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EVALUATION OF SEED PRIMING ON GERMINATION, GROWTH AND YIELDS OF CHICKPEA (*Cicer arietinum L.*) UNDER VARYING PRE-SOWING SOIL MOISTURE LEVELS

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DECLARATION AND RECOMMENDATION

DECLARATION

I, Kamithi David Kuria, hereby declare that this work is original and has not been presented in any other university.

Sign…….. Date 14/4/2016

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RECOMMENDATION

We, the undersigned supervisors, hereby declare that this work is presented with our approval.

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DEDICATION

I dedicate this thesis to my parents, the late mother Beatrice Wamaitha Kamithi who died 12 hours before this proposal defense and my late father Mr. Kamithi Ng'ang'a who died a day after my last Kenya Certificate of Secondary Education (KCSE) examination paper.

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ABSTRACT

The phase period from sowing to seedling establishment is of considerable importance in crop production and has major impacts on plant growth, final grain yield, and seed quality. Due to poor and non-uniform germination in pulse crops and especially chickpea, priming treatments have been used to increase the speed and synchrony of seed germination. Two different but related experiments were conducted at Mwea Irrigation Agricultural Development Centre (MIAD) Kirinyaga County, Kenya to; (i) to determine the effects of priming on enzyme activities in the germinating chickpea seeds in a shade and (ii) to evaluate the performance of chickpea under different priming methods, varying priming durations and different initial soil moisture levels in thefield. Analysis of variance of data collected was done using GEN STAT Program package version 13 and means separated using the least significant difference (LSD) at $P \leq 0.05$. The highest alpha amylase activities of 12.97 µmoles/ml, was when seeds were halo primed for 8 hrs with 0.1 % $NaCl_2$ (HCL1T8). Non primed seeds (control) had significantly the least enzymatic activities (7.05 µmoles/ml). Increasing pre sowing irrigation from 25% FC to 100% FC, increased plants/m^2 in both season I and II. Priming chickpea seed before sowing did not show any significant differences in season I where plant population ranged between 12 to 14 plants/m^2. During the drier season II, significantly higher number of plants/m^2 that ranged between 3 and 8 plants/m^2 was with treatment combinations HCL_1T_8 (8 plants), HCL_1T_{10} (7 plants), HCL_1T_{12} (7 plants), HCL2T8 (7 plants) and HyT_{12} (7 plants). The highest dry matter of 5,001.1 and 3,973.0 kg/ha was realized under 100 % FC at 105 DAS in season I and II, respectively. Halo priming HCL2T8 gave significantly the highest DM at all stages of growth. The interaction effects at 90 DAS for the wet season I (SI) revealed that significantly higher DM yields were produced by treatment combinations of 25% FC pre sowing irrigation with HyT0 and HCL2T12, which produced 6,500 kg/ha and 5,900 kg/ha, respectively. These gave statistically equal dry matter with treatments HCL2T8 (6,440 kg/ha); 75% FC- HCL1T10 (6,713 kg/ha) and HCL2T8 (6,970 kg/ha). During the drier season (SII), the highest DM/ha of 5,017 and 4,285 kg/ha was realized by the interaction effects of 100% FC-HCL2T12 and HCL2T10, respectively. Significantly higher plant heights were observed under priming with HyT8 (12.71 cm) and HCL2T10 that had 11.5 and 11.55 cm in season both seasons, respectively. Pre sowing irrigation of 75% FC had the highest number of pods/m^2, i.e., 1,631 and 566 in seasons I and II, respectively. Seed priming treatment HCL1T8 produced significantly higher number of pods/m^2 (1615

and 754), as well as pods/plant, 100 seed weight, and even grain yield in both seasons, respectively. The highest grain yield was under 75% FC pre sowing irrigation in both season I and II, respectively. Treatment combinations HCL1T8 and HCL2T12, significantly increased grain yields and produced 1,365 and 1,251 kg/ha in SI and 563.8 and 539.4 kg/ha in SII, respectively. Interaction effects of irrigation and priming on grain yield (kg/ha) during season I revealed that pre sowing irrigation of 75% FC-HCL1T8, HCL2T12 and HCL3T10 produced significantly higher grain yields of 1,562, 1,604 and 1,460 kg/ha, respectively; along with 100% FC-HyT8 that produced 1,788 kg/ha. During the season II, the interaction effects of irrigation and priming on grain yield revealed a similar trend as in season I where pre sowing irrigation of 75% FC-HCL1T8 and 100% FC-HyT8 produced significantly higher grain yield of 755.0 and 748.3 kg/ha, respectively. In season II, these were the same as for pre sowing irrigation 50% FC-HCL2T12 that produced 921.7 kg/ha. Treatment combinations 0.1% $NaCl_2$ for 8 hours and 0.2% $NaCl_2$ for 12 hours is therefore recommended for desi chickpea priming for realization of higher grain yields of Mwea environment. However effective priming occurs when accompanied by adequate rainfall (or soil moisture) during germination. Initial soil moisture content of 75% field capacity and above is necessary for effective seed priming with 0.1-0.2% $NaCl_2$ solution for 8 to 12 hours, which results in n alpha amylase activity of 12.03 - 12.97 µmoles/ml thus a higher germination and seedling establishment.

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LIST OF ACRONYMS AND ABBREVIATIONS

a.s.l	Above sea level
ASAL	Arid and Semi Arid Lands
CGR	Crop growth rate
Ch	Chickpea
DAS	Days after sowing
DM	Dry Matter
FC	Field capacity
Fig.	Figure
Ha	Hectare
HCL	Halo priming
HCL_1	0.1% $Nacl_2$ solution
HCL_2	0.2% $Nacl_2$ solution
HCL_3	0.3%$Nacl_2$ solution
HI	Harvest index
Hr/hr	hours
Hy	Hydro priming {for 8 (HyT_8), 10 (HyT_{10}) and 12 (HyT_{12}) hours)
LAI	Leaf Area Index
M	meter
MOA	Ministry of Agriculture
P_0	No priming
SI/Season I	Season one
SII/Season II	Season two
T_{10}	Priming for 10 hours
T_{12}	Priming for 12 hours
T_8	Priming for 8 hours

CHAPTER ONE

1.0 INTRODUCTION

Chickpea is primarily grown for its mature seeds, which are used as human food. These are consumed alone or together with cereals as a side dish in the form of a sauce or soup (Kamithi, 2008). The composition of mature raw chickpea seeds per 100 g edible portion is: water 11.5 g, energy 1525 kJ (364 kcal), protein 19.3 g, fat 6.0 g, carbohydrate 60.7 g, dietary fibre 17.4 g, Ca 105 mg, Mg 115 mg, P 366 mg, Fe 6.2 mg, Zn 3.4 mg, vitamin A 67 IU, thiamin 0.48 mg, riboflavin 0.21 mg, niacin 1.5 mg, vitamin B_6 0.54 mg, folate 557 µg and ascorbic acid 4.0 mg. The essential amino-acid composition per 100 g edible portion is: tryptophan 185 mg, lysine 1291 mg, methionine 253 mg, phenylalanine 1034 mg, threonine 716 mg, valine 809 mg, leucine 1374 mg and isoleucine 828 mg. The principal fatty acids are per 100 g edible portion: linoleic acid 2593 mg, oleic acid 1346 mg, palmitic acid 501 mg, linolenic acid 101 mg and stearic acid 85 mg (USDA, 2014). The protein content of chickpeas is lower than that of most other pulses, but this is compensated for by the higher protein digestibility. Antinutritional factors include trypsin inhibitors, haemagglutinins, tannins and oligosaccharides (USDA, 2014). Due to its increased demand the crop is gaining popularity in Kenya. The chickpea line ICCV 97107 (desi) and ICCV 95423 (Kabuli) were released as varieties Chania I and China KI, in year 2013, while ICCV 92944 (desi) was released as China desi 3 in 2014, respectively by Egerton University. These crops do well in cool the dry lands.

Seed germination is a complex and dynamic stage of plant ontogeny, with a number of interactive metabolic processes undergoing changes from storage to a mobilization phase (Bewley and Black, 1994; Ashraf and Foolad, 2005). The multitude of simultaneous metabolic processes taking place in germinating seed makes it difficult to examine events related to the initiation of the germination process. In an entire seed, the catabolic processes in the storage tissues can confound measurements and interpretation of anabolic and growth processes occurring in the developing embryo. The time from sowing to seedling establishment is of considerable importance in crop production and has major impacts on plant growth, final yield, and post harvest seed quality (Harris *et al.,* 2005). Seed germination entails three distinct *phases: phase I* is imbibitions process, in which water is taken up by the seed but little metabolic activity;

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phase II is a lag phase in which there is little water uptake but considerable metabolic activity; and *phase III* is marked by an increase in water content coinciding with radical growth and emergence (Bradford,1986). The length of *phase III* is important because germination is considered complete when embryo growth is initiated. During seed germination, the soil environment is often not conducive to rapid germination and seedling growth. Often, adverse abiotic and biotic stresses, such as low and high temperatures; soil crusting, shortage or excess of water, salinity, pathogenic diseases, and insects can reduce the rate or completely inhibit seed germination and seedling emergence.

Although dry seed is often characterized as having a low rate of metabolism due to low water content (5-10 %), it does not lack the potentiality for active metabolism ,and at least a few enzymes remain active (Girolamo and Barbanti, 2012; Ashraf *et al.*, 2003; Poljakoff - Mayber, 1994; Guerrier, 1988). Desiccated seed is a well equipped functional unit that can undergo many biochemical reactions if the initial hydration of proteins, particularly enzyme protein, has taken place (Mayer and Poljakoff, 1989; Bewley and Black, 1982). Although only a few minor changes may be observed in chemical composition of dry seed, as soon as the seed is hydrated, marked chemical changes such as breakdown and transport of reserve materials, especially transport from endosperm or cotyledons to the growing parts of the embryo and synthesis of new materials may occur (Mayer and Poljakoff, 1989).

One of the first physiological disorders taking place during seed germination under dry conditions is a decrease in water uptake by the seed due to low water potential of the germination medium. Controlled imbibitions of seed followed by dehydration, also referred as "seed priming", were shown to improve germination and early seedling growth under salt stress compared to plants grown from untreated seed. During priming, seed are generally exposed to an external water potential that is low enough to prevent germination but allows some pre-germinative physiological and biochemical processes to take place (Bradford, 1986). Primed seed germinate more rapidly than unprimed seed when placed in appropriate germination environment. Rapid seed germination and uniform field emergences are essential to the establishment of successful crops. Slow or sporadic germination and emergence generally result in fewer and small plants, which are more vulnerable to different biotic and abiotic stresses. A

prolonged emergence period may also lead to deterioration of the seedbed and increased soil compaction, which result in poor crop establishment. Seed priming is a common practice to increase the rate and uniformity of field crop germination and emergence in many important crop plants.

Various pre-hydration or priming treatments have been employed to increase the speed and synchrony of seed germination (Bradford, 1986). Common priming techniques include osmo priming (soaking seed in osmotic solution such as polyethylene glycol -PEG), halo priming (soaking seed in salt solutions), hydro priming (soaking seed in water), matrix priming (treating seeds with a solid matrix), thermo priming (treating seed with low or high temperatures), and priming seeds with plant growth hormones. Also bio priming (coating seed with bacteria and soaked in warm water until the moisture content rises to 35-40 %) can be done (Ashraf and Foolad, 2005).

1.1 Statement of Problem

Dry lands experience unreliable erratic rainfall that's never adequate for crop development to reach maturity. With adequate soil moisture, chickpea germination percentages are reported to be high leading to high crop yields. With low soil moisture regimes as it is in ASAL areas, poor crop germination is experienced leading to poor crop stand and hence low crop yields. Primed seed will only germinate if it takes up additional moisture from the soil after sowing. Sowing pre-germinated seed under dry land conditions can result in total failure to emerge. There are various technologies like seed priming, application of irrigation water, good crop nutrition, etc that can be applied to ensure good uniform crop germination. There is therefore need to explore on these various technologies that can ensure early and uniform crop germination that will eventually enhance optimum crop stand and establishment leading in to optimal crop yields in the ASAL environments.

1.2 Objectives

1.2.1 General Objective

To evaluate the performance of chickpea under different types of priming methods, varying priming durations and different initial soil moisture levels

1.2.2 Specific Objectives

(i) Determine the effects of priming on enzyme activities in the germinating seed

(ii) Determine the effects of priming on germination, growth and yield of chickpea

(iii) Determine the effects of varying priming duration on germination, growth and yield of chickpea

(iv) Determine the interaction effects of different types of priming and varying priming durations on germination, growth and yield of chickpea

(v) Determine the effects of different pre sowing soil moisture levels on germination and seedling establishment and their relationships

1.3 Hypothesis (Ho)

(i) Different priming applications do not affect enzyme activities in the germinating seed

(ii) Different priming applications do not affect germination, growth and yields of chickpea in dry land environment.

(iii) Varying priming durations do not affect germination, growth and yields of chickpea grown in dry land environment.

(iv) Different priming's and varying priming durations do not affect germination, growth and yields of chickpea grown in dry lands environments

(v) Different pre sowing soil moisture levels do not affect germination and seedling establishment and their relationships

1.4 Justification

In order to increase food grain production, there is need to increase area under crop cultivation. However, due to shortage of available arable land, the only option is to grow crops in the marginal lands that fall in the arid and semi arid lands (ASAL) of Kenya. Drought is a major limiting factor that limits the productivity of crops in these ASAL regions. Farmers in the ASAL areas continue to grow food crops that require high soil moisture levels leading to low crop yields and sometimes a total crop failure when irrigation is not applied; leading to famine and malnutrition related diseases. Some pulses are hardy crops that does well under low soil moisture regimes, low soil fertility, fixes atmospheric nitrogen and yields a high nutritious grain to the range of 1.2 to 1.8 tons per hectare depending on the agronomic management put in place. There

is therefore need to explore ways and means that can be employed to maximize on this grain yield production in the ASAL areas. Soil moisture at sowing and during seedling establishment is critical for optimum crop stand, growth, development and ultimate grain yield. Rapid seed germination and uniform field emergences are essential to the establishment of successful crops. In many crop species, biotic and abiotic stress, including diseases and pests, extreme temperatures, soil crusting, excess or limitation of water may individually or in combination adversely affect the germination process, leading to reductions of the rate of germination, poor crop stand establishment and low crop yield. If the stress effect can be alleviated at the germination stage, chances of attaining a good crop with economic yield production would be higher. Some chemical or physical treatments of seeds prior to sowing can significantly alleviate adverse effects of the germinating environment. The purpose of priming is to partially hydrate the seed to a point where early phases of germination processes begin before sowing the seed. Slow or sporadic germination and emergence generally result in fewer and small plants with poor vigour, which are more vulnerable to different biotic and abiotic stresses. A prolonged emergence period may also lead to deterioration of the seedbed and increased soil compaction, which result in poor crop emergence and establishment leading to poor crop yields. For these reasons a study was proposed to evaluate the effects of priming on germination, growth and yields of chickpea and therefore establish the standard practice that would be economical and farmer friendly.

CHAPTER TWO

LITERATURE REVIEW

In many agricultural areas, a major cause of poor crop stand establishment and low crop yield is unfavorable environmental conditions for seed germination and seedling emergence (Gupta *et al.*, 2008; Ashraf and Foolad, 2005). However, rapidly germinating seedling could emerge and produce deep roots before the upper layers of the soil are dried out and crusted, which may result in good crop establishment and higher crop yields. Any factor that facilitates rapid germination may contribute to establishment of a successful crop. Seed priming has become a common practice to increase the rate and uniformity of field germination and emergence in many crops i.e. tomatoes, asparagus, cucumber, pepper, maize, leek, etc. Priming is an approach that involves treatment of seeds with different inorganic or organic chemicals and or with high or low temperatures to improve germination, early seedling growth and final crop yield (Girolamo and Barbanti, 2012; Ashraf and Foolad, 2005).

2.1 Pulse crop to be grown

2.1.1 Chickpea

Chickpea is a hardy crop grown on marginal soils with residual moisture on soil not suitable for crops such as wheat (Kamithi, 2008). According to ICRISAT (2014), the production of chickpea in 2009–2013 amounted to 10.9 million t per year from 12.3 million ha. The main producing countries were India (4.1 million t per year from 6.3 million ha), Turkey (600,000 t from 600,000 ha), Pakistan (500,000 t from 1.1 million ha), Canada (250,000 t from 200,000 ha), Mexico (250,000 t from 150,000 ha) and Australia (200,000 t from 200,000 ha). The annual production in sub-Saharan Africa was about 280,000 t from 430,000 ha, the main producers being Ethiopia (168,000 t from 191,000 ha), Malawi (35,000 t from 88,000 ha), Sudan (25,000 t from 13,000 ha), Tanzania (25,000 t from 63,000 ha) and Kenya (20,000 t from 55,000 ha).Chickpea yields 500-600 kg/acre. However, yields of over 3 tons/ha have been reported in Kenya under good agronomic practices (MOA, 2008).

2.2 Effects of Priming on Seed Chemical Constituents

Although dry seed is often characterized as having a low rate of metabolism due to low water content (5-10%), it does not lack the potentiality for active metabolism, and at least a few enzymes remain active (Ashraf *et al.*,2003; Poljakoff- Mayber,1994; Guerrier,1988). Desiccated seed is a well equipped functional unit that can undergo many biochemical reactions if the initial hydration of proteins, in particular enzyme proteins, has taken place (Mayer and Poljakoff, 1989; Bewley and Black, 1982). Although a few minor changes may be observed in chemical composition of dry seed, as soon as the seed is hydrated, marked chemical changes such as breakdown and transport from endosperm or cotyledons to the growing parts of the embryo, and synthesis of new materials may occur (Mayer and Poljakoff, 1989).

One of the first physiological disorders taking place during seed germination under drought stress is a decrease in water uptake by the seed due to low water potential of the germinating medium. In addition to causing various structural changes at different levels of organization in the seed, slow late of imbibitions may lead to a series of metabolic changes, including up regulation or down regulation of enzyme activities (Ashraf *et al.*, 2002; Guerrier, 1988), perturbance in the mobility of inorganic nutrients to developing tissues (Ashraf and Wahid, 2000), disturbance of N metabolism and imbalances in the levels of plant growth regulators (Ashraf and Foolad., 2005), reduction in hydrolysis and utilization of food reserves (Ahmad and Bano, 2002) and accumulation of compatible osmotica such as soluble sugars, free praline, and soluble proteins (Ashraf *et al.*, 2003; Poljakoff - Mayber, 1994). These processes may lead to poor or complete lack of seed germination (Poljakoff - Mayber, 1994). Rapid and uniform seed germination and early seedling establishment are critical components for crop production. Seed germination and early seedling growth are generally the stages most sensitive (Ashraf *et al.*, 2003).

2.3 Nitrogen in Plant Shoots

Nitrogen is remobilized from vegetative to reproductive parts (Turner *et al.*, 2005). In soy beans, 85% of the total fixed nitrogen is found in reproductive parts at maturity (Warembourg *et al.*, 1982). Despite the ability of leguminous plants to fix atmospheric nitrogen, they remain heavily dependent on remobilized nitrogen (Turner *et al.*, 2005). Estimated remobilization of nitrogen is

much greater than that of carbon in all grain legumes. This is consistent with the observation that, in chickpea, the harvest index for nitrogen is nearly twice the harvest index of carbon. The dual labeling of chickpea with ^{13}C and ^{15}C prior to podding showed that, in irrigated plants, less than 10% of the carbon in the seed arises from pre-podding carbon, whereas in the same plants more than 60 % of the seed nitrogen is derived from nitrogen accumulated before podding (Davies *et al.*, 2000). This high dependence of nitrogen is attributed to high requirement for nitrogen for protein and substantial decreases in nitrogen fixation common during seed filling (Turner *et al.*, 2005).

2.4 Effects of Water on Crop Growth and Development

Water is the most important single factor limiting food production in many parts of the world, particularly in arid and semi arid regions. It is therefore evident why water has received and will continue to receive major attention as an environmental variable in the global need to increase food production (Kamithi *et al*, 2008).

The amount of soil water available to plants depends on the water balance, a difference between intake (rainfall or irrigation) and outflow {evaporation (ET), drainage (D), and runoff (R)}. Evaporation from the soil and crops (evapotranspiration) accounts for the largest part of water lost from the soil, while rainfall is the most important input (Kamau, 1999).

The amount of available water depends mainly on the amount of rain falling during the growing season and to some extent, on the soil water storage capacity (Cooper *et al.*, 1981). Although humid regions receive rainfall in excess of evapotranspiration (ET); short term variations in the distribution of rainfall result in periods of negative water balance and moisture stress on crops during the growing season. The length and frequency of these periods vary according to sub region or zone; they tend to be rather accentuated in the transitional zone between the humid and sub humid tropics (e.g. East Africa). To reduce the risk of crop failure and to increase production, a better knowledge of water use by crops is required for better planning (Palta *et al.*, 2005). Since the year 2007, Kenya's rainfall has been low and erratic. This has lead to different sowing times and poor crop stands due to early or late and unpredictable first rainfall incidences. Poor crop stands having poor vigor easily succumbs to diseases and pests that occasionally

resulted into crop failure. Investigations to evaluate methods to offset poor and uneven crop germination and establishment (lag phase) are needed in our efforts to enhance grain yields.
Water deficits decrease photosynthesis, but extent depends on species, timing, and severity of the water deficit (Daie, 1996). Plants respond to drought by closing or partially closing their stomata, thereby decreasing the amount of water lost through transpiration and at the same time decreasing carbon dioxide (CO_2) exchange (Hensons *et al.*, 1989; Turner and Henson, 1989). Water deficits also lead to decrease in shoot growth and leaf expansion (David *et al.*, 1998; Lecour and Guilioni, 1998; Munns and Sharp, 1993). This response indicates the presence of water- deficit stress signal that is perceived by the plant prior to reduced turgor in the leaf tissue.

Stomatal closure as a result of water deficits leads to reduced CO_2 exchange. Photosynthesis can also be reduced from prolonged and direct effects of water deficits. Photosynthesis declines in chickpea subject to water deficit (Palta *et al.*, 2005; Leport *et al.*, 1999; Hooda *et al.*, 1989). Under irrigated conditions in the field, the maximum rates of photosynthesis under clear sunny skies are about 20 to 30 $\mu mol/m^2/s$ in both white lupin (*Lupinus albus* L.) and chickpea.

Reductions in canopy photosynthesis occur through reductions in leaf area. In plants subjected to water deficits, there is a reduction in the time from flowering to physiological maturity, particularly in indeterminate species. Corresponding with this shortened duration is a reduction in leaf area (Lecour and Guilioni, 1998; Andriani *et al.*, 1991; Singh, 1991). This is particularly critical when drought begins in the vegetative phase. Reduced leaf area can be a result of slower rates of leaf production and expansion or increased rates of leaf senescence and abscission (Muchow *et al.*, 1986). This may result in increased assimilate partitioning to the reproductive organs, which has been shown to increase yield under some conditions (French and Turner, 1991). This is dependent upon the timing and degree of water deficit in relation to plant development. Water deficits and high temperatures late in the season can result in increased pod and seed abortion of late set pods (Leport *et al.*, 2005; Behboudian *et al.*, 2001; Davies, 1999). Studies to evaluate soil moisture deficit effects at sowing to seed establishment are however, lacking. This period is considered to have the slowest rate of growth, but it is critical to crop survival and subsequent growth, development and yields.

2.5 Effects of Osmo priming on Germination and Yields

Osmo priming contributes to significant improvement in seed germination and seedling growth in different plant species. Osmotic priming to improve seed germination performance may also enhance general crop performance. Priming chickpea (*Cicer arietinum*) seed with either 4% mannitol or water for 24 hours improved crop performance under field conditions, compared to a control crop based on non primed seed (Harris *et al.*, 2005). While the average seed yield per plant was 3.6 g in control crop, it was 5.0 or 5.9 g in the water or mannitol primed crops, respectively, showing an increase of 39 or 64%.

Osmo priming of soybeans (*Glycine max*) seed produced variable results while priming with mannitol did not alter field emergence. Priming with PEG promoted rapid and uniform emergence in early planting (Helsel *et al.*, 1986). However, once the stand was established, other environmental and growth factors promoted or inhibited yield expression. The low water potential of the treatment solution allows partial seed hydration so that pre-germination metabolic processes begin but germination is inhibited (Mottram and Harris, 2005; McDonald, 2000).

2.6 Effects of Halo priming on Germination, Growth and Yield

Pre sowing treatment with inorganic salts not only promote seed germination, but also may stimulate subsequent growth and metabolic processes and enhance final crop yield (Ahmad and Bano, 2002). Pre soaking of broad bean (*Vicia faba*) seed in potassium (KCL) or sodium chloride ($NaCL_2$) solutions resulted in significant increase in growth parameters. Pre-treatment of soybean seed with 0.25M $CaCl_2$ for 24 hours resulted in plants with increased seed number and reduced number of seedless pods, although it did not affect the 100 seed weight (Ahmad and Bano, 2002). This was coupled with an increase in nitrogen (N) contents in immature seeds. Although considerable improvement in germination and later growth stages has been observed in different crop species in response to halo priming, for each plant species, the optimal salt composition, concentration and period of incubation (soaking) need to be determined.

2.7 Effects of Hydro priming on Germination, Growth and Yields

A low cost approach designated as "on farm seed priming" was proposed by Harris (1992) and involved soaking of seed in water before sowing. The seed imbibe water and go through the first phase of germination in which pre-germination metabolic activities are preceded while the later two phases of germination are inhibited (Mottram and Harris, 2005). Although soaking seed in water and drying before sowing is the easiest way to achieve hydration, a major disadvantage is that it may result in uneven hydration and non uniform germination (Mottram and Harris, 2005). Also, soaking is not suitable for some plant species, as rapid hydration may cause leakage of essential nutrients out of the seed, resulting in seed damage. To overcome these potential problems, various methods have been devised to deliver appropriate hydration to seed. One method is seed humidification (a pre-sowing treatment in which seed are equilibrated under conditions of high humidity (Suzuki and Khan, 2001). In snap beans (*Phaseolus vulgaris*), humidification resulted in improved germination (Suzuki and Khan, 2001).Hydro priming of chickpea was reported to have increased plants/m^2, 100 seed weight and grain yield under dry land conditions (Kumar *et al.*, 2002). He also determined safe maximum lengths of time for which chickpea seed should be primed as ten hours.

