	2.535	0.6	384.085	45	42.465	0.072
15/11/16	0.39	2.535	0.6	386.62	0	39.93	0
16/11/16	0.37	2.405	0.6	389.025	0	37.525	0
17/11/16	0.37	2.405	0.6	391.43	0	35.12	0
18/11/16	0.37	2.405	0.6	393.835	0	32.715	0
19/11/16	0.37	2.405	0.6	396.24	0	30.31	0
20/11/16	0.34	2.21	0.6	398.45	0	28.1	0
21/11/16	0.34	2.21	0.6	400.66	0	25.89	0
22/11/16	0.34	2.21	0.6	402.87	0	23.68	0
23/11/16	0.34	2.21	0.6	405.08	0	21.47	0

APPENDIX 2

Leaf area (cm^2)

	Week l	Week 2	Week 3	Week 4	Week 5	Week 6
Treatment l	l.8^{abc}	3.000^{b}	9.450^{a}	l7.38^{bc}	22.20^{bc}	23.47^{d}
Treatment 2	l.6^{ab}	2.925^{ab}	9.l25^{a}	l7.l3^{b}	2l.65^{b}	23.27^{bc}
Treatment 3	l.7^{ab}	2.975^{b}	9.575^{ab}	l7.l0^{b}	20.62^{a}	23.l7^{ab}
Treatment 4	l.5^{a}	2.625^{a}	9.500^{ab}	l6.60^{a}	20.20^{a}	23.l2^{a}
Control l	2.0^{c}	3.600^{c}	l0.575^{bc}	l8.l3^{d}	22.55^{c}	23.50^{d}
Control 2	l.8^{bc}	3.350^{c}	l0.675^{c}	l7.70^{cd}	22.40^{bc}	23.37^{cd}

Table of Means (Fisher‘s protected LSD test)

Analysis of Variance tables

```
Variate: leaf_Area week l

Source of variation          d.f.       s.s.       m.s.     v.r.   F pr.

Rep stratum                     3    0.l4833    0.04944     l.08

Rep.*Units* stratum
Tt                              5    0.68333    0.l3667     2.99   0.046
Residual                       l5    0.68667    0.04578

Total                          23    l.5l833

Variate: leaf_Area week l

Stratum                        d.f.         s.e.        cv%
Rep                               3       0.0908        5.2
Rep.*Units*                      l5       0.2l40       l2.3
```

```
Variate: leaf_Area week 2

Source of variation           d.f.        s.s.        m.s.      v.r.   F pr.

Rep stratum                      3     0.l4458     0.048l9      0.99

Rep.*Units* stratum
Tt                               5     2.36708     0.47342      9.76   <.00l
Residual                        l5     0.72792     0.04853

Total                              23        3.23958

Variate: leaf_Area week 2

Stratum                            d.f.          s.e.          cv%
Rep                                   3        0.0896          2.9
Rep.*Units*                          l5        0.2203          7.2


Variate: leaf_Area week 3

Source of variation           d.f.        s.s.        m.s.      v.r.   F pr.

Rep stratum                      3      l.9900      0.6633      l.28

Rep.*Units* stratum
Tt                               5      8.3333      l.6667      3.23   0.036
Residual                        l5      7.7500      0.5l67

Total                           23     l8.0733

Variate: leaf_Area week 3

Stratum                            d.f.          s.e.          cv%
Rep                                   3         0.332          3.4
Rep.*Units*                          l5         0.7l9          7.3
```

```
Variate: leaf_Area week 4

Source of variation          d.f.        s.s.        m.s.      v.r.    F pr.

Rep stratum                     3     0.25125     0.08375      0.90

Rep.*Units* stratum
Tt                              5     5.59375     1.11875     12.06    <.001
Residual                       15     1.39125     0.09275

Total                          23     7.23625

Variate: leaf_Area week 4

Stratum                          d.f.           s.e.         cv%
Rep                                 3         0.1181         0.7
Rep.*Units*                        15         0.3045         1.8



Variate: leaf_Area week 5

Source of variation          d.f.        s.s.        m.s.      v.r.    F pr.

Rep stratum                     3      0.5846      0.1949      0.68

Rep.*Units* stratum
Tt                              5     19.2621      3.8524     13.49    <.001
Residual                       15      4.2829      0.2855

Total                          23     24.1296

Variate: leaf_Area week 5

Stratum                          d.f.           s.e.         cv%
Rep                                 3          0.180         0.8
Rep.*Units*                        15          0.534         2.5
```

```
Variate: leaf_Area week 6

Source of variation            d.f.        s.s.        m.s.      v.r.   F pr.

Rep stratum                       3    0.09l250    0.0304l7      4.29

Rep.*Units* stratum
Tt                                5    0.482083    0.0964l7     l3.6l   <.00l
Residual                         l5    0.l06250    0.007083

Total                            23    0.679583

Variate: leaf_Area week 6

Stratum                            d.f.          s.e.        cv%
Rep                                   3        0.07l2        0.3
Rep.*Units*                          l5        0.0842        0.4
```