2.8 Effects of Priming on Enzyme Activities in the Germinating Seed

Amylases are key enzymes that play a vital role in hydrolyzing the seeds starch reserve, thereby supplying sugars to the developing embryo (Andoh and Kobata, 2002). In primed seed of both wheat and barley, the activity of α-amylase at 12 hours after sowing was 2.7 and 2.8 times, respectively greater than in non primed seeds. The primed seeds also exhibit a faster rate of germination and seedling emergence. Priming may have significant beneficial effects on enzyme activity required for rapid seed germination (Andoh and Kobata, 2002). Relatively few and small chemical changes are observed in dry seed; however, many changes occur in the seed immediately after rehydration (Bewley and Black, 1994). Of these, changes in activity of enzymes involved in hydrolysis of storage products play important roles in initial growth and development of the embryo (Ashraf and Foolad, 2005). Priming seeds may significantly alter activity of enzymes in germinating seed. Seeds primed with mixed salt solution resulted in significant increase in activity of α-amylase, ß-amylase, and root dehydrogenase, and moderate increase in the activity of shoot catalase under salt stress conditions (Ashraf and Foolad, 2005).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Site description

Two different but related experiments were conducted at Mwea Irrigation Agricultural Development Centre (MIAD) Kirinyaga County, Kenya were instituted; (i) in a shade to determine the effects of priming on enzyme activities in the germinating chickpea seeds and (ii) in a field experimentation at the MIAD farm in two seasons of year 2012/2013, to evaluate the performance of chickpea under different priming methods, varying priming durations and different initial soil moisture levels.

3.2 Climate and Weather Conditions of (MIAD)

The centre is located on grid $0^{0}39^{1}$S and $37^{0}17^{1}$E, at an altitude of 1195m above sea level (m asl), (Jaetzhold and Schmidt, 1982).The experimental site lies in transition between agro ecological zone middle highlands 5 (UM_5) and lower highlands (LH_4) and as such, it has a hot and dry climate most of the year. The area receives a bimodal rainfall with an annual mean below 700mm, with a wide variation between the years. Although mean temperature is about 18^{0}C, daily values range from 7^{0}C at late night during the wet chilly season (July to August) to about 32^{0}C during the dry months. The relative humidity varies between 70-85%. The climatic and weather conditions were recorded during the experiment using the centre's automatic weather station.

3.3 Soils of MIAD

The soils are described by Jaetzhold and Schmidt, (1982) as generally black cotton soils (clay sandy loams to clay soils). Experiment site soils are slightly acidic (pH 5.5-6.5). Soil analysis showed that, the soils are insufficient in nitrogen (N; 0.053-0.144%) and phosphorus (P; 6-12 ppm).

3.4 Field experiment preparation

The experimental plot field was prepared to a suitable tilth by ploughing and harrowing twice. Chickpea was planted at a spacing of 45cmx15cm. Phosphate fertilizer (TSP) at a rate of 40 Kg P_2O_5/ha was be used at planting to supply phosphorus {Kamithi, (2008)}.

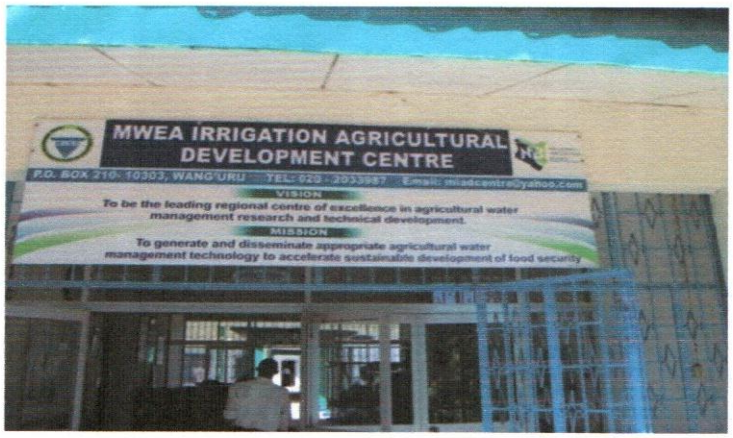


Plate 1: Mwea Irrigation Agricultural Development Centre (MIAD)

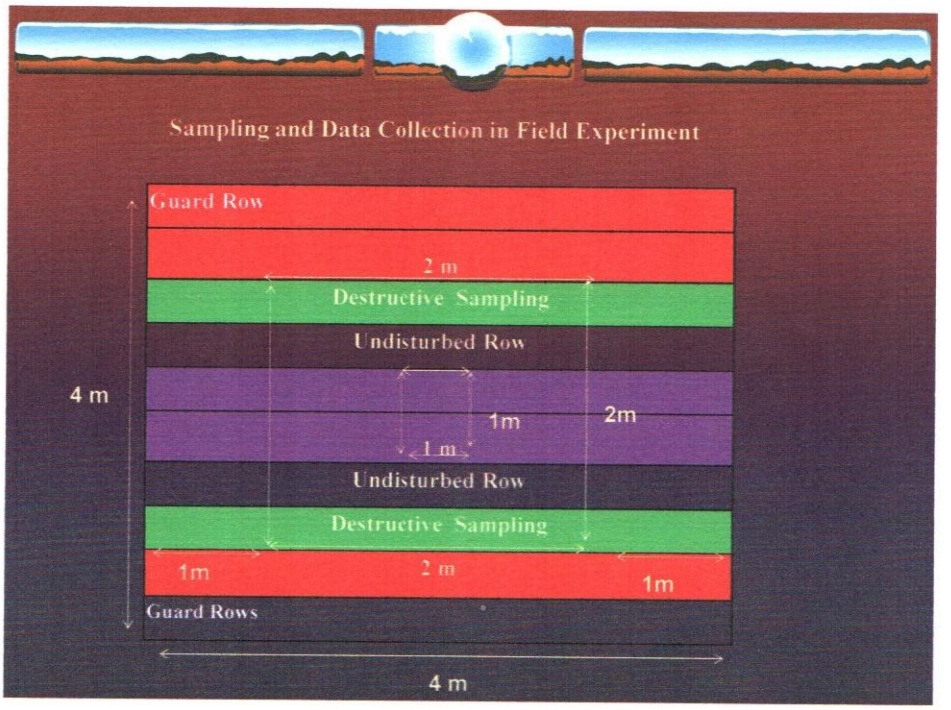
Calcium of Ammonium Nitrate (CAN) was applied as a starter nitrogen source at planting time at a rate of 30 kg/ha. All other agronomic practices were carried out as recommended.

3.5 Soil Analysis

Soil sampling was done prior to sowing and after harvest. Prior to sowing soil samples were taken from all the plots to a depth of 90cm and analyzed for total – N by Kjedahl method as outlined by Breemmer and Mulvency (1982). After harvesting the same analyses were repeated so as to compute total nitrogen in soil at planting and harvesting. Soil texture was determined by procedures described by Bouyoucous (1962) and soil bulk density by the core method as described by Blake (1965). Field capacity measurements were done by saturating the soil and waiting for 24-48 hrs and then measuring the soil moisture content by use of a neutron probe. The electron conductivity was determined using electron conductivity meter while soil P^H 1:2.5 meter was used to determine the soil P^H:

3.6 Sampling

For plant growth parameters, sampling was done at the following growth periods; 25 (branching), 50 (flowering), 75 (grain filling) and 90 (physiological maturity) days after sowing (DAS), respectively. The yield parameters that were recorded included; Plant height, periodic dry matter accumulation, No. of pods/plant, No. of pods/m^2, 100 seed weight, harvest index and grain yield/ha.



3.7 Parameters Measured and their Determination

3.7.1 Plant Parameters

Percentage Germination

Fifty seeds of the pulse crop under study (chickpea) were immersed in distilled water or kept dry at the same temperature. Soaked seeds were removed from the water; surface dried and set to germinate at the same temperature on moist filter paper, surface dried and set to germinate at the same temperature on moist filter paper in Petri dishes or lidded plastic containers, depending on seed size. The ratio of germinated seeds was calculated and expressed a percentage.

Days to Seedling Emergence

This was determined at the various treatment combination net plots using a calendar year days.

Periodic Plant Height

Plant height was measured using a ruler on three selected plants per plot, tagged to ensure readings are taken on the same plant at branching 25, 50, 75, 90 and 105 DAS.

Periodic Dry Matter (DM gm/plant)

Periodic dry matter was determined by weighing oven dried harvested samples as described by Steduto and Hsiao (1998) and was be used in the computation of growth. Samples were taken at 25, 50, 75 and 90 DAS.

Yield and yield Components

Yield components were determined from the middle rows of each plot from where a net plot was marked. They include No. of pods/plant, No. of pods/m^2, 100 seed wt (test weight), grain yield/ha and Harvest index.

- *No. of pods/plant*

This was recorded from the sampling unit (net plot) at harvesting

- *No. of pods/m^2*

Was recorded from the sampling unit (net plot) at harvesting

- *Hundred (100) Seed Weight*

Hundred grains were randomly picked from amongst sun dried grains harvested from each net plot and their weights recorded in grams

- *Grain and Above Biomass Yield*

The harvest materials from the net plot were labeled and sun dried for 3-4 days. The bundles were weighed prior to threshing using a spring balance. The chickpea plants harvested were threshed and the grains were cleaned. The grains and above ground biomass were weighed separately and finally expressed in yields per hectare basis.

- *Harvest Index (HI)*

The grain yield/ha was expressed as percentage of the total harvested biomass yield and reported as harvest index.

Alpha Amylase Determination

Colorimetric method for the determination of alpha amylase activity (ICC method) was used as outlined by Harald Perten (1966).

3.7.2 Soil Parameters

Soil Moisture Content

Soil moisture content was determined using Neutron Probe as described by Greacen (1981), after every 0.3 meter (m) layer, until 0.9m depth. The Neutron Probe was calibrated insitu using undisturbed core samples. Thereafter, it was inserted in pre-drilled holes in which PVC pipes or aluminum access tubes are inserted to respective depth and counter readings taken. The 0 – 0.15 m moisture content were measured by gravimetric method as per the equation given by Socias and Medrane, (1994):

Soil water content (SWC) = 100(SFW – SDW)/SDW

Where SFW and SDW are fresh and dry weight soil samples.

3.8 Experimental Design

3.8.1 Experiment 1

Thirty nine treatment combinations were laid out in a Randomized Complete Design (RCD) in a shade at Mwea Irrigation Agricultural Development Centre (MIAD), Kenya and was replicated thrice.

3.8.2 General Objective

To evaluate the performance of chickpea seeds under different priming methods and varying priming durations.

3.8.3 Specific Objectives

- Determine the effects of priming on enzyme activities in the germinating seeds
- Determine the effects of varying priming duration on alpha amylase activities in the germinating seeds
- Determine the interaction effects of priming and varying priming durations on alpha amylase activities in the germinating chickpea seeds

Pulse

Ch=Chickpea

Type of Priming (Treatment combinations)

a) No Priming

1=PO

b) Hydro priming

2=HyT_8 = Hydro priming for 8 hours

3=HyT_{10} = Hydro priming for 10 hours

4=HyT_{12} = Hydro priming for 12 hours

c) Halo priming

- HCL1 = Halo priming at 0.1 % ($\mathbf{C_1}$) $NaCl_2$ for $\mathbf{T_8}$, $\mathbf{T_{10}}$ and $\mathbf{T_{12}}$ hrs.

  5 = $NaCl_1T_8$,

  6 = $NaCl_1T_{10}$

  7 = $NaCl_1T_{12}$

- HCL2= Halo priming at 0.2 % ($\mathbf{C_2}$) $NaCl_2$ for $\mathbf{T_8}$, $\mathbf{T_{10}}$ and $\mathbf{T_{12}}$ hrs

  8 = $NaCl_2T_8$,

  9 = $NaCl_2T_{10}$

  10 = $NaCl_2T_{12}$

- HCL3= Halo priming at 0.3 % ($\mathbf{C_3}$) $NaCl_2$ for $\mathbf{T_8}$, $\mathbf{T_{10}}$ and $\mathbf{T_{12}}$ hrs

  11 = $NaCl_3T_8$,

  12 = $NaCl_3T_{10}$

  13 = $NaCl_3T_{12}$

NB: Sodium chloride (NaCl2) used was table salt kensalt

d) Experiment I: Shade experiment layout

Rep 1	Rep 2	Rep 3
1	2	3
4	5	6
7	8	9
10	11	12
13	14	15
16	17	18
19	20	21
22	23	24
25	26	27
28	29	30
31	32	33
34	35	36
37	38	39

e) Fertilizer Application

Triple super phosphate fertilizer at a rate of 40 Kg P_2O_5/ha was used at planting to supply phosphorus. Calcium of Ammonium Nitrate (CAN) fertilizer was applied as a starter nitrogen source at planting time at a rate of 30 kg/ha.

3.8.2 Experiment 2: Field Experiment

An experiment testing effects of three different primes (no priming , hydro priming & halo prime at three levels of i.e. 0.1, 0.2 and 0.3 % $NaCl_2$ concentration) , three priming durations (8, 10 and 12 hours) and one type of pulse (Chickpea- ICCV 97105) on germination, growth and yield was conducted. The experimental design was be a split plot with 13 treatment combinations replicated three times.

Cropping History of the Experimental Field

The history of the experimental field during the preceding three years revealed that since the year 2009, the field was under subsistence maize production with *Biden pilosa* as the main dominant weeds.

General Objective

To evaluate the performance of chickpea under different priming methods, varying priming durations and at different initial soil moisture levels

Specific Objectives

- Determine the effects of priming on growth and yield of chickpea
- Determine the effects of varying priming duration on growth and yield of chickpea
- Determine the interaction effects of priming and varying priming durations on growth and yield of chickpea
- Determine the effects of different pre sowing soil moisture levels on germination, growth and seedling establishment

Pulse

Ch=Chickpea

Type of Priming (Priming treatment combinations)

a) **No Priming**

1=PO

b) **Hydro priming**

2=HyT_8 = Hydro priming for 8 hours

3=HyT_{10} = Hydro priming for 10 hours

4=HyT_{12} = Hydro priming for 12 hours

c) **Halo priming**

- HCL1= Halo priming at 0.1 % ($\mathbf{C_1}$) $NaCl_2$ for $\mathbf{T_8}$, $\mathbf{T_{10}}$ and $\mathbf{T_{12}}$ hrs.

  5=HCL_1T_8,

  6=HCL_1T_{10}

  7=HCL_1T_{12}

- HCL2= Halo priming at 0.2 % ($\mathbf{C_2}$) $NaCl_2$ for $\mathbf{T_8}$, $\mathbf{T_{10}}$ and $\mathbf{T_{12}}$ hrs

  8=HCL_2T_8,

9=HCL_2T_{10}

10=HCL_2T_{12}

- HCL3= Halo priming at 0.3 % ($\mathbf{C_3}$) $NaCl_2$ for $\mathbf{T_8}$, $\mathbf{T_{10}}$ and $\mathbf{T_{12}}$ hrs

11=HCL_3T_8,

12=HCL_3T_{10}

13=HCL_3T_{12}

- Priming's=Sub plots

Irrigations

- 1st Pre-sowing irrigation to have soils at field capacity (FC), 75 % FC, 50 % FC and 25 % FC=Main plot

FC=Field capacity

100% FC

75% FC

50% FC

25% FC

Field layout for the field experiment

25% FC	1	2	3	4	5	6	7	8	9	10	11	12	13
50% FC													
75% FC													
100% FC													

Block I

25% FC	1	2	3	4	5	6	7	8	9	10	11	12	13
50% FC													
75% FC													
100% FC													

Block 2

25% FC	1	2	3	4	5	6	7	8	9	10	11	12	13
50% FC													
75% FC													
100% FC													

Block 3

Experimental models

The shade experiment model

- Complete Randomized Design (RCD) was used

$Y_{ij} = \mu + Ti + \epsilon ij$

Where:

Y_{ij} = observations corresponding to i^{th} priming effect and j^{th} replication

μ = Overall mean;

Ti = i^{th} priming effect;

ϵ_{ij} = Random error component.

Field Experimental model

- For field experiment, split plot design was used;

$Y_{ijk} = \mu + \Theta i + \alpha j + \epsilon j(i)w + \gamma\kappa + (\alpha\gamma)_{jk} + \epsilon k_{(ij)}s$

Where:

Y_{ijk} = observations corresponding to i^{th} irrigation effect on the j^{th} treatment of the K^{th} priming block effect of the whole plot;

U = general mean;

Θi = i^{th} block effect;

αj = effect of j^{th} irrigation on the whole plots;

$\epsilon j(i)w$ = random effect of the whole plots;

$\gamma\kappa$ = effect of the k^{th} priming effect;

$(\alpha\gamma)_{jk}$ = interaction effect of j^{th} irrigation on the whole plots and k^{th} priming on the split plots;

$\epsilon k_{(ji)}s$ = random effect of the split plots(split plot error term).

3.9 Data Analysis and Production Functions

Analysis of variance of data collected was done using GEN STAT program package version 13 and significant different mean were separated using the Turkey least significant difference (LSD at $P \leq 0.05$). Regression analysis were carried out using computer excel program and dependent

varables like DM, height, grain yield and grain yield attributes related to independent vaarieables (% FC, primation durations and priming concentrations). Regression analysis was done according to Little and Hill(1978). Production functions relating % FC, priming and priming durations were computed and graphs drawn using Microsoft Excel and Power Point. Seasonal % FC, priming and priming durations was related to germination, growth parameters (plant height, DM/ha), grain yield attributes (pods/plant, pods/m^2, 100 seed weight) and grain yield (kg/ha).

CHAPTER FOUR

RESULTS

4.1 Effects of Priming on Alpha (α) Amylase Enzyme activity

4.1.1 Effects of Priming Chickpea Seeds on Alpha (α) Amylase Enzyme activity

Alpha (α) - amylase activity estimates are given in Table 1 below. Amylase activity was expressed in terms of μmoles/ml of maltose (maltose units) produced by 1 ml of enzyme solution at 37°C for 30 min. Treatment combinations of $NaCl_2$ – 0.1% for 8 hrs (HCL1T8) and $NaCl_2$ – 0.1% for 12 hrs (HLC1T12) had significantly the highest α-amylase enzyme activities at sowing, 4 days after sowing (DAS) and 8 DAS (Table 1 and Fig 1 & 2).

Table 1: Effects of priming chickpea seeds on alpha amylase enzyme activity

Treatment	*alpha amylase at sowing (μmoles/ml)*	*alpha amylase 4DAS (μmoles/ml)*	*alpha amylase 8 DAS (μmoles/ml)*
P0	7.05f	8.17d	10.20f
HYT8	8.20be	9.80d	12.00ef
HYT10	12.70a	15.93b	19.13cd
HYT12	8.67de	14.90c	17.23d
HCL1T8	12.97a	18.17a	23.97a
HCL1T10	11.30c	17.03a	23.30a
HLC1T12	12.07ab	18.03a	23.10a
HCL2T8	12.07ab	16.10b	24.47a
HCL2T10	12.03ab	16.43b	24.40a
HCL2T12	12.43a	14.97bc	19.97c
HCL3T8	9.53d	13.60c	20.90bc
HCL3T10	11.33bc	15.07b	22.37ab
HCL3T12	11.57b	16.67ab	23.67a
LSD	0.97	1.70	2.11
CV%	5.30	6.70	6.20

Means within a column followed by the same letter are not significantly different at $P \leq 0.05$

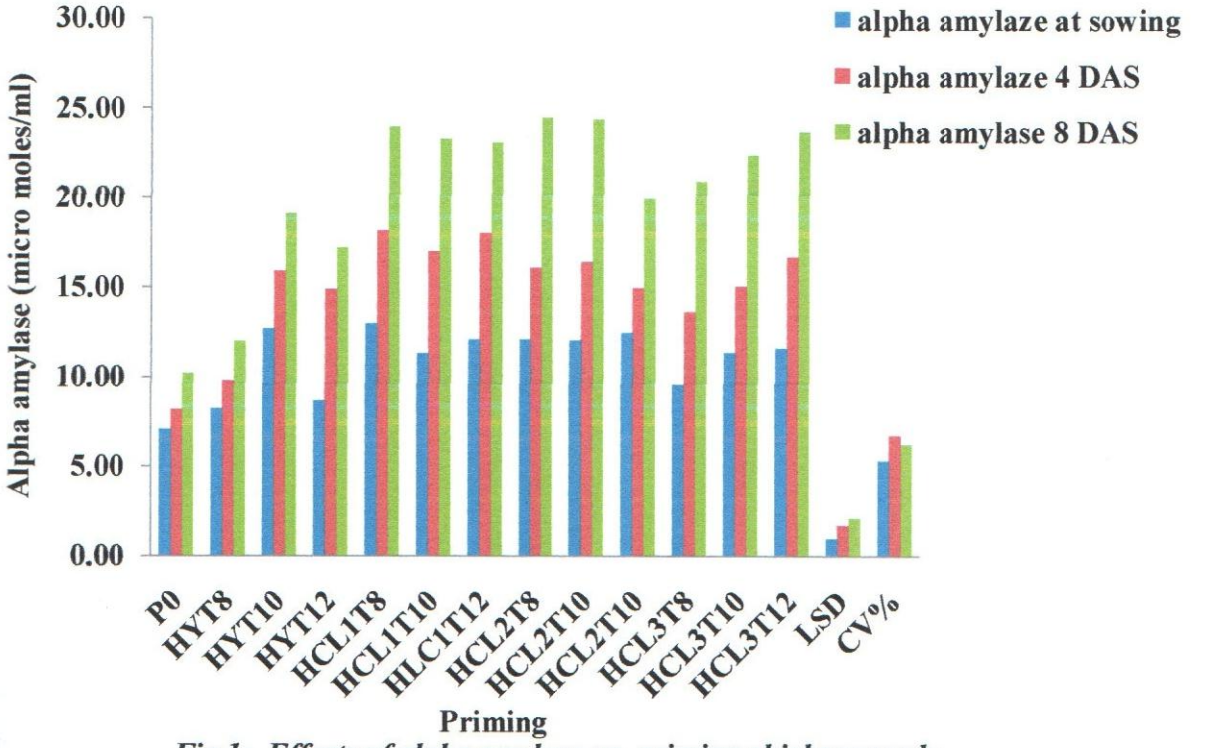


Fig 1: Effects of alpha amylase on priming chickpea seeds

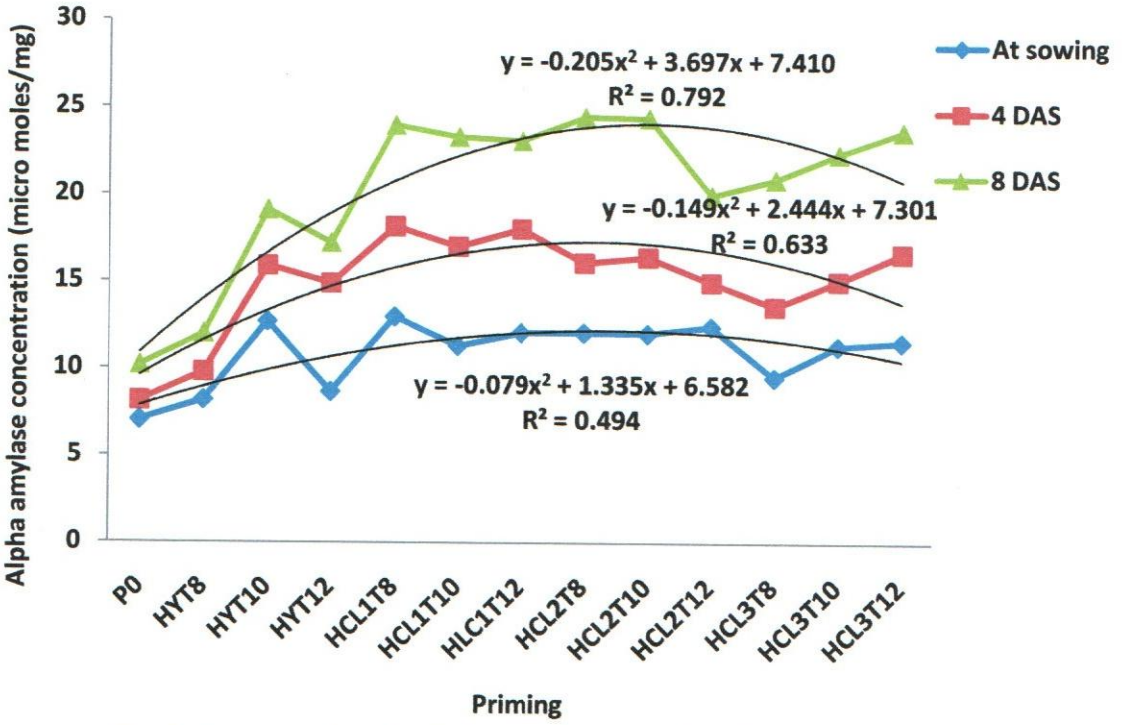


Fig 2: Relationship of priming and priming duration to concentration (micro moles/mg) of alpha amylase

4.1.2 Effects of Priming Chickpea seeds at Sowing on α - Amylase Activity

The highest α- Amylase (12.97 µmoles/ml) activity was with treatment combinations HCL1T8 which was statistically equal to HYT10 (12.70 µmoles/ml), HCL2T12 (12.43 µmoles/ml) HLC1T12 (12.07 µmoles/ml), HCL2T8 (12.07 µmoles/ml), and HCL2T10 (12.03 µmoles/ml) (Table 1).

4.1.3 Effects of Priming Chickpea on α- Amylase Activity 4 DAS

HCL1T8 (18.17), HLC1T12 (18.03), HCL1T10 (17.03) and HCL3T12 (16.67) had significantly the highest alpha amylase activities four days after sowing (DAS) (Table 1).

4.1.4 Effects of Priming Chickpea seeds on α- Amylase Activity 8 DAS

HCL2T8 (24.47), HCL2T10 (24.40), HCL1T8 (23.97), HCL3T12 (23.67), HCL1T10 (23.30), HLC1T12 (23.10), and (HCL3T10 (22.37) had significantly higher enzyme activities than other treatment combinations. Control had the least enzymatic activities (Table 1).