APPENDIX 3

Flowering (Anova tables)

	Week 5	Week 6	Week 7	Week 8	Overall mean
Treatment 1	5^{b}	10^{b}	4^{ab}	2^{a}	5.312
Treatment 2	5^{b}	9^{a}	6^{c}	3^{b}	5.812
Treatment 3	5^{b}	9^{a}	5^{b}	3^{b}	5.25
Treatment 4	4^{a}	9^{a}	7^{d}	4^{c}	5.875
Control 1	5^{b}	12^{c}	4^{a}	2^{a}	5.5
Control2	6^{bc}	11^{b}	4^{ab}	3^{b}	5.812
F prob	0.331	<.001	<.001	<.001	0.036
LSD(0.05)	0.215	0.885	0.810	0.5209	0.5
CV (%)	12.2	7.3	10.9	12.0	5.5

Table of means Fishers protected LSD
Analysis of variance
Variate: week 5

```
Source of variation          d.f.        s.s.        m.s.      v.r.    F pr.

Rep stratum                     3       0.833       0.278      0.25

Rep.*Units* stratum
Tt                              5       7.000       1.400      1.26    0.331
Residual                       15      16.667       1.111

Total                          23      24.500



Stratum                         d.f.           s.e.         cv%
Rep Variate: week5

                                   3          0.215         4.5
Rep.*Units*                       15          1.054        12.2
```

Week 6

Variate: Flowering week 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	9.3333	3.llll	9.03	
Rep.*Units* stratum					
Tt	5	24.8333	4.9667	l4.42	<.00l
Residual	l5	5.l667	0.3444		
Total	23	39.3333			

Variate: Flowering week 6

Stratum	d.f.	s.e.	cv%
Rep	3	0.720	7.3
Rep.*Units*	l5	0.587	6.0

Variate: Flowering week 7

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	2.l667	0.7222	2.50	
Rep.*Units* stratum					
Tt	5	35.3333	7.0667	24.46	<.00l
Residual	l5	4.3333	0.2889		
Total	23	4l.8333			

```
Variate: Flowering week 7

Stratum                    d.f.          s.e.        cv%
Rep                           3         0.347        7.l
Rep.*Units*                  l5         0.537       l0.9


Variate: Flowering week 8

Source of variation      d.f.        s.s.        m.s.      v.r.   F pr.

Rep stratum                 3      0.4583      0.l528      l.28

Rep.*Units* stratum
Tt                          5     l4.3750      2.8750     24.07   <.00l
Residual                   l5      l.79l7      0.ll94

Total    23      l6.6250

Variate: Flowering week 8

Stratum                    d.f.          s.e.        cv%
Rep                           3        0.l596        5.6
Rep.*Units*                  l5        0.3456       l2.0
```

APPENDIX 3

Pod formation

	Week 5	Week 6	Week 7	Week 8
Treatment l	3.750^{c}	7.500c^{d}	l0.500^{cd}	l3.50^{b}
Treatment 2	3.000^{b}	6.750^{c}	9.250^{bc}	l2.50^{b}
Treatment 3	l.750^{a}	4.250^{b}	7.750^{ab}	9.25^{a}
Treatment 4	l.250^{a}	3.000^{a}	6.750^{a}	8.25^{a}
Control l	5.250^{d}	9.000^{e}	l2.750^{e}	l5.00^{c}
Control 2	4.250^{c}	7.750^{d}	ll.750de	l3.75b^{c}