Plate 2: Priming the 13 treatment combinations in the laboratory



Plate 3: Layout of poly bags planted with primed seeds under a shade



Plate 4: Primed germinated chickpea under shade



Plate 5: Lab dried primed chickpea plant samples for alpha amylase analysis

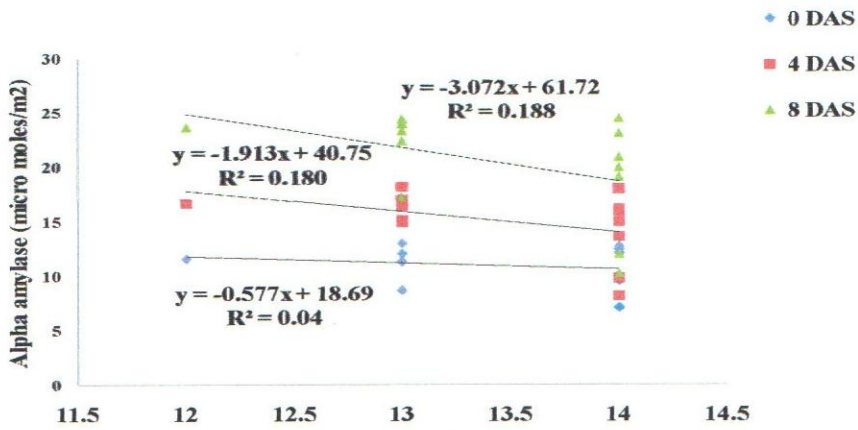


Fig 3: Relationship of alpha amylase content in germinating seed (0-4 DAS) hypocotyle growth (4 DAS) & seedling emergency - 2 leaves (8 DAS) with plants/m2 at 7 DAS

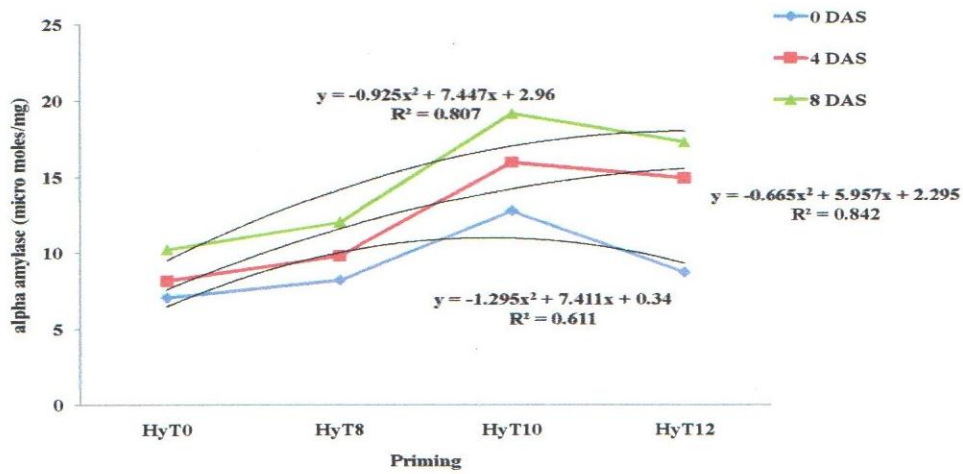


Fig 4: Relationship of hydro priming and priming duration to concentration (micro moles/mg) of alpha amylase

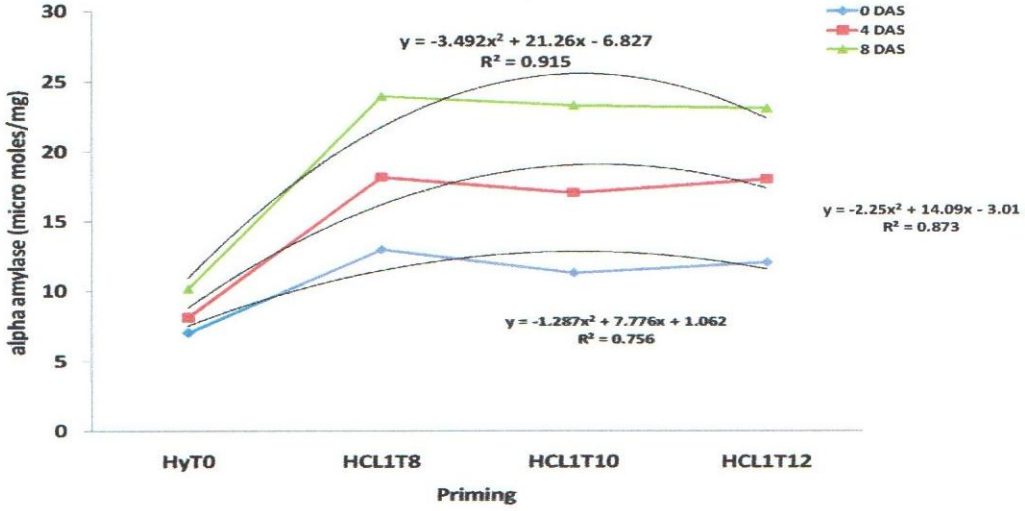


Fig 5: Relationship of halo priming (0.1 % Nacl2) and priming duration to concentration (micro moles/mg) of alpha amylase

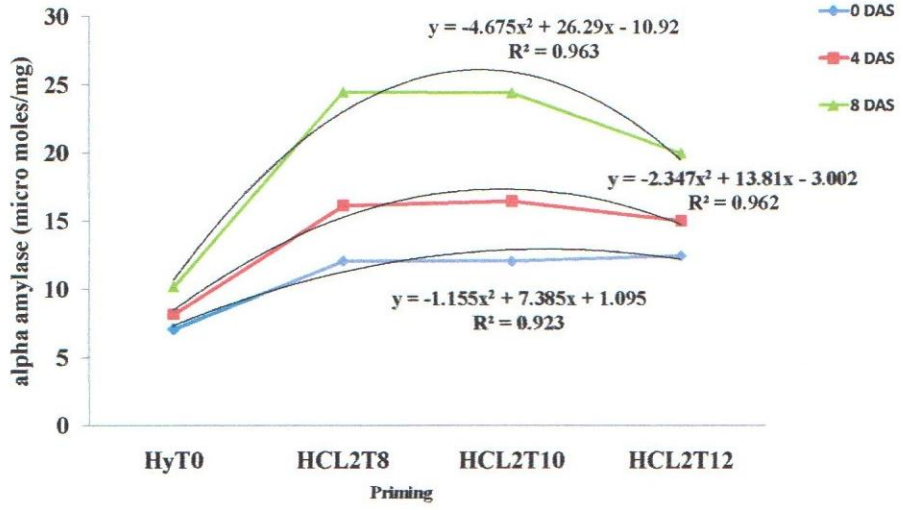


Fig 6: Relationship of halo priming (0.2 % Nacl2) and priming duration to concentration (micro moles/mg) of alpha amylase

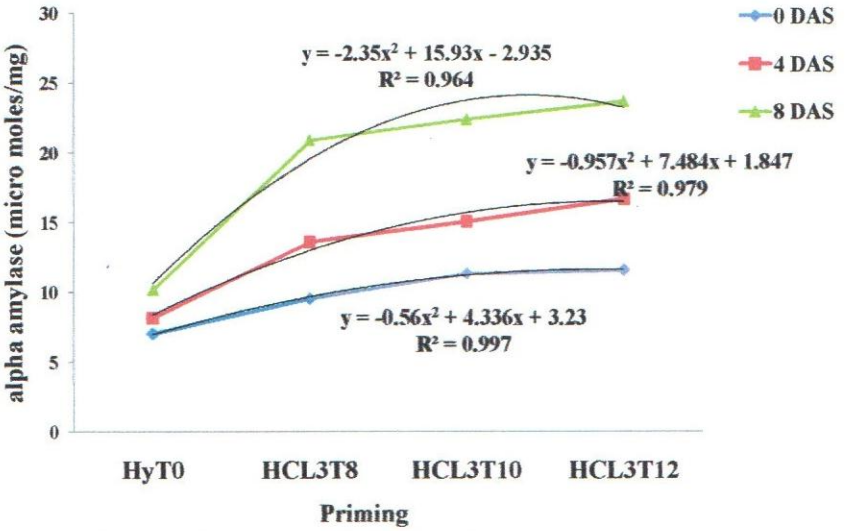


Fig 7 : Relationship of halo priming (0.3 % Nacl2) and priming duration to concentration (micro moles/mg) of alpha amylase

4.2 Effects of Treatments on Germination of Desi Chickpea ICCV 97105

4.2.1 Effect of Pre-sowing Irrigation at 25%, 50%, 75% and 100% Field Capacity (FC) on Chickpea Crop Germination (plants/m^2) in Season I and II

Table 2 shows that increasing pre sowing irrigation from 25% field capacity (25% FC) to 100% FC, increased plants/m^2 in both season I and II which were however, not significantly different. Plant population density increased from 11-15 plants/m^2 in season I (SI) and 5-6 plants/m^2 in season II (SII), respectively (Table 2) in response to pre sowing irrigation (Fig. 10 & 12). The plants/m^2 increased with increase in pre-sowing irrigation with the highest plant density/m^2 occurred 100% FC in season I and at 75% field capacity in season II. The increase in plant/m^2 by the 11^{th} days after sowing (DAS) was explained by the power equation (1) $y = 10.45x^{0.256}$ with a good fit $R^2 = 0.78$) for season I and equation. (2) $y = 4.859x^{0.15}$ with an $R^2 = 0.74$ (Fig.10).

There was a strong positive correlation (of 0.939 - SI and 0.894 - SII) between soil water at sowing and plants/m^2 at emergence of desi chickpea in Mwea.

Table 2: Effect of Pre Sowing Irrigation and Priming on chickpea DM at 25, 50, 75, 90 and 105 DAS

	Plants/m^2		Dry matter (kg/ha)									
	7 DAS		25 DAS		50 DAS		75 DAS		90 DAS		105 DAS	
	SEASONS											
	I	II	I	II	I	II	I	II	I	II	I	II
Main Plot: Irrigation												
$I_{25\%FC}$	11	5	75.2	36.6	197.1b	85.5	511.0c	329	3000.0c	1709	3375.6	2652
$I_{50\%FC}$	11	5	75.8	37.5	230.4a	128	512.0c	336	3377.0bc	1738	3835.2	2755
$I_{75\%FC}$	14	6	83.3	47.5	234.1a	119.2	707.0b	385	4097.0a	2480	4610.1	3657
$I_{100\%FC}$	15	6	91.6	52.2	224.7ab	137.9	982.0a	447	4524.0a	2851	5001.1	3973
LSD (P<0.05)	10	4	13.33	37.46	30.99*	98.33	172.9*	209.1	718.4*	1976.3	3533.11	2949.6
Sub-plot: Priming												
HyT_0	14a	6bc	99.6bc	56.0a	228.3ab	119.2a	671.0c	448.0b	4153.0b	2408.0ab	4593.8a	3323a
HyT_8	14a	7ab	79.7d	49.6ab	216.2b	132.5a	646.0c	396.0b	4035.0bc	2621.0a	4502.9a	3807a
HyT_{10}	14a	4de	56.7e	26.4c	192.5bc	67.1b	655.0c	218.0d	3840.0c	1675.0c	4318.3a	2708b
HyT_{12}	13a	7ab	79.2d	56.1a	202.5b	144.6a	565.0d	381.0bc	3920.0c	2795.0a	4337.7a	3763a
HCL_1T_8	14a	8a	63.4e	36.6bc	143.8d	108.3b	526.0d	329.0c	3678.0cd	2009.0b	4241.8a	3374a
HCL_1T_{10}	13a	7ab	65.8de	37.7b	200.2b	130.3a	618.0c	389.0b	4122.0b	2187.0b	4563.7a	3261ab
HCL_1T_{12}	14a	7ab	104.8b	53.6a	208.3b	109.6ab	803.0b	398.0b	3695.0c	1813.0bc	4101.3ab	2862b
HCL_2T_8	14a	7ab	126.8a	60.2a	229.2a	141.7a	1073.0a	688.0a	5092.0a	3074.0a	5559.7a	4048a
HCL_2T_{10}	13a	5cd	71.3d	41.2b	233.3a	152.7a	815.0b	462.0b	3095.0d	1958.0b	3580.2b	2832b
HCL_2T_{12}	14a	6bc	100.2b	51.6a	164.2cd	116.2a	735.0bc	449.0b	4647.0ab	2880.0a	5186.4a	4131a
HCL_3T_8	14a	4de	80.7d	36.8b	273.3a	156.2a	542.0d	299.0cd	4378.0b	2348.0b	4833a	3406a
HCL_3T_{10}	13a	3e	73.3d	30.3c	205.4b	87.1b	548.0d	229.0d	3270.0d	1304.0c	3667.3b	2436b
HCL_3T_{12}	12b	3e	82.0cd	29.0c	219.6b	64.2b	617.0cd	179.0d	4195	1459.0c	4562.3a	2425b
LSD P≤0.05	1.6	1.3	17.21*	18.61*	46.85*	46.82*	126.6*	119.2*	643.8*	703.6*	1867.6*	1252.2*
CV%	36.9	7	8	43.1	7.4	41.8	12.8	28	9	45.1	11.1	26.2

Means within a column followed by the same letter are not significantly different at P≤0.05

4.2.2 *Effect of Priming on Chickpea Crop Germination (plants/m^2)*

Priming chickpea seed before sowing did not show any significant differences in season I where plant population ranged between 12 to 14 plants/m^2. In season II, plant population ranged between 3 and 8 plants/m^2 and the treatment combinations HCL_1T_8 (8 plants), HCL_1T_{10} (7 plants), HCL_1T_{12} (7 plants), HCL2T8 (7 plants) and HyT_{12} (7 plants) had significant higher number of plants/m^2 (Table 2).

Halo priming (0.3% $Nacl_2$) for 12 hours (HCL3T12) gave the lowest plants/m^2 in both seasons (Table 1). The treatment combination had plant germination of 12 and 3 plants/m^2 in season I and II, respectively which was significantly lower than the other treatment combinations (Table 2 and Fig. 12).

4.2.3 *Interaction Effects of Pre Sowing Irrigation (% FC) and Priming on Germination (plants/m^2)*

There were no interaction effects during season I. However, in season II pre sowing irrigation 50%FC with (HyT_8 and HyT_{12}); 75% FC (HyT_{12}, HCL1T8, HCL1T10, HCL1T12, HCL2T10 and HCL_2T12) had significantly higher plants/m^2 at germination (Table 3).

Table 3: Interaction effects of pre sowing irrigation (%FC) and priming on germination (plants/m^2) during season II

Irrigation	Priming												
	HyT_0	$Hy T_8$	$Hy T_{10}$	$Hy T_{12}$	$HCL_1 T_8$	$HCL_1 T_{10}$	$HCL_1 T_{12}$	$HCL_2 T_8$	$HCL_2 T_{10}$	$HCL_2 T_{12}$	$HCL_3 T_8$	$HCL_3 T_{10}$	$HCL_3 T_{12}$
$I_{25\%FC}$	5b	5b	3b	5b	4b	5b	4b	4b	3b	5b	4b	3b	1c
$I_{50\%FC}$	5b	6ab	4b	6ab	5b	5b	5b	5b	3b	5b	4b	2bc	4b
$I_{75\%FC}$	6ab	7a	5b	8a	10a	6ab	6ab	5b	6ab	6ab	5b	3b	4b
$I_{100\%FC}$	7a	5b	5b	6ab	8a	8a	8a	6ab	6ab	5b	5b	3b	4b
LSD	4.4		CV %	14.9									

4.3 Effects of Treatments on Growth of Desi Chickpea ICCV 97105

4.3.1 Effect of Pre-sowing Irrigation at 25%, 50%, 75% and 100% Field Capacity on Dry Matter of Chickpea in Season I and II

Dry matter accumulation (kg/ha) increased with increasing time of growth, i.e. from 25 DAS to 105 days after sowing (DAS) in both season I and II under the varying pre sowing irrigation conditions (Table 2). Dry matter also increased with increased pre sowing irrigation from 25 % field capacity (25% FC) to 100% FC at every stage of growth i.e., 25,50,75,90 and 105 DAS (Table 2), in both season I and II. Regression Correlation coefficients for irrigation to dry matter relationships, was very high at 0.91 and 0.92 at 25 DAS (Fig. 24), 0.98 and 0.80 at 50 DAS (Fig 25), 0.99 and 0.99 at 75 DAS (Fig. 26) , 0.99 and 0.94 at 90 DAS (Fig. 27), 0.98 and 0.93 at 105 DAS (Fig. 28), for both season I and II, respectively. The highest dry matter was realized at 105 DAS which was 5001.1 and 3973.0 kg/ha (kg/ha) in season I and II, respectively under 100 % FC (Table 2).

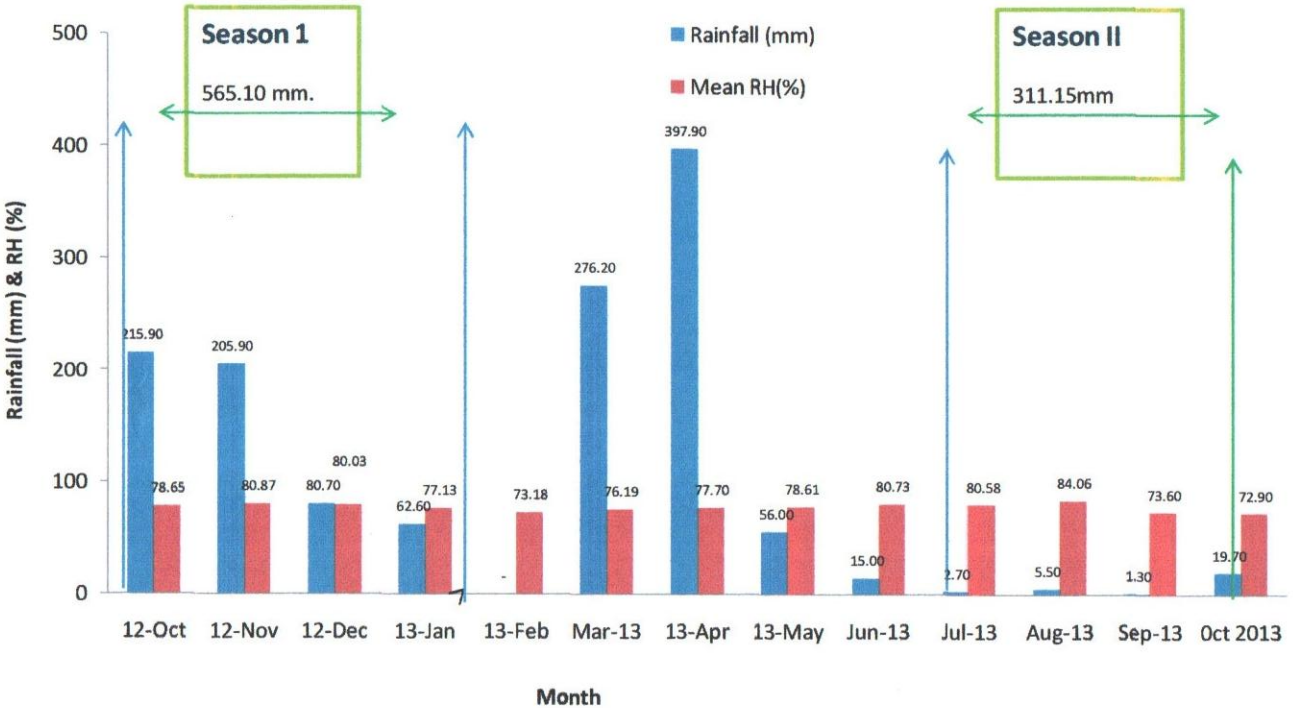


Fig 8: Rainfall (mm) and Relative Humidity (%) during Season I and II

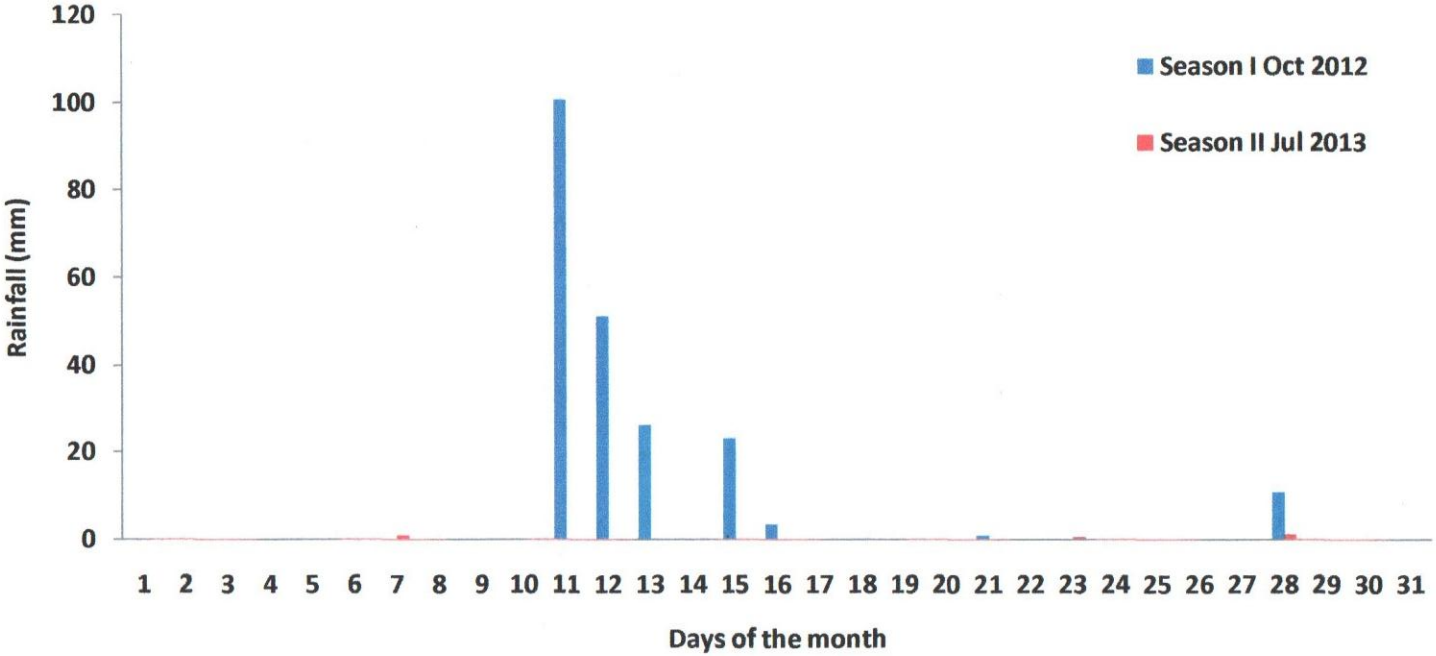


Fig 9: Rainfall received at sowing of chickpea in Mwea for SI (Oct 2012) and SII (Jul 2013)

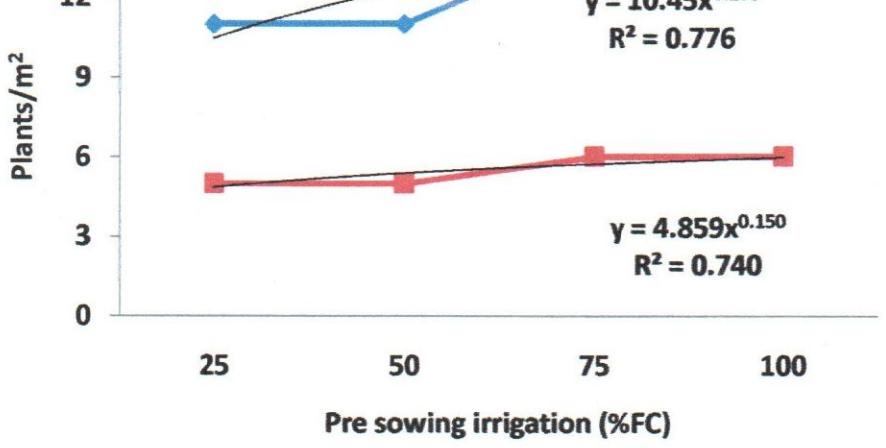


Fig 10: Relationship of pre sowing irrigation to plants /m² of chickpea in semi arid Mwea

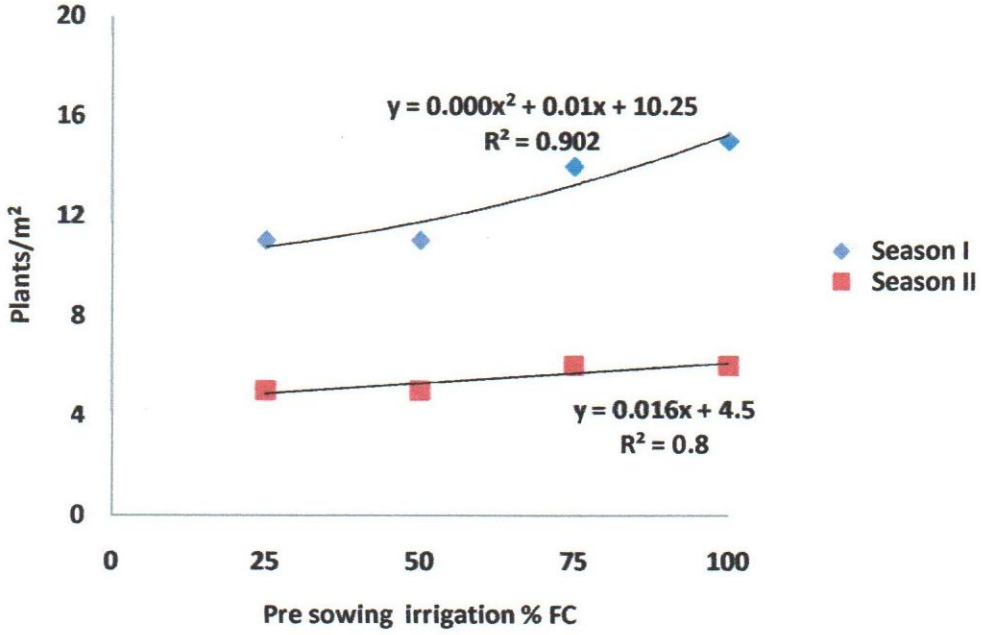


Fig 11: Relationship of pre sowing irrigation to plants /m² of chickpea in semi arid Mwea

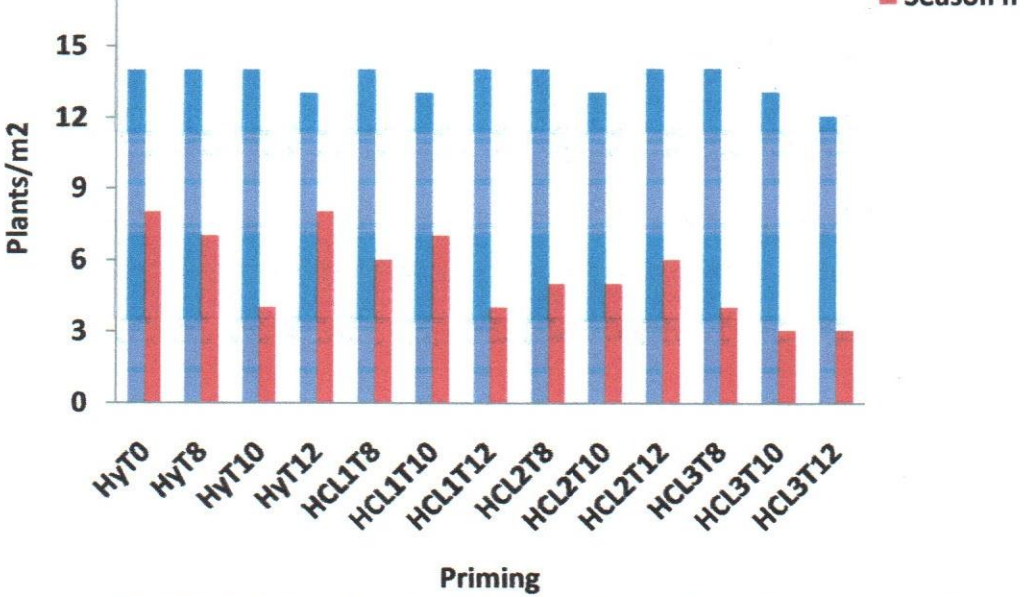


Fig 12: Relationship of priming on plants/m² of chickpea in semi arid Mwea

Effect of Pre-sowing Irrigation at 25%, 50%, 75% and 100% Field Capacity on Chickpea Growth and Crop Growth Rate

It was evident that growth of chick pea increased at an increasing rate from the 25 DAS to 90 DAS, after which it slowed down to give a sigmoid curve (Fig. 13, 15, 17 and 19). The growth rate curves followed a similar pattern (Fig. 14, 16, 18 and 20). The Crop growth rate (CGR) at 25 % FC was highest (39.3 kg/ha/day in season I & 17.9 kg/ha/day for SII) between 50-75 DAS, period of early branching and flowering (EBF), followed by (120 kg/ha/day in season I & 68.4 kg/ha/day for SII) between 75 – 90 DAS (Table 4), the period from branching and podding (B-Fl-P).