Table of means Fishers protected LSD

Analysis of variance
Variate: pod formation week_5

```
Source of variation          d.f.        s.s.        m.s.      v.r.    F pr.

Rep stratum                     3      l.79l7      0.5972      4.57

Rep.*Units* stratum
Tt                              5     46.2083      9.24l7     70.79    <.00l
Residual                       l5      l.9583      0.l306

Total                          23     49.9583


Variate: pod formation week_5

Stratum                          d.f.          s.e.          cv%
Rep                                 3        0.3l55          9.8
Rep.*Units*                        l5        0.36l3         ll.3
```

```
Variate: Pod formation week_6

Source of variation          d.f.        s.s.        m.s.     v.r.   F pr.

Rep stratum                     3      3.l250      l.04l7     3.79

Rep.*Units* stratum
Tt                              5    l04.3750     20.8750    75.9l   <.00l
Residual                       l5      4.l250      0.2750

Total    23        lll.6250
Variate: pod formation week_6

Stratum                         d.f.          s.e.        cv%
Rep                                3         0.4l7        6.5
Rep.*Units*                       l5         0.524        8.2

Variate: pod formation week_7

Source of variation          d.f.        s.s.        m.s.     v.r.   F pr.

Rep stratum                     3      l2.792       4.264     2.9l

Rep.*Units* stratum
Tt                              5     l07.208      2l.442    l4.65   <.00l
Residual                       l5      2l.958       l.464

Total    23        l4l.958

Variate: Pod formation week_7

Stratum                         d.f.          s.e.        cv%
Rep                                3         0.843        8.6
Rep.*Units*                       l5         l.2l0       l2.4

Variate: pod formation week_8

Source of variation          d.f.        s.s.        m.s.     v.r.   F pr.

Rep stratum                     3      4.4583      l.486l     l.62

Rep.*Units* stratum
Tt                              5    l44.7083     28.94l7    3l.48   <.00l
Residual                       l5     l3.79l7      0.9l94

Total                          23    l62.9583
```

Variate: pod formation week_8

Stratum	d.f.	s.e.	cv%
Rep	3	0.498	4.l
Rep.*Units*	l5	0.959	8.0

APPENDIX 4

Plant height (cm)

Fisher‘s protected LSD test means

	Weekl	Week2	Week3	Week4	Week5	Week6	Week7	Week8	Week9	Weekl0
Treatmentl	2.944^{bc}	5.667^{c}	8.525^{bc}	l2.22^{c}	l6.73^{bc}	l9.l7^{b}	2l.57^{bc}	23.85^{c}	26.33^{c}	28.367
Treatment2	l.972^{a}	4.694^{ab}	7.025^{a}	9.90^{abc}	l5.90^{abc}	l8.77^{ab}	l9.27^{a}	22.40^{ab}	25.l3^{b}	28.553
Treatment3	2.778^{b}	5056^{abc}	7.875^{ab}	ll.60^{bc}	l5.95^{abc}	l9.00^{ab}	20.47^{ab}	22.77^{bc}	24.73^{a}	28.433
Treatment4	l.9l7^{a}	4.36l^{a}	6.850^{a}	8.47^{a}	l4.68^{a}	l7.52^{a}	l9.47^{a}	2l.47^{a}	24.93^{ab}	28.533
Control l	3.333^{c}	5.583^{bc}	9.l25^{c}	ll.92^{bc}	l7.50^{c}	20.37^{bc}	23.37^{d}	25.52^{d}	27.57^{e}	28.667
Control 2	2.556^{bc}	4.583^{a}	7.950^{ab}	9.57^{ab}	l5.43^{ab}	2l.32^{c}	22.l0^{cd}	23.95^{c}	27.l0^{d}	28.700

Analysis of variance

Variate: Week_l

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	7.2037	2.40l2	22.27	
Rep.*Units* stratum					
Tt	5	6.l975	l.2395	ll.50	<.00l
Residual	l5	l.6l73	0.l078		
Total	23	l5.0l85			