The chickpea crop growth rate (CGR) at 50 % FC was highest (135.1 kg/ha/day for SI & 69.5 kg/ha/day for SII) between 75 to 90 DAS, the period from branching and podding (B-Fl-P), (Table 4 and Fig.16).

The Crop growth rate (CGR) at 75 % FC was highest (163.9 kg/ha/day for SI & 99.2 kg/ha/day for SII) between 75 to 90 DAS, the period from branching and podding (B-Fl-P), (Table 4 and Fig.18)

The desi chickpea crop growth rate (CGR) at 100 % FC was highest (181.0 kg/ha/day for SI & 114.0 kg/ha/day for SII) between 75 to 90 DAS, the period from branching and podding (B-Fl-P), (Table 4 and Fig. 20).

Table 4: Effect of pre-sowing irrigation at 25%, 50%, 75% and 100% field capacity on chickpea crop growth rate (kg/ha/day)

Pre sowing irrigation	25%FC		50%FC		75%FC		100%FC	
Growth phase	CGR SI	CGR SII	CGR SI	CGR SII	CGR SI	CGR SII	CGR SI	CGR SII
0-25 - Emergence & establishment	3.3	1.5	3.0	1.5	3.3	1.9	3.7	2.1
25-50 -Vegetative Lag	7.9	3.4	9.2	5.1	7.4	4.8	9.0	5.5
50-75 - Early branching & flowering	39.3	17.9	28.3	15.4	20.5	13.4	20.4	13.2
75-90 - Branching & podding	120.0	68.4	135.1	69.5	163.9	99.2	181.0	114.0
90-105 - Maturity	135.0	106.1	153.4	110.2	184.4	146.3	200.0	158.9
DM (kg/ha)	3000.0	1709.0	3377.0	1738.0	4097.0	2480.0	4524.0	2851.0
Grain yields (kg/ha)	943.0	375.6	1017	458.2	1177.0	513.1	1122.0	477.1

The maximum/optimum crop growth rate (CGR) of desi chickpea was achieved with 100% FC during wet season I (October, 2012-January, 2013) which was 181.0kg DM/ha/day, while it was 114 kg DM/ha/day with 90-96% FC during the drier season II (July -Oct 2013). Desi chickpea grows slowly under low seasonal rainfall (311.2 mm) than higher seasonal rainfall (565.1 mm). Therefore, it is necessary to apply higher pre sowing irrigation of up to 100% FC in dry areas. Relating CGR during 75-90 days after sowing (DAS) phase period with DM and CGR to grain yield (Fig. 22) at harvest 120 DAS revealed that it is possible to predict DM and grain yield with 80.5 and 77.5% confidence by use of linear production functions:

DM (at harvest) =2480+9.777x (i)

Grain yield=875.2+1.46x (ii)

In season II, it was possible to predict DM and grain yield (Fig.23) by use of linear production functions:

DM (at harvest) =1320+11.62x (R^2=0.762) (iii)

Grain yield=361.5+1.256x (R^2=0.837) (iv)

This has great implications as it enables planning for harvest, storage and marketing 30 days prior to final harvesting

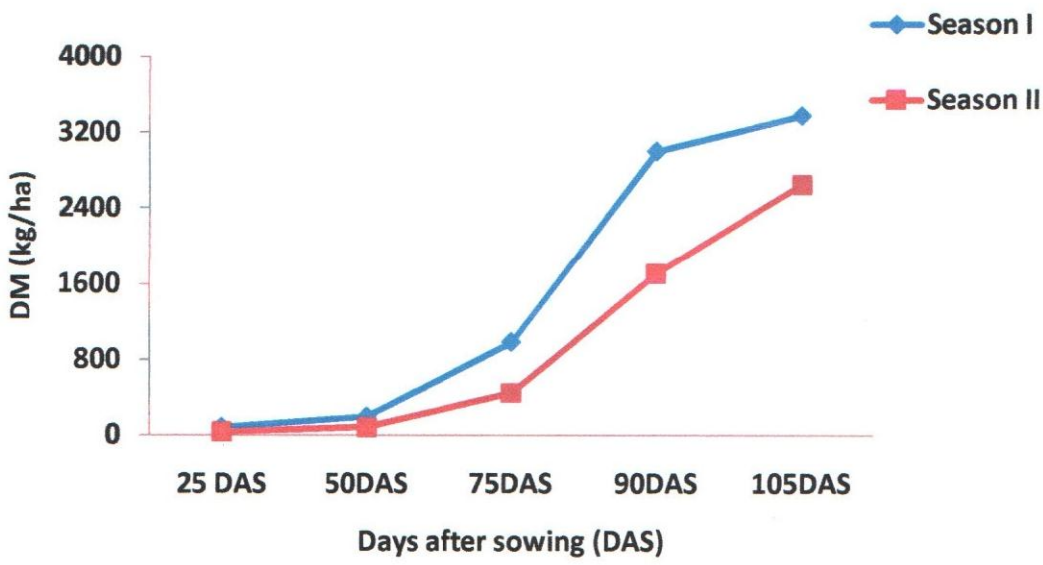


Fig 13: Relationship of 25% FC-Pre sowing irrigation on growth of chickpea in semi arid of Mwea

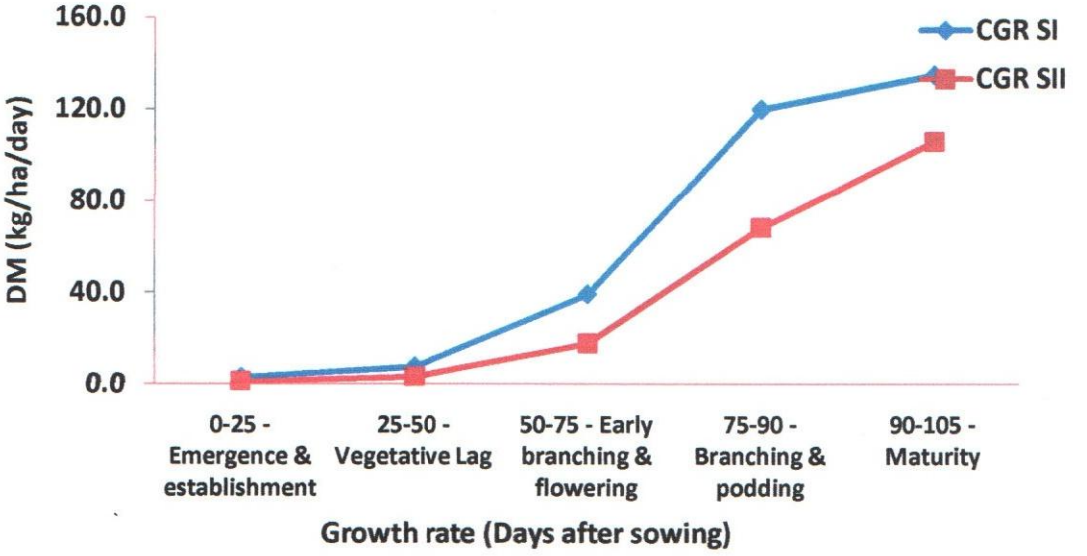


Fig 14: Relationship of chickpea growth rate under 25%FC Pre sowing irrigation in season I & II

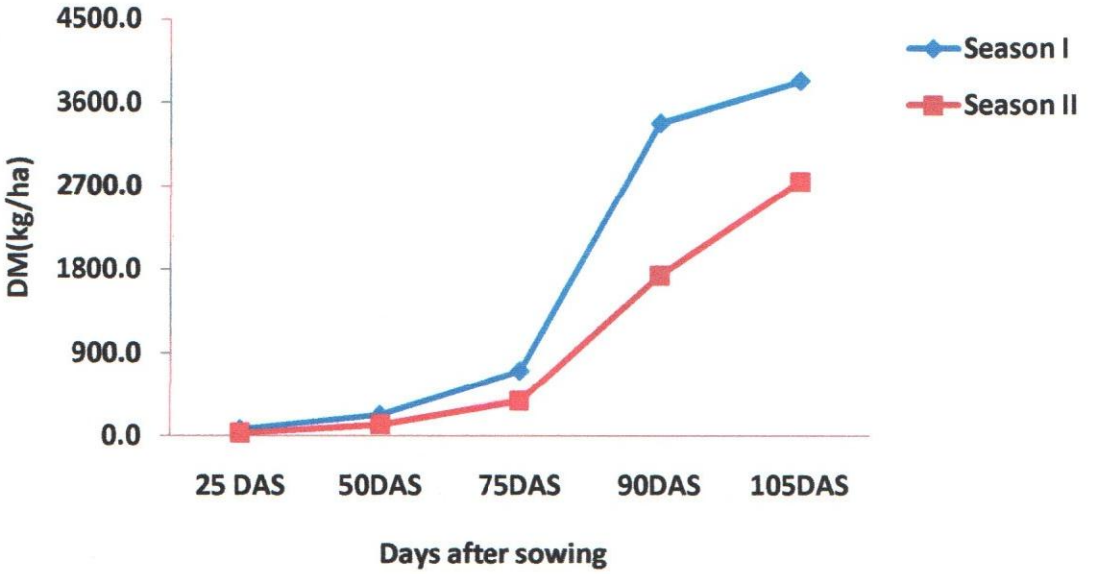


Fig 15: Relationship of 50% FC-Pre sowing irrigation on growth of chickpea in semi arid of Mwea

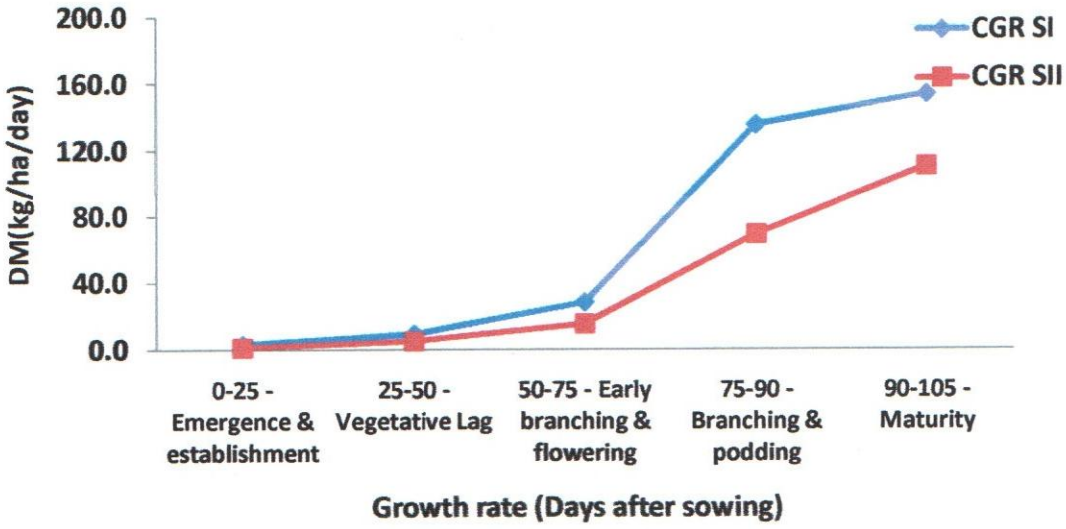


Fig 16: Relationship of chickpea growth rate under 50% FC Pre sowing irrigation in season I & II

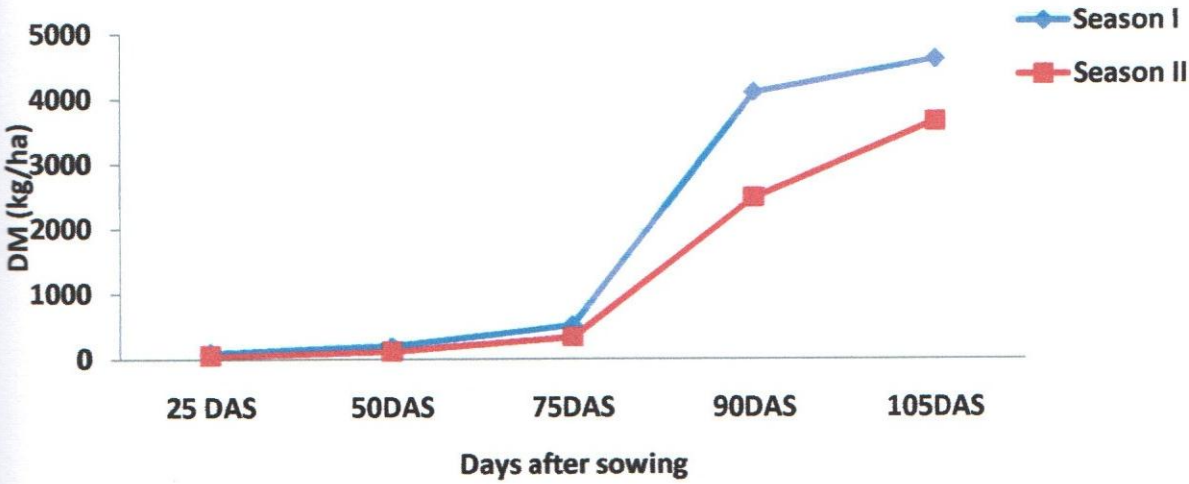


Fig 17: Relationship of 75%FC-Pre sowing irrigation on growth of chickpea in semi arid of Mwea

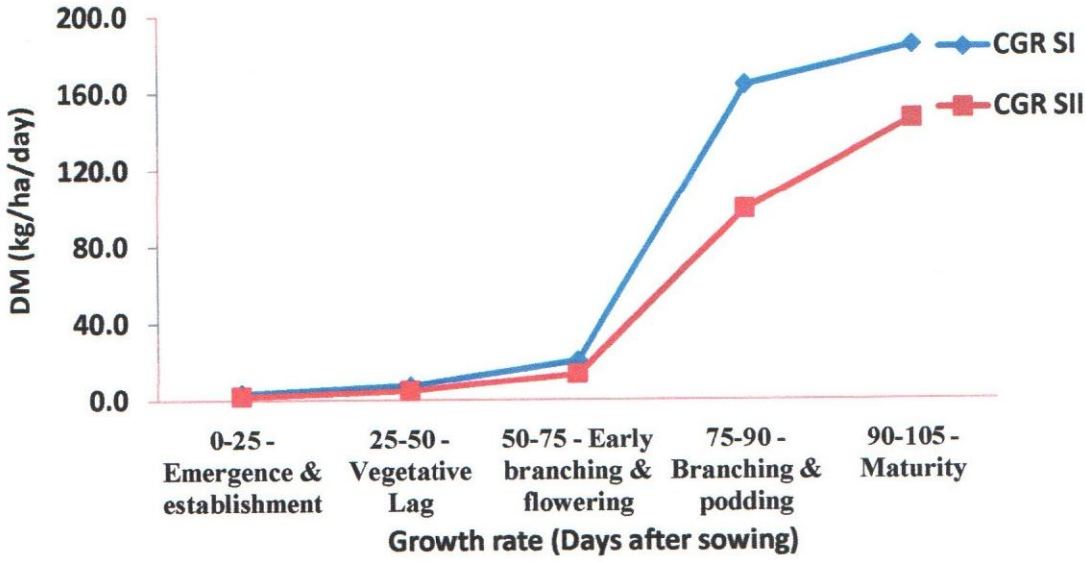


Fig 18: Relationship of chickpea growth rate under 75%FC-Pre sowing irrigation in season I & II

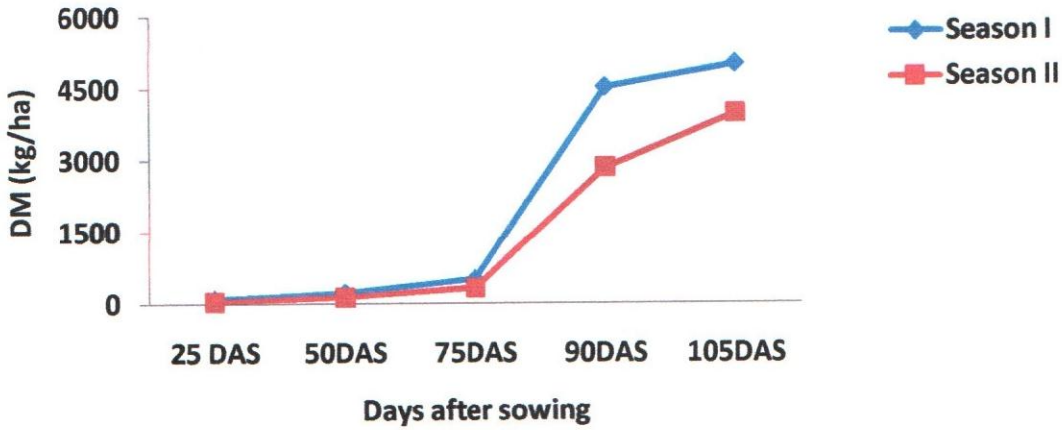


Fig 19: Relationship of FC-Pre sowing irrigation on growth of chickpea in semi arid Mwea

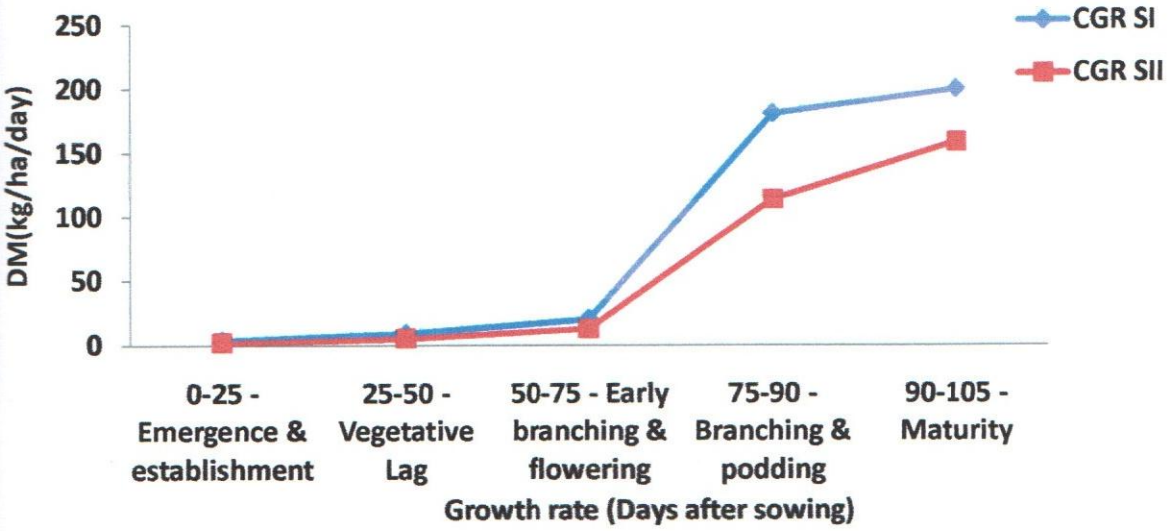


Fig 20: Relationship of chickpea growth rate under 100% FC-Pre sowing irrigation in season I &II

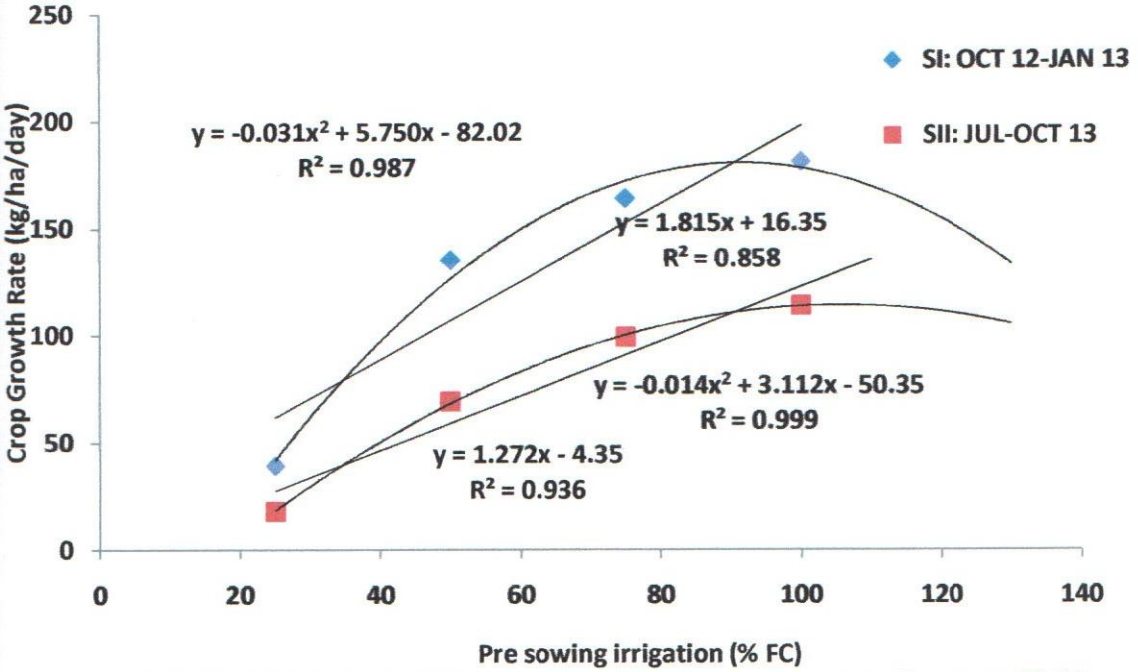


Fig 21: Relationship of pre sowing irrigation to crop growth rate at 75-90 DAS of desi chickpea grown under varying pre sowing irrigation and priming in SI

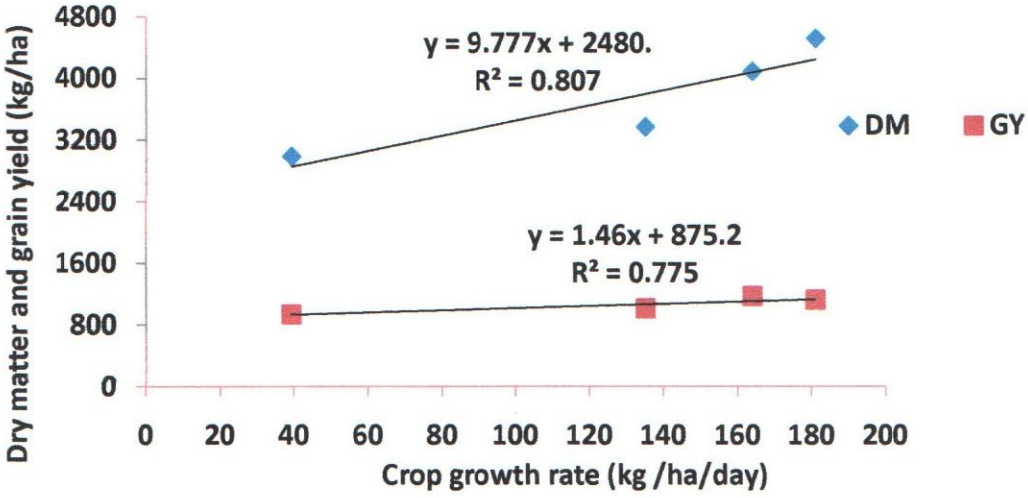


Fig 22: Relationship of CGR at 75-90 DAS -DM and Grain yield at harvest (120 DAS) of desi chickpea grown under varying pre sowing irrigation and priming in SI

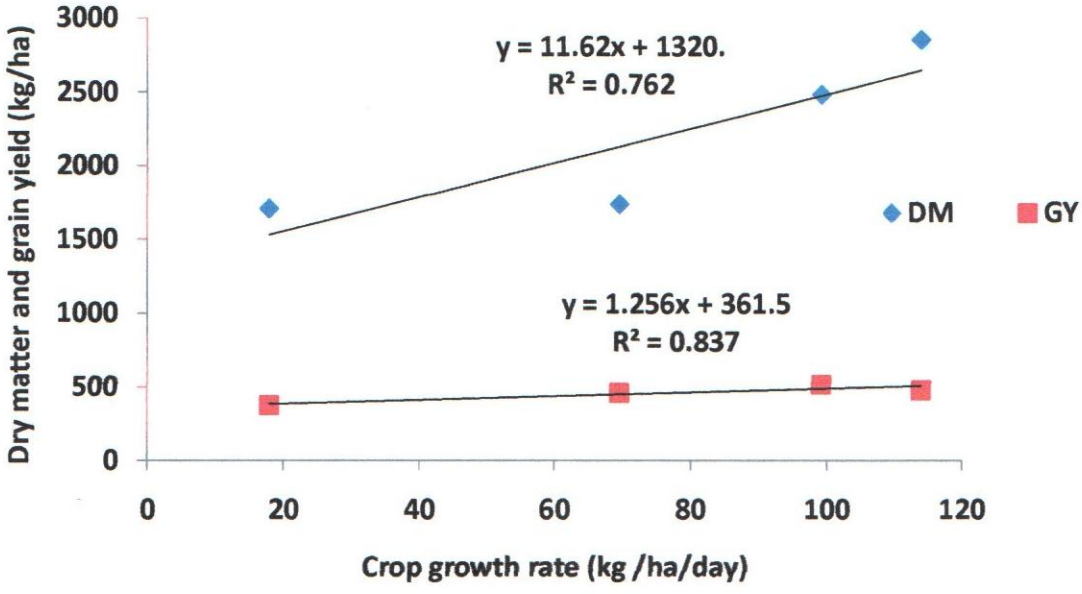


Fig 23:Relationship of CGR at 75-90 DAS -DM and Grain yield at harvest (120 DAS) of desi chickpea grown under varying pre sowing irrigation and priming in SII

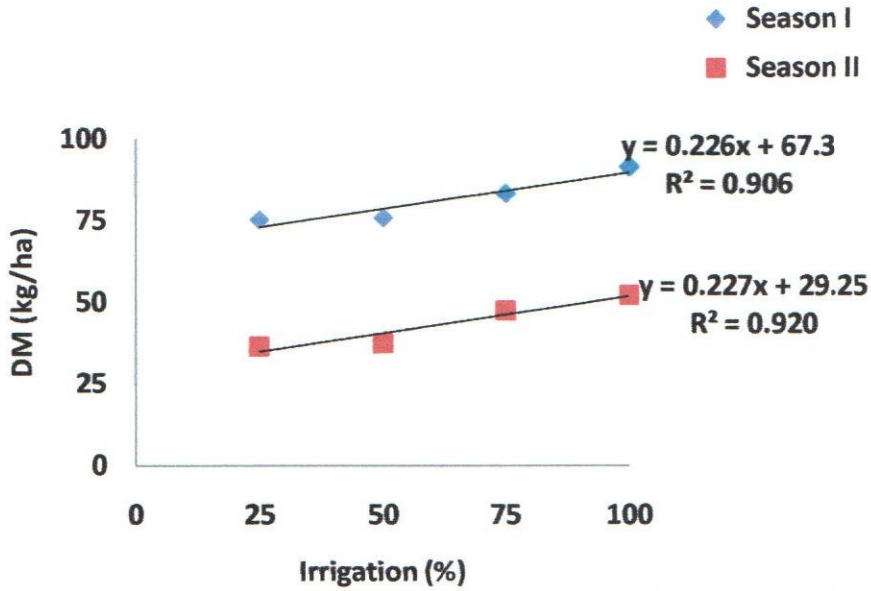


Fig 24: Relationship of pre sowing irrigation (%FC) to dry matter 25 DAS

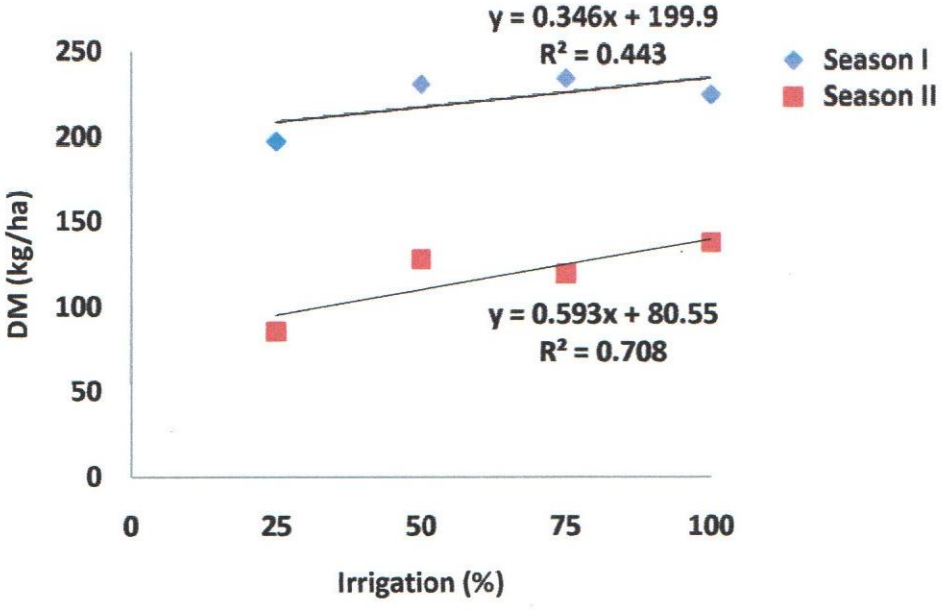


Fig 25: Relationship of pre sowing irrigation (% FC) to dry matter 50 DAS

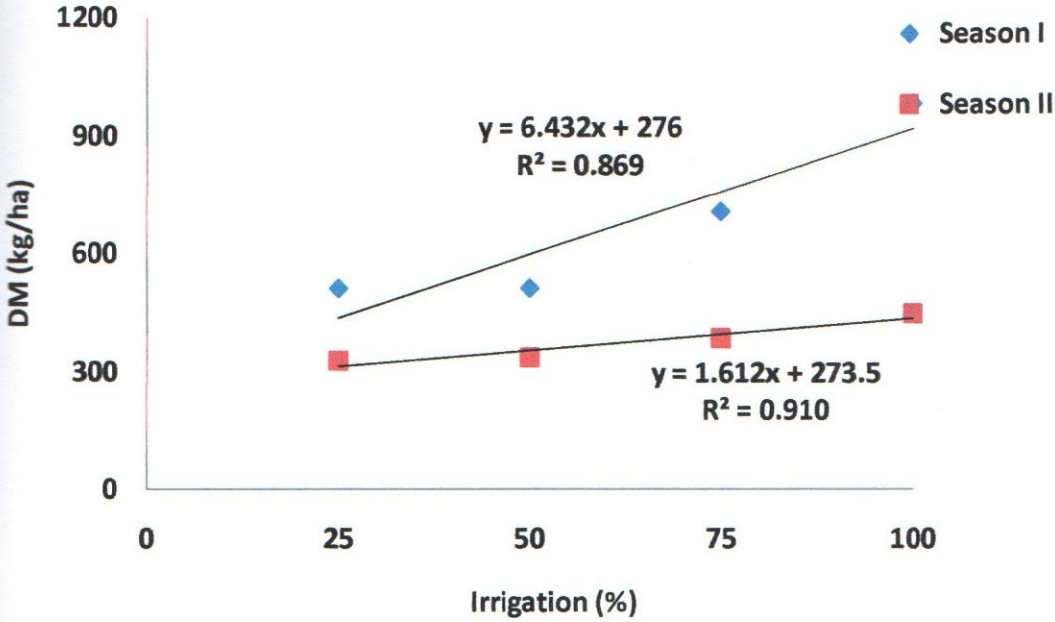


Fig 26: Relationship of pre sowing irrigation (%FC) to dry matter 75 DAS

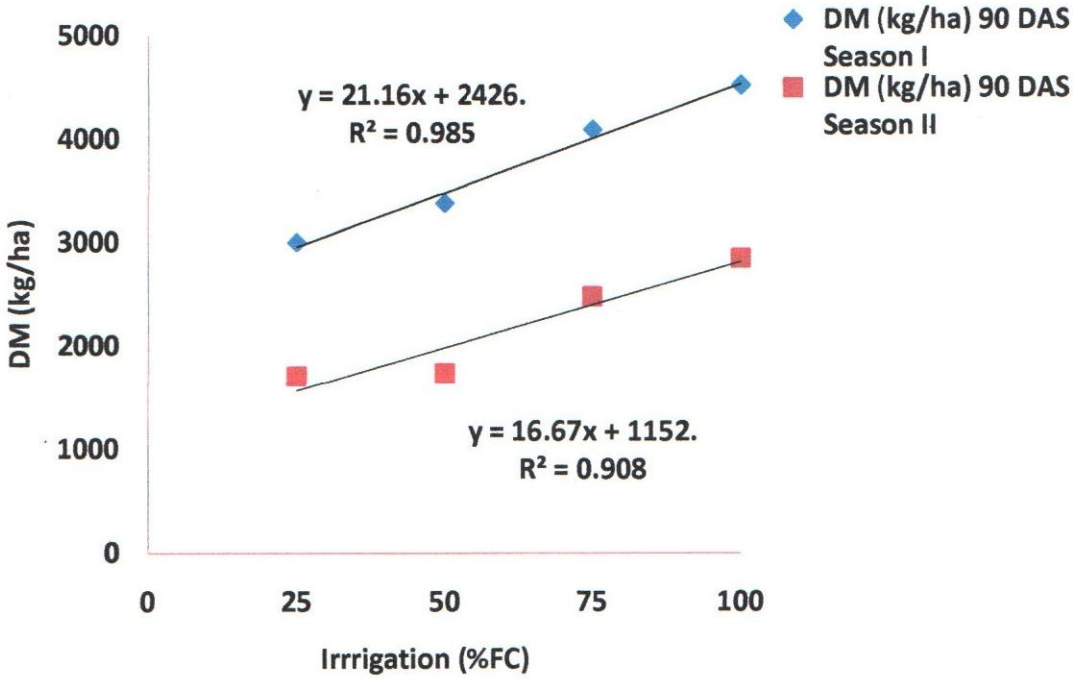


Fig 27: Relationship of pre sowing irrigation to dry matter 90 DAS

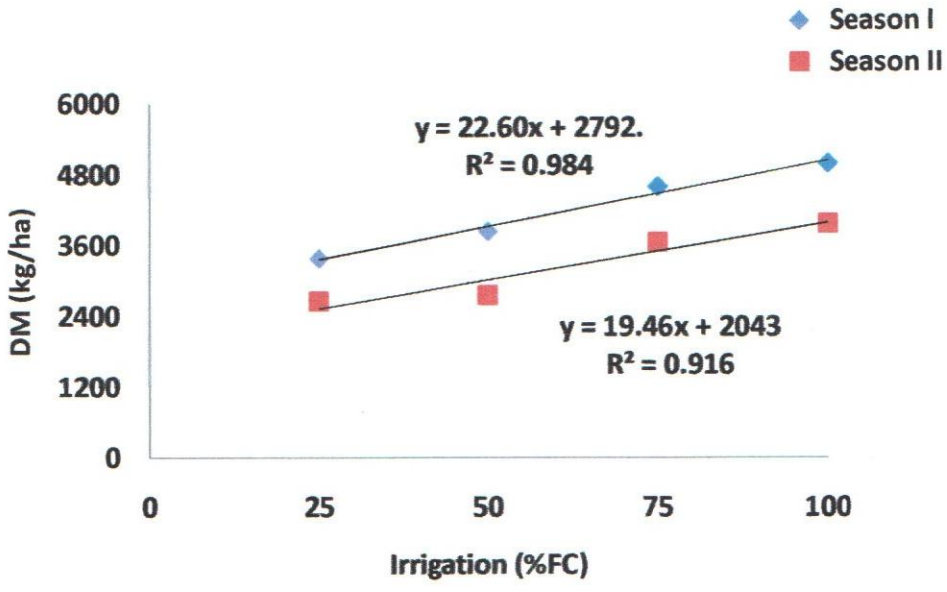


Fig 28: Relationship of pre sowing irrigation (% FC) to dry matter at 105 DAS

4.3.2 Effect of Priming on Chickpea Growth

Effects of Priming on Dry Matter at 25, 50, 75 and 90 DAS

Halo priming for 8 hours (hrs) with $NaCl_2$ at 0.2% gave significantly the highest DM at all stages of growth (Table 2 and Figs. 29, 30, 31, 32).

Effect of Priming on Chickpea DM at 25 DAS

Dry matter (DM) of chickpea at 25 DAS was significantly higher (126.8 kg DM/ha) under the 0.2 % $NaCl_2$ halo priming for 8 hours in SI and SII. In Season II however, it was same with HyT0 (no priming), HyT8 (hydro priming for 8 hours), HyT12 (hydro priming for 12 hrs), HCL1T12 (Halo priming -0.1% Nacl2 for 12 hrs) and HCL1T12 (halo priming-0.1% $NaCl_2$ for 12 hrs), that produced 56.0, 49.6, 56.1, 53.6, 60.2, 51.6 kg DM/ha, respectively (Table 2 and Fig. 29).

Effect of Priming on Chickpea DM at 50 DAS

Chickpea DM at 50 DAS was significantly higher (273.3 and 156.2 kg DM/ha) under the 0.3 % $NaCl_2$ halo priming for 8 hours in SI and SII, respectively. However, in season I these were the same with HCL2T10 (0.2% $Nacl_2$ for 10 hours), HCL2T8 (0.2% $Nacl_2$ for 8 hours) and HyT0

(no priming) that produced 233.3, 229.2 and 228.3 kg DM/ha, respectively. In Season II, these were the same with HyT0 (no priming), HyT8 (hydro priming for 8 hrs), HyT12 (hydro priming for 12 hrs), HCL1T10 (0.1 % $NaCl_2$ for 12 hours), HCL1T12 (0.1 % $NaCl_2$ for 12 hours), HCL2T8 (0.2 % $NaCl_2$ for 8 hours), HCL2T12 (0.2 % $NaCl_2$ for 12 hours), and HCL3T8 (0.3 % $NaCl_2$ for 8 hours), that produced 119.2, 132.5, 144.6, 130.3, 109.6, 141.7, 116.2, and 156.2 DM kg/ha respectively (Table 2 and Fig. 30).

Effect of Priming on Chickpea DM at 75 DAS

Halo priming for 8 hours (hrs) with $NaCl_2$ at 0.2% (HCL2T8) gave significantly the highest DM at 75 DAS of 1073.0 and 688.0 DM (kg/ha) in season I and II, respectively, (Table 2 and Fig. 31).

Effect of Priming on Chickpea DM at 90 DAS

Halo priming for 8 hours (hrs) with $NaCl_2$ at 0.2% (HCL2T8) produced the highest dry matter of 5092.0 and 3074.0 kg/ha in seasons I and II, respectively. These were the same with HCL2T12 (0.2 % $NaCl_2$ for 12 hours) that produced 4647.0 and 2880.0 kg/ha in season I and II, respectively. However, in season II, HyT0 (no priming), HyT8 (Hydro priming 8 hrs) HyT12 (Hydro priming 12 hrs) produced similar dry matter (DM) of 2408.0, 2621.0, and 2795.0 DM kg/ha respectively (Table 2 and Fig. 32).

4.3.3 Interaction Effects of pre Sowing Irrigation (%FC) and Priming on Dry Matter (DM) 25 Days after Sowing (DAS)

Interaction effects of pre-sowing irrigation and priming (Table 5) for the season I crop reveals that irrigation 100% FC – HCL1T12 (0.1% $NaCl_2$ for 12 hours), HCL2T8 (0.2% $NaCl_2$ for 8 hours); irrigation 50% FC – HCL2T12 (0.2% $NaCl_2$ for 12 hours) and HCL2T12 (0.2% $NaCl_2$ for 12 hours); and irrigation 75% FC – HCL3T12 (0.3% $NaCl_2$ for 12 hours), gave significantly higher DM yields/ha at 25 DAS.

Interaction effects of pre-sowing irrigation and priming (Table 6) for the season II crop reveals that pre sowing irrigation 100% FC – HCL1T12 (0.1% $NaCl_2$ for 12 hours)-182.7 kg/ha and HCL2T12 (0.2% $NaCl_2$for 12 hours)-149.7kg/ha; and pre sowing irrigation 75% FC – HCL3T12

(0.3% $NaCl_2$ for 12 hours)-201.7 kg/ha, gave significantly higher DM yields/ha at 25 DAS in SI. These treatments showed similar trend as in the case of SII. This means that they can reliably be depended upon to result in increase initial DM production for chickpea. Furthermore, treatment interactions at Pre sowing irrigation 75% FC – HyT12 and 100% FC – T0 gave the highest DM yield as those mentioned above, for season II only. Season II had poor rainfall at the initial 0 – 25 DAS and therefore benefitted from the 100% FC treatment.

Analyzing for pre-sowing treatment, effect on Dry matter (DM), applying a pre-sowing irrigation of 100 FC gave relatively higher (non-significant) DM (52.2kg/ha) in season I. In season II however, while the DM were same at 25 DAS, (82.7 kg DM/ha), it was relatively the 3rd highest.

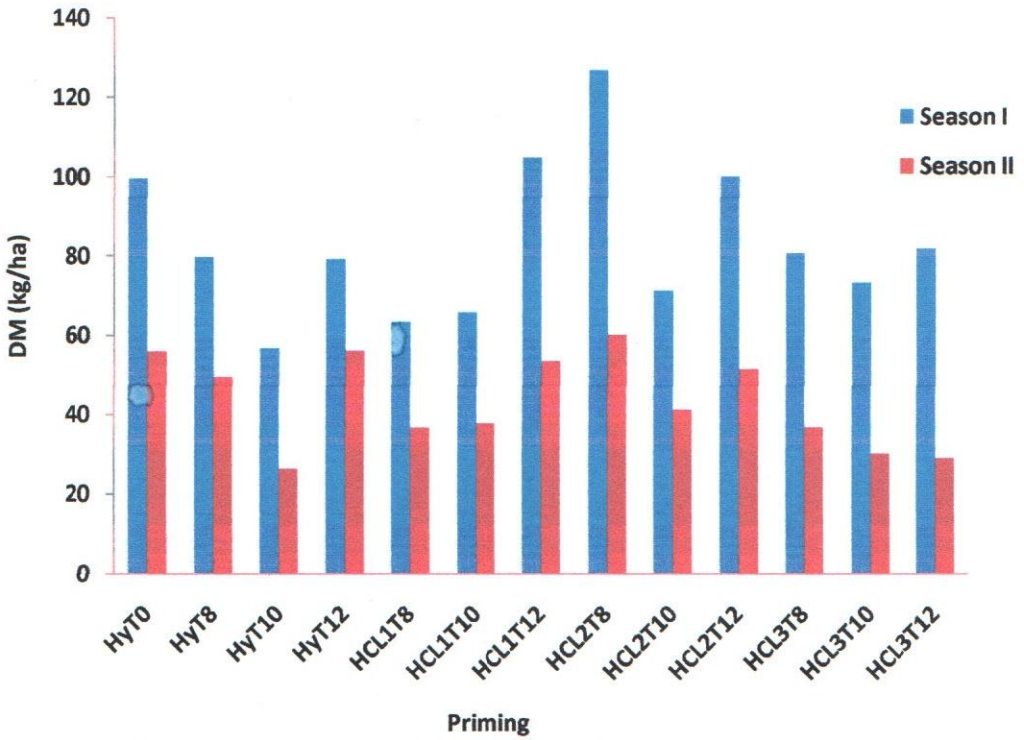


Fig 29 : Relationship of Priming on Dry Matter (kg/ha) 25 DAS

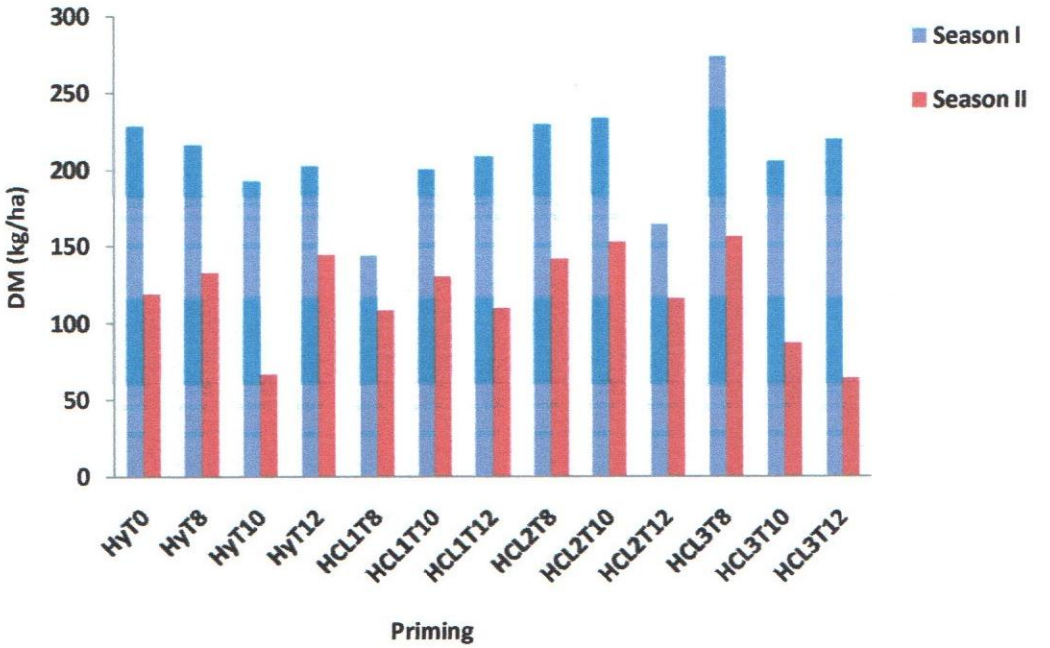


Fig 30: Relationship of Priming on Dry Matter (kg/ha) 50 DAS

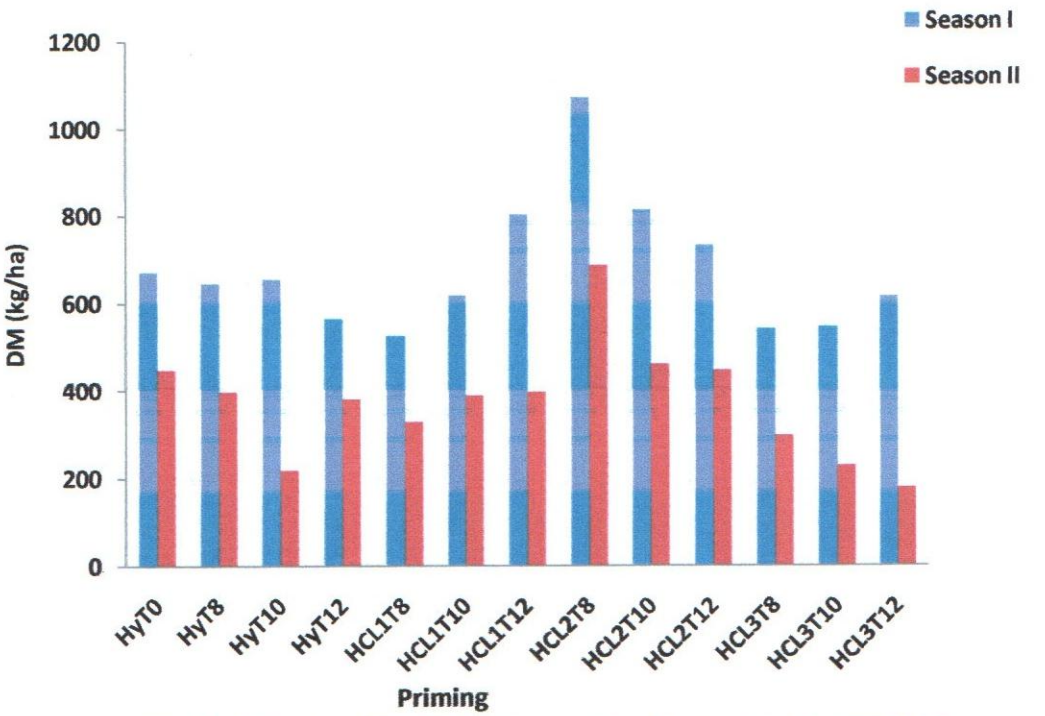


Fig 31: Relationship of Priming on Dry Matter (kg/ha) 75 DAS

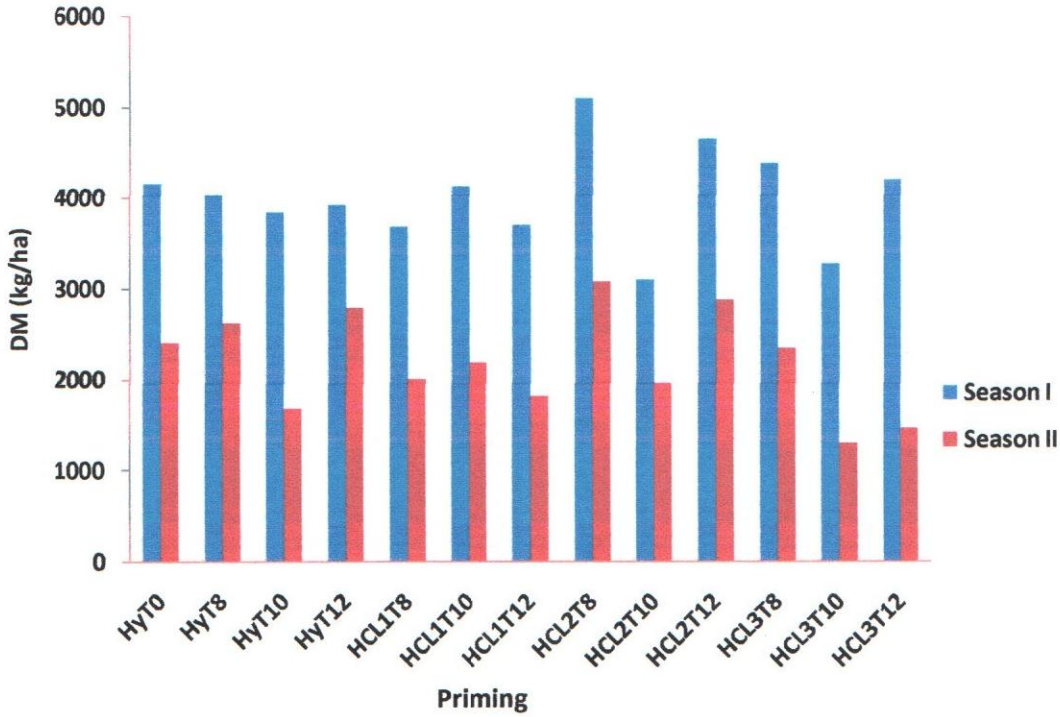


Fig 32: Relationship of Priming on Dry Matter (kg/ha) 90 DAS

Increase in pre-sowing irrigation from 25% FC to 100% FC was observed to have significant increase in DM at both 90 and 105 DAS, for both seasons. Therefore, increasing soil water (through pre-sowing irrigation) in conditions of well distributed rainfall tended to increase germination, plant stand, and DM production of chickpea. In conditions with irregular intra seasonal rainfall effects of pre-sown irrigation might become confounded and not evident, as in the case of SII where rainfall was only 311.15 mm and irregularly distributed.