Variate: Week_l

Stratum	d.f.	s.e.	cv%
Rep	3	0.63	24.5
Rep.*Units*	l5	0.33	l2.

```
Variate: Week_2

Source of variation              d.f.         s.s.         m.s.      v.r.    F pr.

Rep stratum                         3      l0.9239       3.64l3      9.l2

Rep.*Units* stratum
Tt                                  5       5.8498       l.l700      2.93    0.048
Residual                           l5       5.9897       0.3993

Total    23        22.7634

Variate: Week_2

Stratum                             d.f.             s.e.          cv%
Rep                                    3             0.78          l5.6
Rep.*Units*                           l5             0.63          l2.7

Variate: Week_3

Source of variation              d.f.         s.s.         m.s.      v.r.    F pr.

Rep stratum                         3       6.43l7       2.l439      3.67

Rep.*Units* stratum
Tt                                  5      l5.0483       3.0097      5.l5    0.006
Residual                           l5       8.7583       0.5839

Total    23        30.2383

Variate: Week_3

Stratum                             d.f.             s.e.          cv%
Rep                                    3             0.598          7.6
Rep.*Units*                           l5             0.764          9.7
```

```
Variate: Week_4

Source of variation              d.f.          s.s.          m.s.       v.r.    F pr.

Rep stratum                         3        24.530         8.l77       2.84

Rep.*Units* stratum
Tt                                  5        45.803         9.l6l       3.l8    0.037
Residual                           l5        43.240         2.883

Total    23         ll3.573

Variate: Week_4

Stratum                            d.f.              s.e.          cv%
Rep                                   3             l.l67          ll.0
Rep.*Units*                          l5             l.698          l6.0

Variate: Week_5

Source of variation              d.f.          s.s.          m.s.       v.r.    F pr.

Rep stratum                         3         4.l25         l.375       l.l9

Rep.*Units* stratum
Tt                                  5        l9.477         3.895       3.37    0.03l
Residual                           l5        l7.348         l.l57

Total                                    23               40.950

Variate: Week_5

Stratum                            d.f.              s.e.          cv%
Rep                                   3             0.479           3.0
Rep.*Units*                          l5             l.075           6.7
```

```
Variate: Week_6

Source of variation          d.f.        s.s.        m.s.      v.r.   F pr.

Rep stratum                     3       3.058       1.019      0.90

Rep.*Units* stratum
Tt                              5      35.059       7.012      6.17   0.003
Residual                       15      17.040       1.136

Total                          23      55.156

Variate: Week_6

Stratum                        d.f.            s.e.          cv%
Rep                               3           0.412          2.1
Rep.*Units*                      15           1.066          5.5

Variate: Week_7

Source of variation          d.f.        s.s.        m.s.      v.r.   F pr.

Rep stratum                     3      2.6679      0.8893      1.06

Rep.*Units* stratum
Tt                              5     50.9821     10.1964     12.17   <.001
Residual                       15     12.5696      0.8380

Total                                      23          66.2196

Variate: Week_7

Stratum                        d.f.            s.e.          cv%
Rep                               3           0.385          1.8
Rep.*Units*                      15           0.915          4.3
```

```
Variate: Week_8

Source of variation           d.f.          s.s.         m.s.       v.r.    F pr.

Rep stratum                      3        0.8979       0.2993       0.47

Rep.*Units* stratum
Tt                               5       40.347l       8.0694      l2.55    <.00l
Residual                        l5        9.6446       0.6430

Total    23         50.8896

Variate: Week_8

Stratum                         d.f.           s.e.          cv%
Rep                               3           0.223          l.0
Rep.*Units*                      l5           0.802          3.4

Variate: Week_9

Source of variation           d.f.  (m.v.)         s.s.         m.s.        v.r.     F pr.

Rep stratum                      2      (l)      0.02333      0.0ll67       0.30

Rep.*Units* stratum
Tt                               5              29.04796      5.80959     l48.96     <.00l
Residual                        l0      (5)      0.39000      0.03900

Total                           l7      (6)     22.20000


Variate: Week_9

Stratum                         d.f.           s.e.          cv%
Rep                               2          0.044l          0.2
Rep.*Units*                      l0          0.l975          0.8
```

```
Variate: Week_l0

Source of variation            d.f.  (m.v.)         s.s.         m.s.      v.r.    F pr.

Rep stratum                       2     (l)       0.l8lll      0.09056      3.33

Rep.*Units* stratum
Tt                                5               0.33265      0.06653      2.44     0.l07
Residual                         l0     (5)       0.27222      0.02722

Total                            l7     (6)       0.70278

Variate: Week_l0

Stratum                             d.f.          s.e.         cv%
Rep                                    2        0.l229         0.4
Rep.*Units*                           l0        0.l650         0.6

Fisher's protected LSD is not calculated as variance ratio for Tt is not significant.
```

APPENDIX 5

Yield

Analysis of variance

```
Variate: yield (g/plant)

Source of variation          d.f.  (m.v.)         s.s.          m.s.       v.r.    F pr.

Rep stratum                     2     (l)        4.778         2.389       0.68

Rep.*Units* stratum
Tt                              5             6903.26l      l380.652     39l.98    <.00l
Residual                       l0     (5)       35.222         3.522

Total                          l7     (6)     52l7.6ll

Variate: yield (g/plant)

Stratum                        d.f.              s.e.          cv%
Rep                               2             0.63l          0.6
Rep.*Units*                      l0             l.877          l.7
```