Table 5: Interaction effects of pre sowing irrigation and priming on dry matter (DM) 25 Days after sowing (DAS) during season I

rrigation	Priming												
	Hy T_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
25%FC	123.0bc	96.7c	73.3d	69.0d	88.0d	41.0e	90.0cd	283.7a	69.0d	19.7f	101.0c	54.7e	81.3d
50%FC	90.7c	70.0d	16.0f	68.7d	65.3d	78.3d	125.0b	82.0d	67.3d	153.0a	70.0d	71.0d	28.0ef
75%FC	77.3d	78.0d	63.0de	113.7c	66.0d	78.7d	21.3f	63.3d	69.0d	78.3d	72.7d	100.3c	201.7a
100%FC	107.3c	74.0d	74.3d	65.3d	34.3e	65.3d	182.7a	78.3d	80.0d	149.7ab	79.0d	67.3d	17.0f
SD	34.8		CV%	25.5									

Table 6: Interaction effects of Irrigation and Priming on dry matter (DM) 25 Days after sowing (DAS) during season II

rrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
25%FC	55.2b	53.1b	19.9b	45.5b	46.4b	19.8b	36.4b	82.1a	43.2b	10.7c	31.2b	21.8b	11.0c
50%FC	43.9b	46.4b	7.7c	49.4b	37.2b	51.7b	53.9b	57.1b	26.0b	41.1b	26.0b	31.5b	16.0b
75%FC	47.9b	57.2b	37.5b	78.8a	43.6b	22.3b	15.7bc	51.2b	35.2b	54.8b	47.5b	44.1b	82.1a
100%FC	77.0a	41.6b	40.6b	50.5b	19.2b	56.9b	108.3a	50.3b	60.6ab	99.8a	42.5b	23.7b	7.0c
SD	48.3		CV%	52.8									

.3.4 Interaction Effects of Pre Sowing Irrigation (%FC) and Priming on Dry Matter (DM) 50 Days after Sowing (DAS)

The interaction effects of pre-sowing irrigation and priming (Table 7) for the season I crop shows that pre sowing irrigation 100% FC - HyT8 (hydro priming for 8 hours); pre sowing irrigation 75% FC-HCL2T10 (0.2% $NaCl_2$ for 10 hours); pre sowing irrigation 50% FC – HyT0 (no priming) and HCL3T12 (0.3% $NaCl_2$ for 12 hours) gave significantly higher DM yields/ha at 50 DAS of 475.0, 391.7, 383.3, and 440.0 kg/ha, respectively.

teraction effects of pre-sowing irrigation and priming (Table 8) for the season II, 50 DAS reveals similar trend like in season I crop, at pre sowing irrigation 50% FC –HyT0 (no priming-233.3 kg/ha) and pre sowing irrigation of 75% FC-HCL2T10 (0.2% $NaCl_2$ for) hours-263.3 kg/ha) were significantly higher in both seasons. These were however the same with pre sowing irrigation 50% FC-yT12 (hydro priming for 12 hours-148.3 kg/a), HCL2T8 (0.2% $NaCl_2$ for 8 hours-170.0 kg/ha), HCL3T8 (0.3% $NaCl_2$ for 8 hours-40.0 kg/ha) ; pre sowing irrigation 75% FC-HyT8 (hydro priming for 8 hours-146.7 kg/ha), HyT12 (hydro priming for 12 hours-66.7 kg/ha), HCL2T8 (0.2% $NaCl_2$ for 8 hours-263.3 kg/ha), HCL2T10 (0.2% $NaCl_2$ for 10 hours-200.0 kg/ha) , HCL3T8 (0.3% aCl_2 for 8 hours-170.0 kg/ha) ; pre sowing irrigation 100% FC-HCL1T8 (0.1% $NaCl_2$ for 8 hours-150.0 kg/ha) , HCL1T12 (0.1% aCl_2 for 12 hours-193.3) , HCL2T10 (0.2% $NaCl_2$ for 10 hours-185.0kg/ha), HCL2T12 (0.2% $NaCl_2$ for 12 hours-258.3 kg/ha) and CL3T8 (0.3% $NaCl_2$ for 8 hours-145.0 kg/ha)

able 7: Interaction effects of Irrigation and Priming on dry matter (DM) 50 Days after sowing (DAS) during season I

rigati	Priming												
n	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
5%FC	130.0d	115.0e	196.7d	313.3b	190.0d	213.3cd	230.0c	253.3c	196.7d	98.3e	226.7c	225.0c	173.3d
0%FC	483.3a	75.0e	80.0e	183.3d	73.3e	373.3b	170.0d	300.0bc	260.0c	136.7d	270.0c	150.0d	440.0a
5%FC	83.3e	200.0d	173.3d	240.0c	88.3e	88.3e	106.7e	270.0c	391.7ab	171.7d	260.0c	136.7d	180.0d
00%FC	216.7c	475.0a	320.0b	73.3e	223.3c	126.0de	326.7b	93.3e	85.0e	250.0c	336.7b	310.0b	85.0e
SD	93.4		CV%	27.7									

Table 8: Interaction effects of Irrigation and Priming on dry matter (DM) 50 Days after sowing (DAS) during season II

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_1
$I_{25\%FC}$	58.3b	63.3b	53.3b	206.7a	100.00b	103.3b	93.3b	73.3b	123.3b	53.3b	70.0b	90.0b	23.3c
$I_{50\%FC}$	233.3a	53.3b	38.3b	148.3a	125.00b	246.7a	73.3b	170.0a	102.5b	36.7b	240.0a	71.7b	125.0b
$I_{75\%FC}$	51.7b	146.7a	103.3b	166.7a	58.3b	61.7b	78.3b	263.3a	200.0a	116.7b	170.0a	60.0b	73.3b
$I_{100\%FC}$	133.3b	266.7a	73.3b	56.7b	150.0a	109.7b	193.3a	60.0b	185.0a	258.3a	145.0ab	126.7b	35.0bc
LSD	124.1		CV%	49.1									

4.3.5 Interaction Effects of Pre Sowing Irrigation (%FC) and Priming on Dry Matter (DM) 75 Days after Sowing (DAS)

The interaction effects of pre-sowing irrigation and priming (Table 9) for the season I crop shows that pre sowing irrigation 25% FC HCL2T8 (0.2 % $NaCl_2$ for 8 hours) gave significantly higher DM yields/ha (2407 kg/ha) at 75 DAS.

The interaction effects of pre-sowing irrigation and priming (Table 10) for the season II crop shows that pre sowing irrigation 25 % FC – HyT0 (no priming)-930.0 kg/ha and HCL2T10 (0.2 % $NaCl_2$ for 10 hours)-1060 kg/ha ; 75% FC HCL2T8 (0.2% $NaCl_2$ for hours)-1010.0 kg/ha gave significantly higher DM yields/ha at 75 DAS.

Table 9: Interaction effects of Irrigation and Priming on dry matter (DM) 75 Days after sowing (DAS) during season I

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_1
$I_{25\%FC}$	1170c	1035c	1082c	783d	380f	640e	1035c	2407a	1770b	590e	567e	525e	780d
$I_{50\%FC}$	773d	675de	560e	825d	660e	1027c	595e	760d	693d	410e	660e	750d	807d
$I_{75\%FC}$	167f	400ef	260f	360f	353f	353f	1173c	567e	627e	950cd	433e	478e	540e
$I_{100\%FC}$	575e	475e	720d	293f	712d	450e	408e	560e	170f	990c	508e	440e	340f
LSD	282.8		CV%	23.0									

Table 10: Interaction effects of Irrigation and Priming on dry matter (DM) 75 Days after sowing (DAS) during season II

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	930ab	570c	293d	517c	200d	310d	420c	697b	1060a	320d	175d	210d	105d
$I_{50\%FC}$	373c	453c	268d	530c	333d	678b	257d	685b	257d	110d	470c	336d	252d
$I_{75\%FC}$	103d	293d	155d	250d	233d	177d	672b	1010a	120d	642bc	283d	210d	220d
$I_{100\%FC}$	387c	267d	157d	227d	550c	392c	242d	360cd	410d	725b	266d	158d	140d
LSD	290.3		CV%	39.3									

4.3.6 Interaction Effects of Pre Sowing Irrigation (%FC) and Priming on Dry Matter (DM) 90 Days after Sowing (DAS)

The interaction effects of pre-sowing irrigation and priming (Table 11) for the season I crop shows that pre sowing irrigation 25% FC – HyT0 (no priming-6500.0 kg/ha) and HCL2T12 (0.2% $NaCl_2$ for 12 hours-5900.0 kg/ha); 50% FC- HCL2T8 (0.2% $NaCl_2$ for 8 hours-6440.0 kg/ha) ; 75% FC- HCL1T10 (0.1% $NaCl_2$ for 10 hours-6713.0 kg/ha) and HCL2T8 (0.2% $NaCl_2$ for 8 hours-6970.0 kg/ha) gave significantly higher DM yields/ha at 90 DAS.

The interaction effects of pre-sowing irrigation and priming (Table 12) for the season II crop shows that pre sowing irrigation of 100% FC-HCL2T12 and HCL2T10 gave the highest DM/ha of 5017.0 and 4285.0 kg/ha, respectively. However, these were not significantly different from the other treatment combinations except for treatment combinations 25% FC – HCL1T10 (0.1% $NaCl_2$ for 10 hours) ; 50% FC- HyT10 (Hydro priming for 10 hours),HCL1T8 (0.1% $NaCl_2$ for 8 hours) ,HCL2T10 (0.2% $NaCl_2$ for 10 hours), HCL2T12(0.2% $NaCl_2$ for 12 hours;75% FC- HCL1T12 (0.1% $NaCl_2$ for 12 hours) and HCL2T10 (0.2% $NaCl_2$for 10 hours) that gave significantly lower DM yields/ha at 90 DAS .

Table 11: Interaction effects of Irrigation and Priming on dry matter (DM) 90 Days after sowing (DAS) during season I

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	6500a	3680c	5212b	3055c	3610c	2453d	5520b	4813b	3097d	5900a	1927d	1800df	4940b
$I_{50\%FC}$	2513d	2925d	1680f	3850c	2860d	3453c	3570c	6440a	2687d	2118d	5200b	3750c	2860d
$I_{75\%FC}$	3167cd	4500bc	2947d	5400b	3312c	6713a	1280f	6970a	1410f	4700b	5330b	3212c	4320c
$I_{100\%FC}$	4433c	5035b	5520b	3373c	4930b	3870c	4410c	2147d	5185b	5870ab	5053b	4320c	4660b
LSD	1370.9		CV%	19.8									

Table 12: Interaction effects of Irrigation and Priming on dry matter (DM) 90 Days after sowing (DAS) during season II

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	3417a	2027a	1413a	2015a	1900a	1188b	2240a	1393a	1943a	2700a	595b	720b	665b
$I_{50\%FC}$	1213b	1950a	805b	3190a	1000b	2282a	1540a	3650a	883b	535b	2410a	1692a	1450a
$I_{75\%FC}$	1963a	3300a	1757a	3750a	2188a	1910a	862b	5872a	720b	3267a	3485a	1410a	1760a
$I_{100\%FC}$	3040a	3207a	2723a	2227a	2950a	3368a	2610a	1380ab	4285a	5017a	2900a	1393a	1960a
LSD	2228.8		CV%	39.6									



Plate 6: Soil analysis in the laboratory



Plate 7: Source of irrigating water



Plate 8: Source of irrigating water



Plate 9: Start of field planting



Plate 10: sowing in progress



Plate 11: Sowing of chickpea in progress



Plate12: Immediately after sowing chickpea

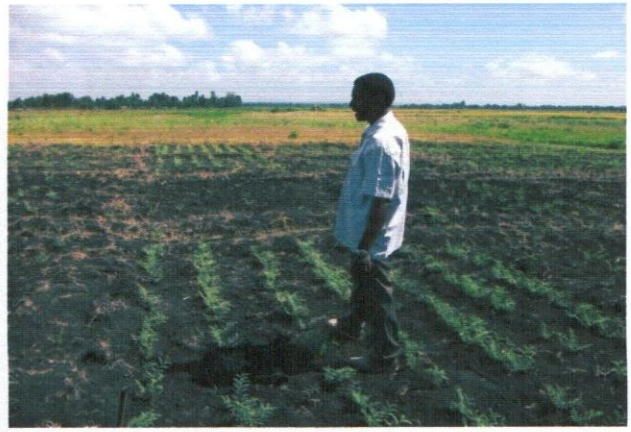


Plate13: Germination and growth of chickpea (10 DAS)



Plate 14: Growth and development of chickpea (15 DAS)



Plate 15: Growth and development of chickpea (25 DAS)



Plate 16: Growth and development of chickpea (50 DAS)



Plate17: Chickpea growth and development 70 DAS



Plate 18: Crop protection against pod borers

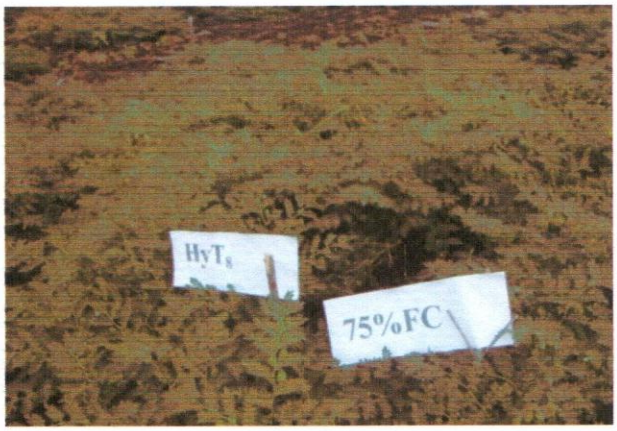


Plate19: Growth and development of chickpea (75 DAS)



Plate20: Growth and development of chickpea (90 DAS)

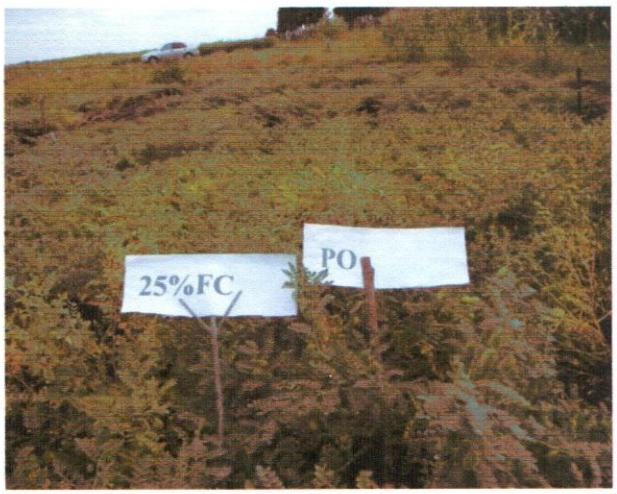


Plate 21: Growth and development of chickpea (90 DAS)



Plate 22: Growth and development of chickpea

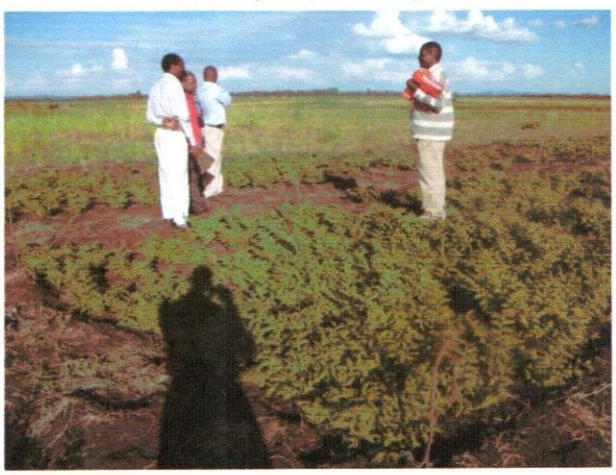


Plate 23: Growth and development of chickpea



Plate 24: Growth and development of chickpea (90 DAS)



Plate 25: Chickpea crop reaching physiological maturity (105 DAS)



Plate 26: Crop performance even without irrigation at 105 DAS

4.4 Effects of Treatments on Plant Height (cm)

4.4.1 Effect of Pre-Sowing Irrigation at 25%, 50%, 75% and 100% Field Capacity on Chickpea Crop Height (cm)

The Plant heights (cm) increased with maturity of chickpea (i.e., increasing days after sowing (DAS)) in all the pre sowing irrigation regimes (Table 13). At 25 DAS, plant heights were significantly higher with application of pre sowing irrigation of 50%, 75% and 100% FC. This is the period (0-25 DAS) is considered to give the best indicator of pre sowing irrigation for both

seasons. Similar trend was observed for heights at 105 DAS. The later growth stages would have been affected by other environmental factors i.e., nutrient and rainfall, temperatures, etc. that influence height and growth (Ashkan *et al.*, 2012)). However, at 90 and 105 DAS, pre sowing irrigation of 75% and 100% FC gave the highest plant heights during season I and II. At 25 DAS and 105 DAS, 50% FC produced significantly lower plant heights (cm), (Table 13).

The relationships of pre sowing irrigation to heights could be explained by fitting linear regressions. Which had high goodness of fit of over (regression coefficients), R^2=0.996 (Figs 33, 34, 35 and 36) in both season I and II. The functions (Figs. 33, 34, 35 and 36) reveals that desi chickpea plant height was increasing at a rate of 0.35cm per 25 mm water applied before sowing at 25% and 50% field capacities (FC). However, application of 75 % to 100% FC pre sowing irrigation resulted in an increase in the rate of increase of chickpea height ranging between 0.361 to 0.375 cm per 25 mm increase in water application. It's important to note that applying a pre sowing irrigation beyond 75% FC slightly reduced rate of increase in chickpea height. Further studies to understand the underling physiological reasons for the decline in the rate of increase in height for desi chickpea in soils watered to field capacities is recommended. Past studies by Kamithi, 2008 revealed yellowing of chickpea plant in waterlogged soils. The yellowing was attributed to bacterial wilt and ascocytus disease (Gaur *et al.*, 2010).

4.4.2 Effect of Priming on Chickpea Crop Height (cm) 25 DAS

Table 13 and Fig. 37 reveals that HyT8 (hydro priming for 8 hours) and HCL2T10 gave significantly higher plant heights (cm) in both season I and II. Therefore for height attributes which is a growth attribute, it can be recommended to use either of the two treatment combination (HyT8 and HCL2T10). Although the two treatment combinations were the same, HyT8 plants had higher plant heights in both season I and II of 12.71 cm. Muhammad Aslam, *et al.*, (2010) and Verghis *et al.*, (1999) reported that chickpea yield is plant height sensitive. One of the simple and suitable methods which can improve seedling vigor and establishment and consequently crop performance in the field is seed priming (McDonald, 2000). The beneficial effects of priming have been demonstrated for many field crops such as barley (Abdulrahmani *et al.*, 2007), maize (Parera and Cantliffe, 1994), lentil (Ghassemi-Golezani *et al.*, 2008), chickpea (Ghassemi-Golezani *et al.*, 2012), pinto bean (Ghassemi-Golezani *et al.*, 2010).

Table 13: Effect of Irrigation and Priming on Chickpea Height (cm)

	Height (cm)									
	25 DAS		50 DAS		75 DAS		90 DAS		105 DAS	
	Season									
	I	II	I	II	I	II	I	II	I	II
Main Plot: Irrigation										
$I_{25\%FC}$	9.73b	9.93b	19.10	19.15	25.55	25.37	33.68	33.68c	37.82b	38.04b
$I_{50\%FC}$	10.58a	10.55a	20.94	20.94	27.42	27.42	34.29	34.29bc	39.42a	39.60ab
$I_{75\%FC}$	10.71a	10.50ab	20.72	20.72	27.37	27.63	34.95	35.51ab	40.68a	40.91a
$I_{100\%FC}$	10.58a	10.78a	21.19	21.27	27.15	27.44	35.88	36.35a	39.54a	40.03a
LSD P≤0.05	0.63	0.627	2.29	2.39	2.77	2.37	1.55	1.653	1.31	1.737
Sub-plot: Priming										
HyT_0	9.50c	9.75c	19.96c	20.71b	25.67d	25.92c	32.79b	32.46b	38.75b	39.58b
HyT_8	12.71a	12.71a	24.17a	24.17a	31.08a	31.08a	35.62a	35.62a	38.83b	39.08c
HyT_{10}	10.0c	10.30c	19.33cd	19.33c	25.67d	25.67c	33.92b	33.92b	38.21b	37.54c
HyT_{12}	10.92b	11.01b	20.58bc	20.58b	28.58bc	28.58b	36.67a	36.67a	39.38b	39.38c
HCL_1T_8	10.08c	10.71c	19.71c	19.83bc	29.88ab	28.62b	34.50ab	36.25a	38.67b	39.17c
HCL_1T_{10}	9.96c	10.95b	21.12b	21.54b	26.00d	26.00c	34.67a	35.00a	38.88b	39.54bc
HCL_1T_{12}	10.79b	10.9bc	21.88b	21.88b	27.12c	27.12b	34.17b	34.17b	39.67ab	39.67b
HCL_2T_8	10.29b	10.04c	21.58b	21.25b	26.50c	27.62b	35.42a	36.71a	41.71a	42.96a
HCL_2T_{10}	11.50ab	11.55ab	21.50b	21.50b	26.42cd	26.42bc	34.75a	34.75a	37.79b	37.79c
HCL_2T_{12}	10.17b	9.54c	21.29b	20.75b	25.62d	26.67b	34.54a	34.83a	39.75a	40.17b
HCL_3T_8	10.12b	10.52c	19.46c	19.46c	26.46c	26.46b	36.42a	36.42a	41.29a	41.67ab
HCL_3T_{10}	9.67c	9.78c	18.04d	18.04cd	25.79d	25.79c	34.58a	34.58ab	38.62b	38.62c
HCL_3T_{12}	9.46c	9.89c	17.71d	17.17d	24.58d	24.58c	33.08b	33.08b	40.21a	40.21b
LSD P≤0.05	1.49	1.46	1.85	1.94	2.22	2.284	2.325	2.300	2.23	2.275
CV%	3.0	17.4	5.6	5.8	5.2	4.4	2.20	2.4	1.7	2.2

Means within a column followed by the same letter are not significantly different at P<0.05

4.4.3 Interaction Effects of Pre Sowing Irrigation and Priming on Height (cm) 25 Days after Sowing (DAS)

In both season I and II (Table 14 and 15), 25%FC-HyT8, HyT12, HCL1T12 and HCL2T10; 50% FC-HyT8 and HCL1T10; 75% FC-HyT8, HyT12 and HCL2T10 and; 100% FC-HCL3T3 and HCL3T12 gave significantly higher plant heights ranging between 11.83-14.73 cm. However, in season I, 100% FC-HyT10 and HCL2T12 gave similar plant heights of 11.83 cm (Table 14).

Table 14: Interaction effects of pre sowing Irrigation and Priming on height (cm) 25 Days after sowing (DAS) during season I

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	9.15bc	12.50a	9.38b	11.83ab	10.17b	10.67	13.22a	8.50c	13.50a	9.70b	9.40b	11.67b	8.50c
$I_{50\%FC}$	7.24c	12.83a	8.44c	8.50c	10.50b	11.83ab	11.67b	11.00b	9.83b	8.00c	8.83c	9.83b	8.33c
$I_{75\%FC}$	10.33b	14.73a	11.17b	12.27a	9.88b	9.24b	10.17b	11.34b	12.42a	11.20b	10.28b	7.83c	9.17b
$I_{100\%FC}$	11.17b	10.83b	11.83ab	11.00b	10.00b	8.22c	8.33c	10.33b	10.88b	11.83ab	12.00a	9.33b	11.83ab
LSD	2.91		CV%	17.7									

Table 15: Interaction effects of pre sowing Irrigation and Priming on height (cm) 25 Days after sowing (DAS) during season II

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	9.17b	13.20a	9.00bc	11.95ab	10.17b	10.67b	13.00a	8.50c	12.50a	9.67b	9.33b	11.67b	8.50c
$I_{50\%FC}$	7.43c	12.85a	8.00c	8.45c	10.54b	11.90ab	11.73b	11.00b	9.83b	8.24c	8.81c	9.83b	8.33c
$I_{75\%FC}$	11.33b	14.67a	11.38b	12.33a	9.70b	9.00bc	10.24b	10.33b	12.00a	11.17b	10.33b	7.83c	9.17b
$I_{100\%FC}$	11.00b	10.80b	11.83ab	11.44b	12.50a	8.43c	8.33c	10.32b	10.67b	9.33b	11.98a	9.33b	11.80ab
LSD	2.87			CV%	17.4								

4.5 Effect of Priming on Chickpea Crop Height (cm) 50, 75 DAS and 90DAS

In both season I and II, HyT8 (hydro priming for 8 hours) gave significantly the highest plant height (cm) in both season I and II (Table 11). However, at 90 DAS, HyT12, HCL1T8, HCL1T10, HCL2T8, HCL2T10, HCL2T12, HCL3T8 and HCL3T10 gave same plant heights in both season I and II (Table 13 and Fig. 38-41).

4.5.1 Interaction Effects of Pre Sowing Irrigation and Priming on Crop Height (cm) 50 DAS

Table 16 and 17 reveals that 25% FC-HyT8,HyT10,HCL1T10,HCL1T12 and HCL2T10; 50% FC- HyT8, HCL1T10, HCL1T12 and HCL2T12 ; 75% FC- HyT8, HyT12, HCL1T12, HCL2T8 and HCL2T10; 100%FC- HyT0, HyT8, HCL2T8 and HCL2T10 and HCL3T8 produced significantly higher plant heights (cm) in both season I and II. These plant heights ranged between 21.17 - 25.19 cm. However, in season I, 50% FC-HCL3T10 and 100% FC-HCL2T12 gave similar heights (Table 16) while in season II, 25% FC-HyT0, 50% FC-HCL2T8, 75% FC-HyT0 and 100% FC-HCL1T8, HCL1T10 and HCL1T12 also gave same plant heights (Table 17).

Table 16: Interaction effects of pre sowing Irrigation and Priming on height (cm) 50 Days after sowing (DAS) during season I

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	21.00b	24.17a	21.67a	20.00b	19.67b	21.67a	22.67a	19.67b	23.33a	20.00b	20.83b	20.83b	16.67c
$I_{50\%FC}$	15.50c	24.67a	16.83c	19.83b	15.83c	22.83a	21.83a	20.67b	19.83b	22.00a	16.83c	14.00a	17.67bc
$I_{75\%FC}$	19.00b	22.67a	18.67b	22.17a	22.67a	20.17b	21.83a	24.00a	21.17ab	20.67b	18.83b	19.33b	18.17b
$I_{100\%FC}$	24.33a	25.17a	20.17b	20.33b	20.67b	19.83b	21.17ab	22.00a	21.67a	22.50a	21.33a	18.00b	18.33b
LSD	4.03		CV%	11.1									

Table 17: Interaction effects of pre sowing Irrigation and Priming on height (cm) 50 Days after sowing (DAS) during seaso

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3
$I_{25\%FC}$	21.00ab	23.17a	21.77a	20.10b	19.70b	21.68a	22.77a	19.68b	23.43a	20.50b	20.73b	20.90b	16.88b
$I_{50\%FC}$	15.80c	24.55a	16.88bc	19.82b	15.85c	22.85a	21.94a	21.33a	19.92b	22.40a	16.94b	14.50c	17.85b
$I_{75\%FC}$	22.00a	22.70a	18.90b	22.33a	21.67a	20.32b	21.92a	22.01a	21.28a	20.68b	18.94b	19.33b	18.57b
$I_{100\%FC}$	24.33a	25.19a	20.33b	20.41b	22.17a	21.50a	21.37a	22.01a	21.67a	20.33b	21.44a	18.60b	18.83b
LSD	4.21		CV%	11.6									

4.5.2 Interaction Effects of Pre Sowing Irrigation and Priming on Height (cm) 75 DAS

Table 18 and 19, reveals that 25% FC-HyT8, HyT10, HCL1T8 and HCL2T10; 50% FC- HyT8 and HCL2T8; 75% FC-HyT8, Hy HCL1T8 and HCL1T12; and 100% FC-HyT8 and HCL3T3 gave significantly higher plant heights (cm). However, in season I, FC-HCL1T8 (Table 18) and in season II 100% FC-HyT0 gave same plant heights (Table 19)

Table 18: Interaction effects of pre sowing Irrigation and Priming on height (cm) 75 Days after sowing (DAS) during seaso

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HC
$I_{25\%FC}$	26.50b	30.67a	29.50a	30.00a	29.17a	28.33b	27.00b	24.67b	31.67a	25.76b	24.00bc	27.33b	22.4
$I_{50\%FC}$	21.50c	31.17a	23.67c	26.33b	29.50a	24.00bc	25.67b	28.67ab	25.00b	24.50b	22.67c	24.17b	25.1
$I_{75\%FC}$	25.67b	32.67a	22.83c	32.00a	33.50a	25.00b	30.00a	25.67b	24.50b	26.15b	28.17b	25.33b	25.0
$I_{100\%FC}$	29.00a	29.83a	26.67b	26.00b	27.33b	26.67b	25.83b	27.00b	24.50b	27.17b	31.00a	26.33b	26.
LSD	4.85		CV%	10.2									

Table 19: Interaction effects of pre sowing Irrigation and Priming on height (cm) 75 Days after sowing (DAS) during season II

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	26.55b	30.88a	29.00a	30.00a	29.28a	27.27b	27.00b	24.90b	31.67a	25.67b	24.15bc	27.00b	22.00c
$I_{50\%FC}$	21.50c	31.28a	23.77c	26.43b	28.50b	23.50c	25.88b	28.77ab	24.75b	24.50b	22.70c	24.28b	25.43c
$I_{75\%FC}$	25.77b	32.67a	22.85c	32.40a	33.45a	25.00b	29.60a	25.82b	23.92c	25.17b	28.34b	25.33b	25.33c
$I_{100\%FC}$	29.30a	29.94a	26.69b	27.10b	27.33b	26.66b	25.80b	27.00b	24.55b	27.00b	29.57a	26.11b	25.67c
LSD	4.80		CV%		10.5								

4.5.3 Interaction Effects of Pre Sowing Irrigation and Priming on Height (cm) 90 DAS

Table 20 and 21 reveal that 25% FC-HyT10; 50% FC-HyT12 and HCL2T8; 75% FC-HCL1T8,HCL2T8 and HCL2T10 and; 100% FC-HyT8,HyT10 and HCL1T10 and HCL2T12 had significantly higher plant heights in both seasons I and II. However, in season I, 25% FC-HyT0, HyT8, HyT12, HCL1T8, HCL3T8, HCL3T10 and HCL3T12 ; 50% FC-HCL1T10, HCL3T8, HCL3T10 and HCL3T12; 75% FC-HyT0, HyT12, HCL1T12, ,HCL3T8, HCL3T10 and HCL3T12 and ;100% FC-HyT0, HyT12, HCL2T8, HCL2T10, HCL2T12, HL3T8 and HCL3T12 had similar plant heights.

Table 20: Interaction effects of pre sowing Irrigation and Priming on height (cm) 90 Days after sowing (DAS) during season I

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	36.00a	35.17a	37.40a	36.00a	36.83a	31.67b	34.00b	31.00b	34.00b	34.17b	35.67a	33.50a	30.83b
$I_{50\%FC}$	24.33d	34.33ab	27.33cd	36.67a	32.67b	36.83a	33.50b	37.00a	32.67b	32.83b	36.17a	34.67a	36.33a
$I_{75\%FC}$	35.17a	34.17b	34.17b	36.50a	35.50a	33.67b	35.67a	36.33a	37.33a	32.33b	36.67a	36.67a	30.17bc
$I_{100\%FC}$	35.67a	38.83a	37.17a	36.50a	33.50b	36.50a	33.50b	35.83a	35.00a	38.83a	37.17a	33.50b	35.00a
LSD	4.64		CV%	8.3									

Table 21: Interaction effects of pre sowing Irrigation and Priming on on height (cm) 90 Days after sowing (DAS) during season II

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	36.00b	35.17b	37.00ab	36.00b	36.83b	31.67c	34.00b	31.00c	34.00b	34.17b	35.67b	33.50b	30.83c
$I_{50\%FC}$	24.33e	34.33b	27.33de	37.67a	32.67c	36.83b	33.50b	38.50a	32.67b	32.83b	36.17b	34.67b	36.33b
$I_{75\%FC}$	33.83b	34.17b	34.17b	36.50b	39.00a	33.67b	35.67b	41.50a	37.33a	32.33c	36.67b	36.67b	30.17cd
$I_{100\%FC}$	35.66b	38.91a	38.37a	36.50b	36.50b	37.83a	33.50b	35.83b	35.00b	40.00a	37.17b	33.50b	35.00b
LSD	4.62		CV%	8.1									

4.5.4 Effect of Priming on Chickpea Crop Height (cm) 105 DAS

HCL2T8 and HCL3T3 gave significantly the highest plant heights (cm) in both season I and II. However, these were the same with HCL1T12, HCL2T12 and HCL3T3 for season I, (Table 13 and Fig. 41).

4.5.5 Interaction Effects of Pre Sowing Irrigation and Priming on Height (cm) 105 DAS

Table 22 and 23 shows that 25 % FC-HyT0 and 75 % FC-HCL2T8 had significantly higher plant heights in both season I and II. However, in season I, 50 % FC-HCL2T8 and HCL3T8; 75% FC-HCL3T8 and 100 % FC-HCL2T12 and HCL3T8 had same heights.

Table 22: Interaction effects of pre sowing Irrigation and Priming on height (cm) 105 Days after sowing (DAS) during season I

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	45.67a	40.33b	41.67b	40.67b	39.00b	37.67c	38.50b	37.67c	37.17c	41.17b	36.67c	36.33c	40.00b
$I_{50\%FC}$	31.17d	36.50c	33.17d	39.33b	35.00cd	38.00c	37.67c	44.67a	37.00c	38.33bc	42.67ab	37.67c	40.50b
$I_{75\%FC}$	39.00b	38.17c	38.67b	42.50b	41.00b	39.83b	42.00b	47.00a	40.17b	36.83c	43.00a	40.83b	39.83b
$I_{100\%FC}$	39.17b	40.33b	39.33b	35.00cd	39.67b	40.00b	40.50b	37.50c	36.83c	42.67ab	42.83a	39.67b	40.50b
LSD	4.41		CV%	7.0									

Table 23: Interaction effects of pre sowing Irrigation and Priming on on height (cm) 105 Days after sowing (DAS) during season II

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	47.00ab	41.33c	41.67c	40.67c	39.00c	37.67d	38.50c	37.67d	37.17d	41.17c	36.67d	36.33d	40.00c
$I_{50\%FC}$	31.17e	36.50d	33.17e	39.33c	35.00de	38.00cd	37.67d	46.00b	37.00d	38.33c	44.17b	37.67d	40.50c
$I_{75\%FC}$	41.00c	38.17c	36.00d	42.50bc	41.00c	39.83c	42.00c	50.67a	40.17c	36.83d	43.00b	40.83c	39.83c
$I_{100\%FC}$	39.17c	40.33c	39.33c	35.00de	41.67c	42.67b	40.50c	37.50d	36.83d	44.33b	42.83b	39.67c	40.50c
LSD	4.59		CV%	7.1									

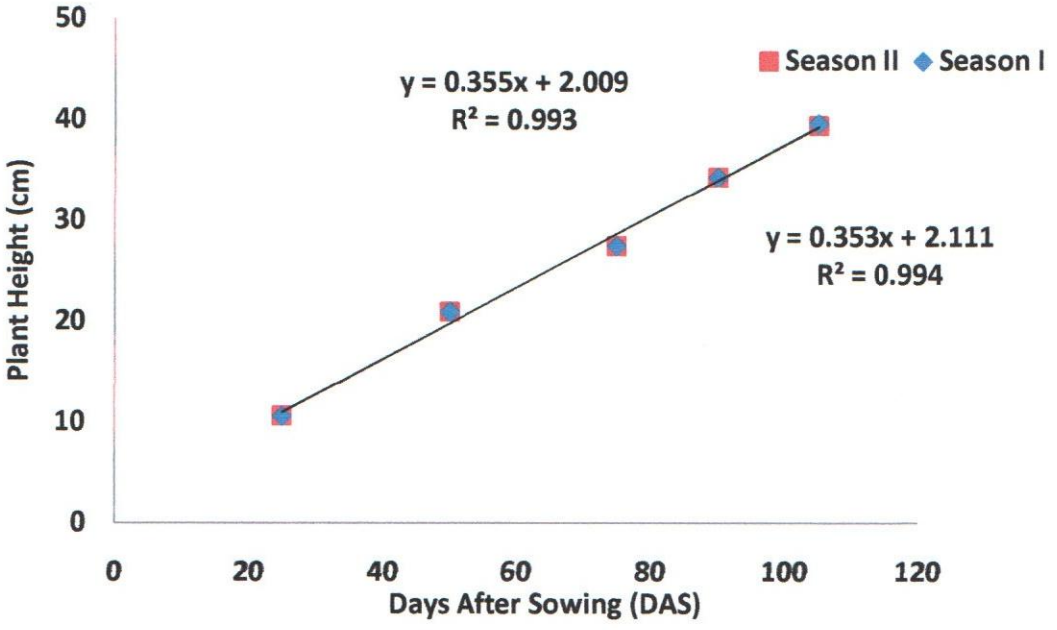


Fig 33: Relationship of Irrigation (25%FC) on Plant Height (cm)

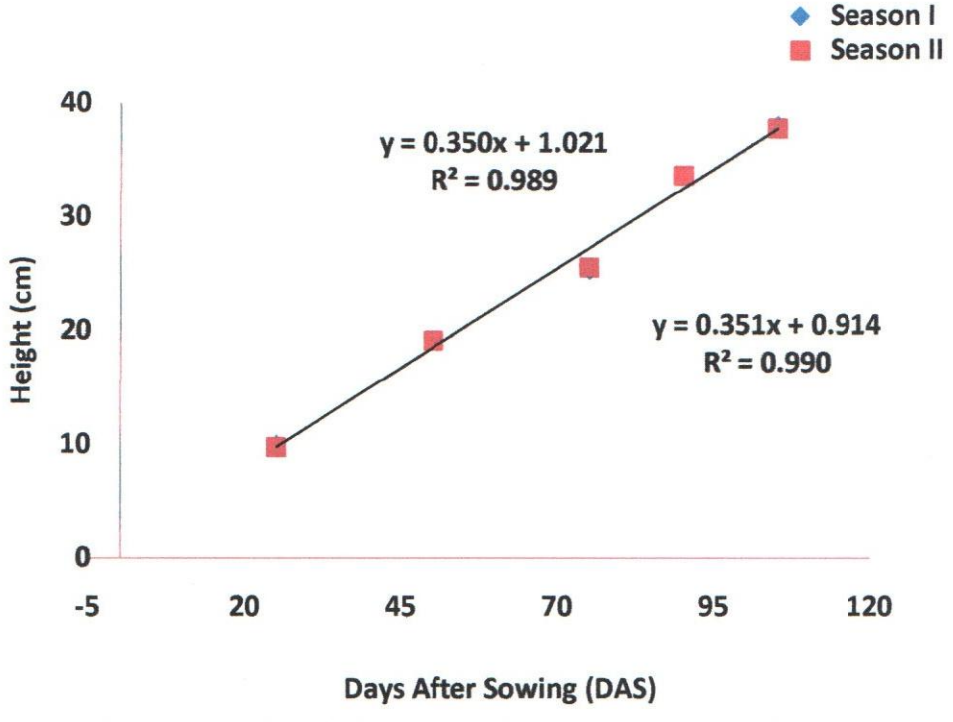


Fig 34: Relationship of Irrigation (50% FC) on Plant Height (cm)

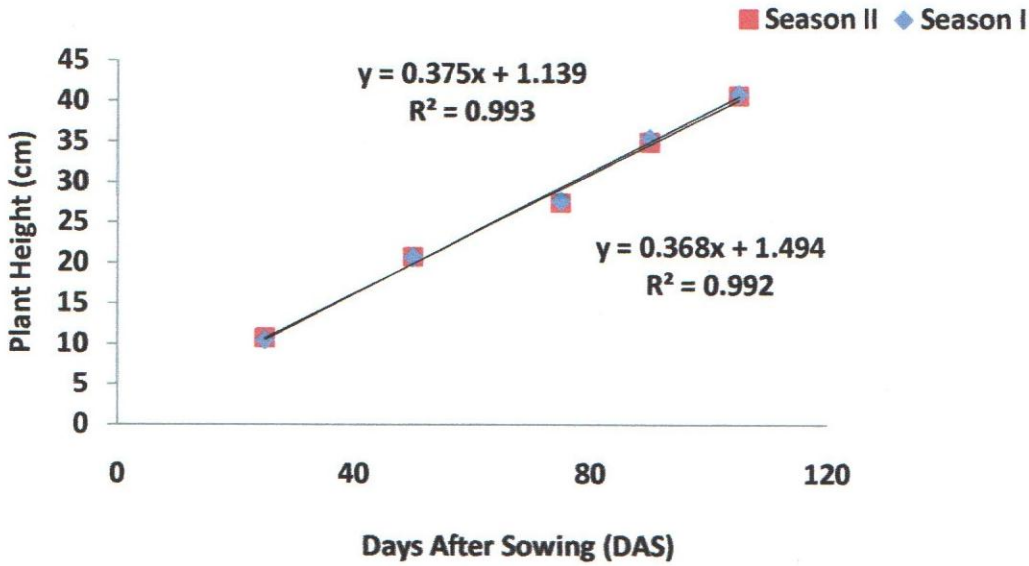


Fig 35: Relationship of Irrigation (75% FC) on Plant Height (cm)

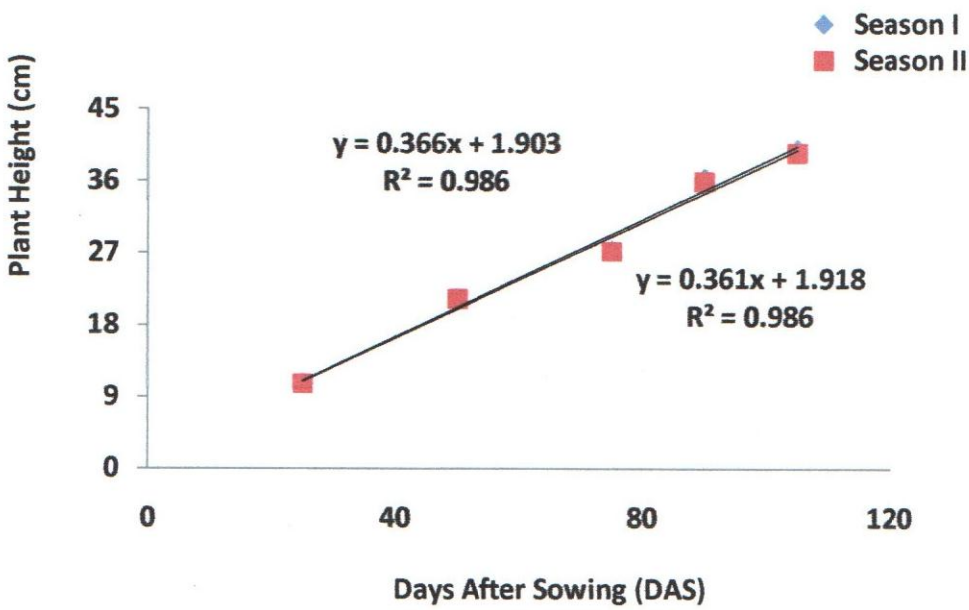


Fig 36: Relationship of Irrigation (FC) on Plant Height (cm)

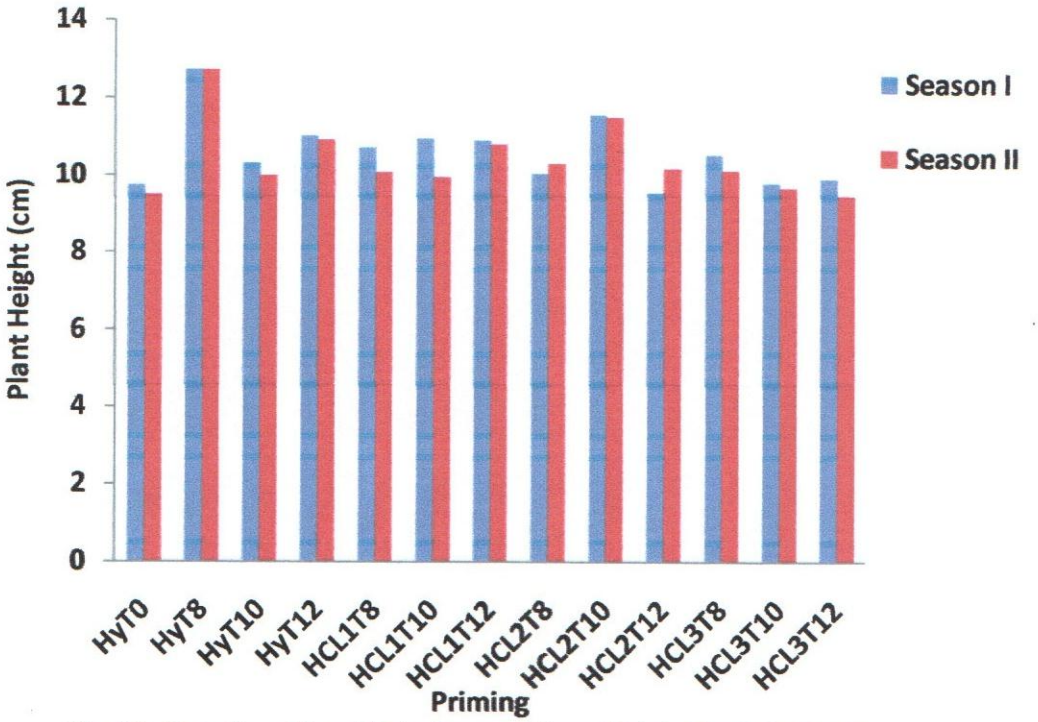


Fig 37: Relationship of Priming on Plant Height (cm) 25 DAS

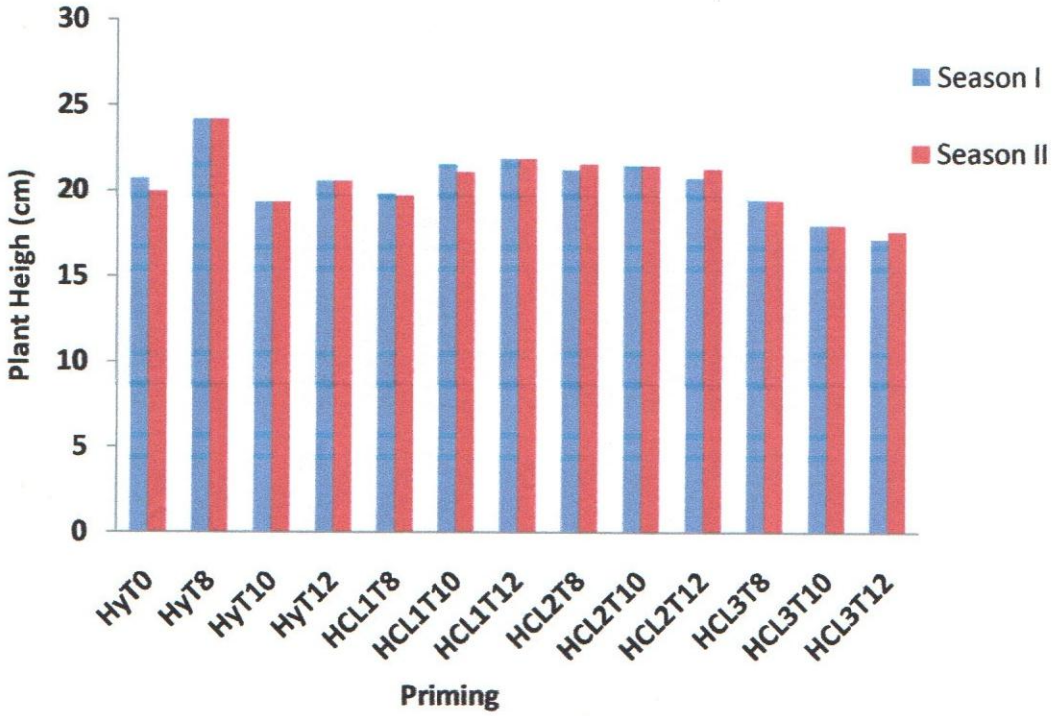


Fig 38: Relationship of Priming on Plant Height (cm) 50 DAS

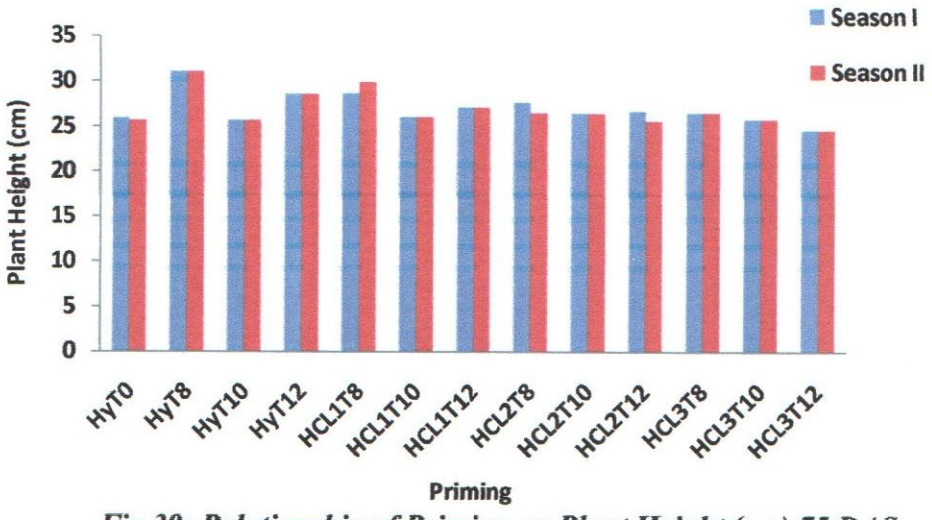


Fig 39: Relationship of Priming on Plant Height (cm) 75 DAS

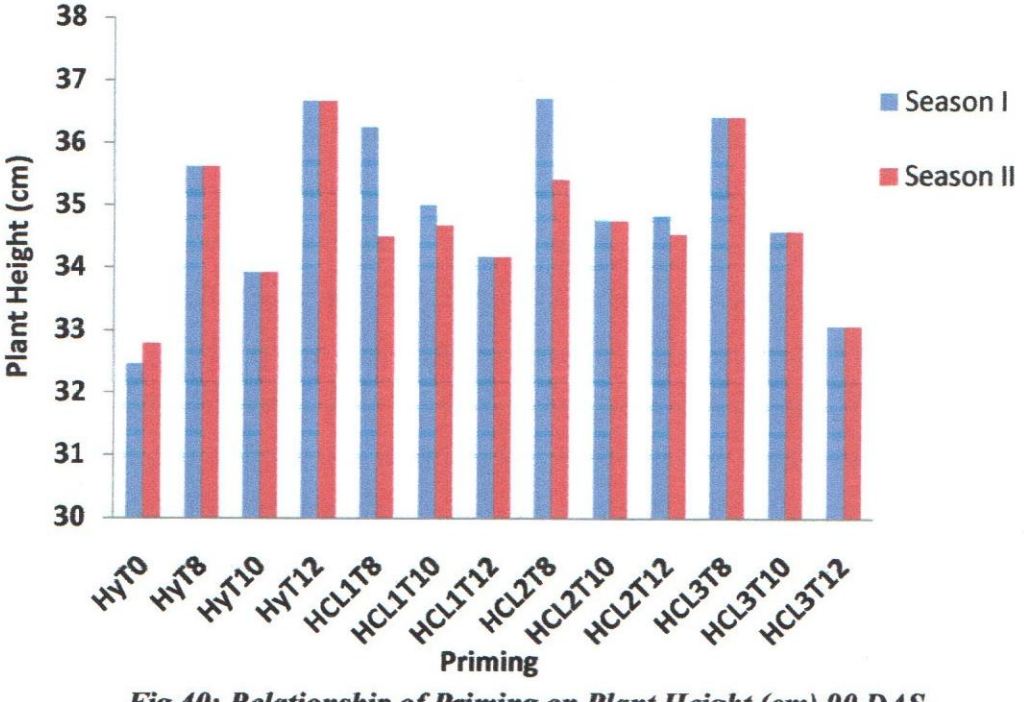


Fig 40: Relationship of Priming on Plant Height (cm) 90 DAS

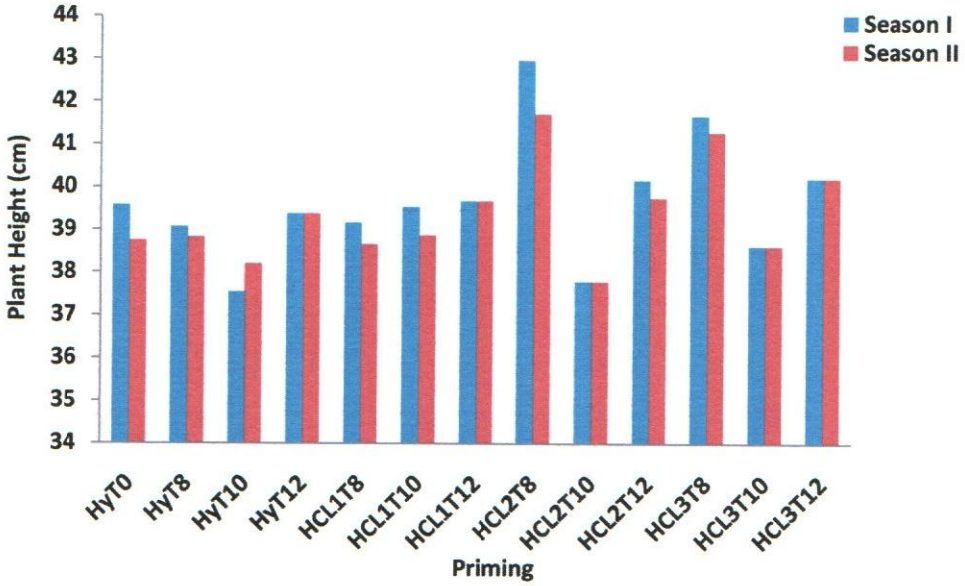


Fig 41:Relationship of Priming on Plant Height (cm) 105 DAS

4.6 Effect of Pre Sowing Irrigation on Grain Yield and Yield Attributes

4.6.1 Effect of Pre Sowing Irrigation on Number of Pods/Plant

Pre-sowing irrigation treatments on number of pods/plant had no significant effects on the number of pods/plant in both seasons (Table 24). Season I crop had more pods/plant ranging between 241-313 pods/plant while in season II, the pod were lower ranging between 45-54 pods/m^2. The 535 % - 580 % higher pods/plant for SI, over SII was attributed to better initial rainfalls that enhanced germination and ensured an ideal (optimum) plant stand and establishment and higher seasonal (565.10 mm) SI rainfall as compared to only 311.2 mm in SII. The 254 mm rainfall difference was estimated to give a difference of 164%. {Muhammad *et al* (2010) & Malik and Anwar (1994)} reported that number of pods/plant, 1000 grains weight and grain yield increased by irrigation in chickpea. Malhotra *et al.* (1997) observed increased seed yield (44%), total dry biomass (49%) and plant height (26%) with irrigation. Water stress decreases dry matter accumulation (DMA) and seed yield per unit area (Singh *et al.*, 2006; Ghassemi – Golezani *et al.,* 1998).

Fig. 42 on page 85 shows a curvilinear relationship between pre sowing irrigation with pods/m^2 had regression coefficients of R^2= 0.84 and R^2= 0.80 in season I and II, respectively. Increasing pre sowing irrigation from 25% FC to 100% FC increased in pods per plant at a rate of 0.59 and

0.27 in season I and II, respectively (Fig 42). The higher rate of producing pods per plant in season I was due to higher amount of rainfall during the season that was well distributed throughout the season.

4.6.2 Effect of Priming on Number of Pods/Plant

HCL_2T_{12} (0.2% $NaCl_2$ for 12 hours-329 & 56 pods/plant), HCL3T8 (0.3% $NaCl_2$ for 8 hours-379 & 52 pods/plant), and HCL_3T_{10} (0.3% $NaCl_2$ for 10 hours-398 & 51 pods/plant), produced the highest number of pods/plant in both season I and II, respectively. However, in season II, HCL_2T_{10}, ((0.2% $NaCl_2$ for 10 hours-50 pods/plant), HCL1T8 (0.1% $NaCl_2$ for 8 hours-64 pods/plant), and HyT_8 (hydro priming for 8 hours-53 pods/plant) produced the same pods/plant at ($P<0.05$) (Table 24 and Fig 52).

Table 24: Effect of Irrigation and Priming on Yield and Yield Attributes

	No. of pods/plant		Plants/m^2		Pods/m^2		100 seed wt(gms)		Grain Yield (kg/Ha)		HI	
	Season											
	I	II	I	II	I	II	I	II	I	II	I	II
Main Plot: Irrigation												
$I_{25\%FC}$	241	50	11	5	1146	563	28.4	60.0c	943	375.6	0.22	0.21
$I_{50\%FC}$	278	54	11	5	1286	571	28.6	64.5b	1017	458.2	0.25	0.25
$I_{75\%FC}$	271	48	14	6	1631	586	29.6	73.7a	1177	513.1	0.24	0.24
$I_{100\%FC}$	313	45	15	6	1509	543	29.4	64.7b	1122	477.1	0.22	0.22
LSD (P<0.05)	74.3	20.3	10.0	5.2	744.3	165.8	1.08	3.89*	177.8	109.49	0.074	0.0295
Sub-plot: Priming												
HyT_0	184d	46b	14a	6bc	1408b	562b	27.8b	60.4b	915de	440.8b	0.20bc	0.20c
HyT_8	174d	53a	14a	7ab	1206c	656a	29.6a	65.2a	1186b	467.9a	0.17c	0.25a
HyT_{10}	273bc	46b	14a	4de	1175c	525b	29.6a	68.8a	1033c	478.3a	0.27a	0.24ab
HyT_{12}	190d	47b	13a	7ab	1442b	534b	28.0b	64.2ab	968d	417.7b	0.15c	0.21bc
HCL_1T_8	284b	64a	14a	8a	1615ab	754a	30.3a	74.2a	1365a	563.8a	0.27a	0.26a
HCL_1T_{10}	282b	42b	13a	7ab	2048a	483c	29.6a	69.6a	1074c	441.7b	0.19c	0.22b
HCL_1T_{12}	279b	49b	14a	7ab	1226bc	550b	29.0a	60.4b	1049c	406.3b	0.26ab	0.27a
HCL_2T_8	220cd	41b	14a	7ab	1206c	509bc	28.8a	60.4b	974cd	467.7ab	0.19c	0.19c
HCL_2T_{10}	283b	50ab	13a	5cd	1435b	534b	28.2b	73.3a	874e	485.2a	0.28a	0.25a
HCL_2T_{12}	329ab	56a	14a	6bc	1863a	622b	29.8a	71.9a	1251ab	539.4a	0.26ab	0.22b
HCL_3T_8	379a	52a	14a	4de	1467b	630ab	28.8a	69.8a	1058c	455.0b	0.23b	0.21bc
HCL_3T_{10}	398a	51a	13a	3e	1007c	501c	29.0a	72.1a	1132bc	397.3bc	0.30a	0.25a
HCL_3T_{12}	310b	42b	12b	3e	1013c	433c	28.5ab	70.0a	966d	367.3c	0.23b	0.21bc
LSD P≤0.05	74.14*	13.6*	1.6	1.3	490.5**	127**	1.93	10.35	155.5**	96.53*	0.059**	0.032**
CV%	13.5	20.7	36.9	9.2	26.7	14.8	1.9	2.9	8.4	12.0	15.9	6.5

Means within a column followed by the same letter are not significantly different at P≤0.05

4.6.3 Interaction Effects of Irrigation and Priming on Number of Pods per Plant during Season I

Interaction effects of pre-sowing irrigation and priming (Table 25) for the season I crop reveals that pre sowing irrigation of 100% FC-HCL3T8 (0.3% $NaCl_2$ for 8 hours), produced the highest pods/plant (537 pods/plant) and these were not significantly differen from treatment combination of 100% FC-HCL1T12 (0.1% $NaCl_2$ for 12 hours) that produced 528 pods/plant. Interaction effects o pre-sowing irrigation and priming (Table 26) for the season II crop shows that highest pods/plants was significantly higher at pr sowing irrigation of 25% FC- HCL1T8 (0.1% $NaCl_2$ for 8 hours-83 pods/plant), and HCL3T10 (0.3% $NaCl_2$ for 10 hours-6 pods/plant) ; 50% FC-HCL1T12(0.1% $NaCl_2$ for 12 hours-69 pods/plant), and HCL2T12(0.2% $NaCl_2$ for 12 hours-96 pods/plant) 75% FC-HCL1T8 (0.1% $NaCl_2$ for 8 hours-69 pods/plant), and HCL3T10 (0.3% $NaCl_2$ for 10 hours-84 pods/plant) ; and 100% FC HyT8 (Hydro priming for 8 hours-66 pods/plant).

Table 25: Interaction effects of Irrigation and Priming on number of pods per plant during season I

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	170n	153no	323hi	162n	349gh	271j	195m	147o	254k	186m	231l	298i	391f
$I_{50\%FC}$	228l	207lm	191m	123o	170n	309i	236kl	221l	381fg	450d	461c	457cd	179mn
$I_{75\%FC}$	154n	70p	326h	228l	337h	256k	157n	287j	258k	367g	286j	435d	363g
$I_{100\%FC}$	185m	266jk	252k	247k	279j	294ij	528b	224l	239k	311i	537ab	401ef	306i
LSD ($P<0.05$)	154.9		CV%	33.2									

Table 26: Interaction effects of Irrigation and Priming on number of pods per plant during season II

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	44b	42b	58b	37b	83a	40b	52b	42b	55b	38b	44b	64ab	13c
$I_{50\%FC}$	51b	59b	36b	61b	53b	59b	69a	32b	42b	96a	57b	37b	45b
$I_{75\%FC}$	42b	45b	38b	35b	69a	42b	31bc	44b	41b	54b	54b	84a	43b
$I_{100\%FC}$	47b	66a	53b	56b	50b	27c	42b	45b	61b	34b	53b	21c	48b
LSD ($P<0.05$)	31.2*		CV%	34.1									

4.7 Effects of Treatments on Pods/m^2

4.7.1 Effect of Pre Sowing Irrigation on Number of Pods/m^2

The number of pods/m^2 were highest (1,631 and 586) in season I and II, respectively under pre sowing irrigation of 75% FC (Table 24). The more pods/m^2 in season I was attributed to the more rainfall that was received and was also well distributed during the season (565.10 mm) as compared to rainfall that was received in season II (311.2 mm). These treatment combinations were however not significantly different from the other pre sowing irrigation regimes. Relationship of pre sowing irrigation to pods/m^2 was shown to be curve linear with correlation coefficients (R^2 =0.84 and 0.78 for seasons I and II, respectively (Fig 43). This signifies the reliability of using these functions in predicting pods/m^2 of chickpea grown in Mwea under different pre sowing irrigation regimes. The rate of production of pods/m^2 was higher in season I (18.83) compared to season II (2.37).

4.7.2 Effect of Priming on Number of Pods/m^2

In both season I and II, HCL1T8 (0.1% $NaCl_2$ for 8 hours), significantly produced higher number of pods/m^2 i.e. 1615 and 754 in season I and II, respectively. In season I however, HCL1T8 was the same as HCL1T10 (0.1 % $NaCl_2$ for 10 hours), and HCL2T12 (0.2% $NaCl_2$ for 12 hours), that produced 2048 and 1863, respectively. In the season II, HCL1T8 (0.1% $NaCl_2$ for 8 hours), had similar pods/m^2 with HyT8 (hydro priming for 8 hours) and HCL3T8 (0.3% $NaCl_2$for 8 hours) that produced 656 and 630 pods/m^2, respectively (Table 24 and Fig. 53).

4.7.3 Interaction Effects of Irrigation and Priming on Number of Pods/m^2

Interaction effects of pre-sowing irrigation and priming (Table 27 and 28) for the season I and II crop reveals that highest pods/m^2 was significantly higher and equal under the following treatments: pre sowing irrigation 25% FC-HCL1T8 (0.1% $NaCl_2$ for 8 hours); 50% FC-HCL2T12 (0.2% $NaCl_2$ for 12 hours); 75% FC- HCL1T8 (0.1% $NaCl_2$ for 8 hours) and HCL3T10 (0.3% $NaCl_2$ for 10 hours); 100% FC-HyT0 (no priming). However, in season I, 50% FC-HCL1T10 (0.1% $NaCl_2$ for 10 hours) and HCL3T8(0.3% $NaCl_2$ for 8 hours) ; 75% FC-HyT10 (hydro priming for 10 hour), HyT12 (hydro priming for 12 hours), HCL1T10 (0.1% $NaCl_2$ for 10 hours) , HCL2T8 (0.2% $NaCl_2$ for 8 hours) , HCL2T12 (0.2% $NaCl_2$for 12 hours), and HCL3T8 (0.3% $NaCl_2$ for 8 hours) ; 100%FC- HyT0 (no priming), HCL1T10 (0.1% $NaCl_2$

for 10 hours) , and HCL2T12 (0.2% $Nacl_2$ for 12 hours) had significantly higher pods/m^2 than the control (1041 in SI and 626 in SII). Pods/m^2, ranged from 1666 pods/m^2 (75%FC pre sowing irrigation + 0.2% $NaCl_2$ for 8 hrs) to 2729 pods/m^2 (100% FC + 0.1% $NaCl_2$ for 10 hrs) in SI (Table 27). In the drier SII the significantly highest pods/m^2 ranged from 788 (75% FC + 0.3% $NaCl_2$ for 10 hrs) to 1068 (25% FC + 0.1% $NaCl_2$ for 8 hrs), respectively. These significant responses to pre-sowing irrigation and priming interactions that resulted in increments of pods/m^2 above the control - ranging between 60 – 162 % in season I and 25 – 70.6 % in season II, respectively, this should however be evaluated/considered in light of other factors such as rain-water availability and use, temperatures, and other environmental factors, between sowing and pod formation periods (over 65 days).

Table 27: Interaction effects of Irrigation and Priming on number of Pods/m^2 during season I

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	1041b	1186b	851b	1002b	2099a	1535b	1100b	665bc	1541b	1260b	1051b	1109b	451c
$I_{50\%FC}$	1277b	1244b	892b	1229b	851b	1788a	999b	1279b	1525b	2277a	1718a	724b	917b
$I_{75\%FC}$	1012b	664bc	1789a	2278a	2338a	2142a	1413b	1666ab	1202b	2168a	1682a	1290b	1562b
$I_{100\%FC}$	2301a	1729a	1168b	1257b	1172b	2729a	1392b	1212b	1471b	1747a	1417b	905b	1120b
LSD (P<0.05)	1131.7		CV%	43.5									

Table 28: Interaction effects of Irrigation and Priming on number of Pods/m^2 during season II

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	626b	552b	642b	346c	1068a	427c	568b	489c	622b	417c	575b	558b	430c
$I_{50\%FC}$	588b	520b	403c	655b	518bc	669b	754b	339c	473c	1016a	728b	358c	403c
$I_{75\%FC}$	456c	589b	449c	561b	809a	506c	440c	626b	373c	593b	636b	788ab	536b
$I_{100\%FC}$	578b	963a	607b	575b	621b	329c	436c	583b	668b	463c	579b	299c	362c
LSD (P<0.05)	280.2**		CV%	27.9									

4.8 Effects of Treatments on Grain Yields (kg/ha)

4.8.1 Effect of Pre Sowing Irrigation on Grain Yield

Table 24, reveals that pre sowing irrigation of 75% FC gave the highest grain yield of 1177.0 and 513.1 kg/ha in season I and II, respectively. These were followed by application of 100% FC that produced 1122.0 and 477.1 kg/ha, 50% FC that produced 1017 and 458 kg/ha and finally 25% FC that produced the least of 943.0 and 375.6 kg/ha in seasons I and II, respectively. However, there were no significant differences.

Fitted quadratic relationship (Fig 45) reveals that increasing pre sowing irrigation increased grain yields (kg/ha). However, the optimal levels were at 75% FC. Beyond which the grain yields starts to decline. The relationship had high reliability accounting for 86.2 to 98.0 % of the variations in seasons I and II, respectively (Fig. 45).

4.8.2 Effect of Priming on Grain Yield

In both seasons HCL1T8 (0.1% $NaCl_2$ for 8 hours) and HCL2T12 (0.2% $NaCl_2$ for 12 hours), significantly increased grain yields (kg/ha) in both season I and II (Table 24). In season I, HCL1T8 (0.1% $NaCl_2$ for 8 hours) and HCL2T12 (0.2% $NaCl_2$ for 12hours) produced 1365.0 and 1251.0 kg/ha of grain yields, respectively. In season II, HCL1T8 (0.1% $NaCl_2$ for 8 hours) and HCL2T12 (0.2 % $NaCl_2$ for 12 hours) produced 563.8 and539.4 kg/ha respectively, however, these were the same as for HyT8 (467.9kg/ha), HyT10 (478.3 kg/ha), HCL2T8 (467.7 kg/ha), and HCL2T10 (485.2 kg/ha). Hydro priming for 8 and 10 hours, Halo priming ($NaCl_2$ at 0.1% (HCL1T8) and 0.3% $NaCl_2$ at 0.1% for about 6 hours gave significantly the highest grain yields (Fig.48, 49, and 51).

4.8.3 Interaction Effects of Irrigation and Priming on Grain Yield (kg/ha)

Interaction effects of Irrigation and Priming on Grain Yield (kg/ha) during season I (Table 29) reveals that pre sowing irrigation of 75% FC-HCL1T8 (0.1% $NaCl_2$ for 8 hours), HCL2T12(0.2% $NaCl_2$ for 12 hours) and HCL3T10(0.3% $NaCl_2$ for 10 hours) produced 1562.0, 1604.0 and 1460.0 kg/ha, respectively; and 100% FC-HyT8 (hydro priming for 8 hours) that produced 1788.0 kg/ha had significantly higher grain yields (Table 29)

Interaction effects of Irrigation and Priming on Grain Yield (kg/ha) during season II reveal a similar trend as in season I where pre sowing irrigation of 75% FC-HCL1T8(0.1% $NaCl_2$ for 8 hours) and 100% FC-HyT8 (hydro priming for 8 hours) produced grain yield of 755.0 and 748.3 kg/ha, respectively and were significantly higher. However, in season II these were the same as for pre sowing irrigation 50% FC-HCL2T12 (0.2% $NaCl_2$ for 12 hours) that produced 921.7 kg/ha (Table 30).

Table 29: Interaction effects of Irrigation and Priming on Grain Yield (kg/ha) during season I

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	657d	985c	955c	818cd	1401b	968c	872c	1148b	779d	759d	1007c	875c	1037c
$I_{50\%FC}$	1154b	932c	1010c	1033c	1136bc	912c	1099c	689d	1111c	1406b	934c	892c	912c
$I_{75\%FC}$	1001c	1040c	941c	949c	1562a	1102c	995c	997c	709d	1604a	1223b	1460ab	1009c
$I_{100\%FC}$	848c	1788a	1225b	1072c	1362b	1315b	1228b	1064c	895c	1233b	1067c	1300b	905c
LSD (P<0.05)	332.8**		CV%	18									

Table 30: Interaction effects of Irrigation and Priming on Grain Yield (kg/ha) during season II

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	345.8d	287.5d	495.8c	348.3d	683.3b	420.8c	325.8d	275.8c	394.2c	350.0d	254.2d	460.0c	241.7d
$I_{50\%FC}$	429.2c	460.0c	275.8d	442.5c	425.0c	425.0c	410.0c	490.0c	491.7c	921.7a	516.7c	312.5d	356.7cd
$I_{75\%FC}$	496.7c	375.8c	576.7b	505.0c	755.0a	429.2c	329.2d	588.3b	588.3b	585.8b	682.5b	366.7c	391.7c
$I_{100\%FC}$	491.7c	748.3ab	565.0b	375.0c	391.7c	491.7c	560.0bc	516.7c	466.7c	300.0d	366.7b	450.0c	479.2c
LSD (P<0.05)	206.23 *		CV%	26.1									

4.9 Effects of Treatments on 100 Seed Weight (gms)

4.9.1 Effect of Pre Sowing Irrigation on 100 Seed Weight (gms)

Table 24 shows that increasing pre sowing irrigation from 25% to 75% FC increased 100 seed weight in grams in both season I and II. The highest seed weight was realized in both season I and II under 75% FC (29.6gms and 73.7 gms, in season I and II, respectively), and was significantly higher in season II. Similarly, Muhammad *et al.* (2010); Malik and Anwar (1994) reported that 100 grains weight increased by irrigation in chickpea. 100 seed weight was observed (Fig. 46) to follow a curvilinear curve with correlation coefficient of R^2=0.81 and 0.74 in season I and II, respectively. Increasing irrigation beyond 75% FC resulted in a decline in grain weight in season I.

4.9.2 Effect of Priming on 100 Seed Weight (gms)

Treatment combination HCL1T8 had significantly higher 100 seed weights in both season 1 (30.3 gms) and season II (74.2 gms). However, these were statistically similar with all the other treatment combinations apart from those of treatment combinations in season I, HyTo, HyT12 and HCL2T10 and treatment combinations HCL1T8, HCL1T12 and HCL2T8 of season II that had significantly lower 100 seed weight (Table 24 and Fig. 55).

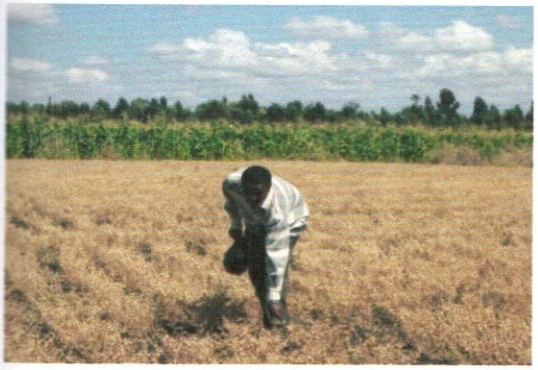


Plate 27: Ready chickpea for harvesting the grains (120 DAS)

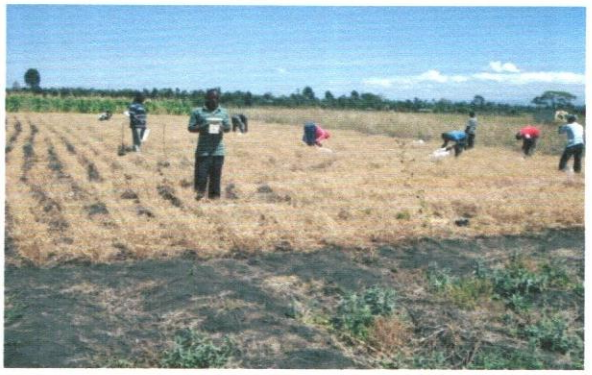


Plate 28: Harvesting, threshing and weighing of the harvested grains in the net

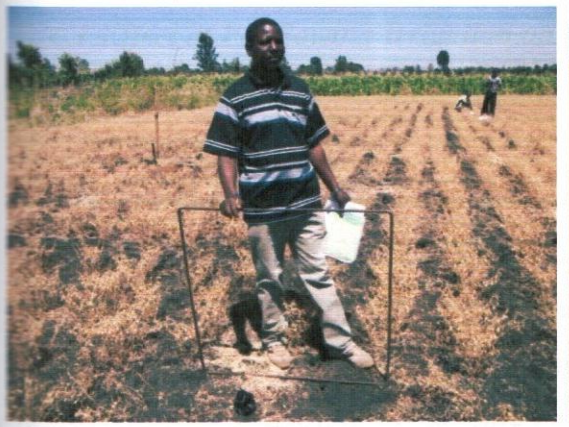


Plate 29: Using of 1 m^2 metal bar (net plot) during harvesting (120 DAS)



Plate 30: Chickpea field ready for harvesting (120 DAS)



Plate 31: Harvesting, threshing and winnowing of the net plot grains (120 DAS)



Plate 32: Harvesting, threshing and winnowing of chickpea (120 DAS)

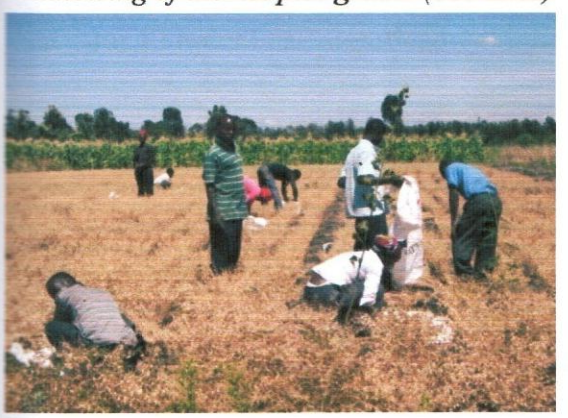


Plate 33: Harvesting, threshing and winnowing of chickpea (120 DAS)

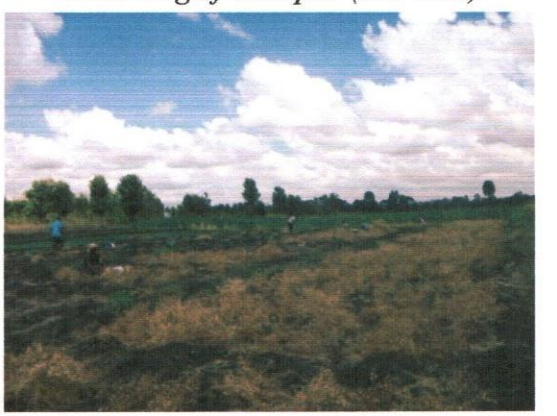


Plate 34: Weighing net plot grain yields (kg)

4.10 Effects of Treatments on Harvest Index (HI)

4.10.1 Effect of Pre Sowing Irrigation on Harvest Index (HI)

The highest harvest index (HI) of 0.25 in both season I and II was highest with application of 50% FC pre sowing irrigation (Table 24). This was followed by harvest index of 0.24 under pre sowing irrigation of 75% FC in both seasons. The lowest harvest indexes were with pre sowing irrigation 0f 100% FC and 25% FC which were between 0.22 and 0.21 in both seasons. Fitted quadratic relationship (Fig 47) revealed that application of up to 60% FC increased HI in both season I and II. The relationship had high regression coefficients of 0.93 and 0.92 in season I and II, respectively. Increase of pre sowing irrigation beyond 60% FC resulted in decline of harvest index.

4.10.2 Effect of Priming on HI

HyT10, HCL1T8, HCL1T12, HCL2T10 and HCL3T10 had significantly higher HI in both season I and II. However, in season I, HCL2T12 and in season II, HyT8 had the same harvest index (Table 24).

4.10.3 Interaction Effects of Irrigation and Priming on HI

Interaction effects of Irrigation and Priming on HI in season I reveals that pre sowing irrigation of 50% FC-HCL2T12(0.2% $NaCl_2$ for 12 hours) had significantly higher harvest index (HI) of 0.68 (Table 31). Interaction effects of Irrigation and Priming on HI in season II shows that pre sowing irrigation 50% FC-HyT10 (hydro priming for 10 hours) and 75% FC-HCL1T12(0.1% $NaCl_2$for 12 hours) had significantly higher HI of 0.38 and 0.43, respectively (Table 32).

Table 31: Interaction effects of Irrigation and Priming on HI during season I

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	0.10e	0.13e	0.31c	0.15e	0.30c	0.28d	0.13e	0.16de	0.17d	0.13e	0.27d	0.38c	0.31c
$I_{50\%FC}$	0.29cd	0.19d	0.25d	0.12e	0.29cd	0.15e	0.22d	0.13e	0.37c	0.68a	0.19d	0.16de	0.19d
$I_{75\%FC}$	0.26d	0.11e	0.27d	0.12e	0.29cd	0.17d	0.28d	0.12e	0.46b	0.18d	0.17d	0.27d	0.19d
$I_{100\%FC}$	0.14e	0.24d	0.25d	0.22d	0.21d	0.16de	0.42bc	0.34c	0.13e	0.06e	0.29cd	0.40c	0.23d
LSD (P<0.05)	0.13**		CV%	31.1									

Table 32: Interaction effects of Irrigation and Priming on HI during season II

Irrigation	Priming												
	HyT_0	HyT_8	HyT_{10}	HyT_{12}	HCL_1T_8	HCL_1T_{10}	HCL_1T_{12}	HCL_2T_8	HCL_2T_{10}	HCL_2T_{12}	HCL_3T_8	HCL_3T_{10}	HCL_3T_{12}
$I_{25\%FC}$	0.09f	0.21d	0.16d	0.21d	0.21d	0.28c	0.19d	0.19d	0.20d	0.11e	0.34b	0.33b	0.17de
$I_{50\%FC}$	0.30c	0.31bc	0.38ab	0.21d	0.29c	0.21d	0.23d	0.10ef	0.31bc	0.33b	0.13e	0.19d	0.24cd
$I_{75\%FC}$	0.24cd	0.20d	0.24cd	0.15d	0.32b	0.14d	0.43a	0.12e	0.33b	0.26c	0.19d	0.25c	0.26c
$I_{100\%FC}$	0.17d	0.26c	0.18d	0.24cd	0.21d	0.26c	0.22d	0.34b	0.15e	0.18d	0.18d	0.24cd	0.17de
LSD (P<0.05)	0.07**		CV%	17.2									

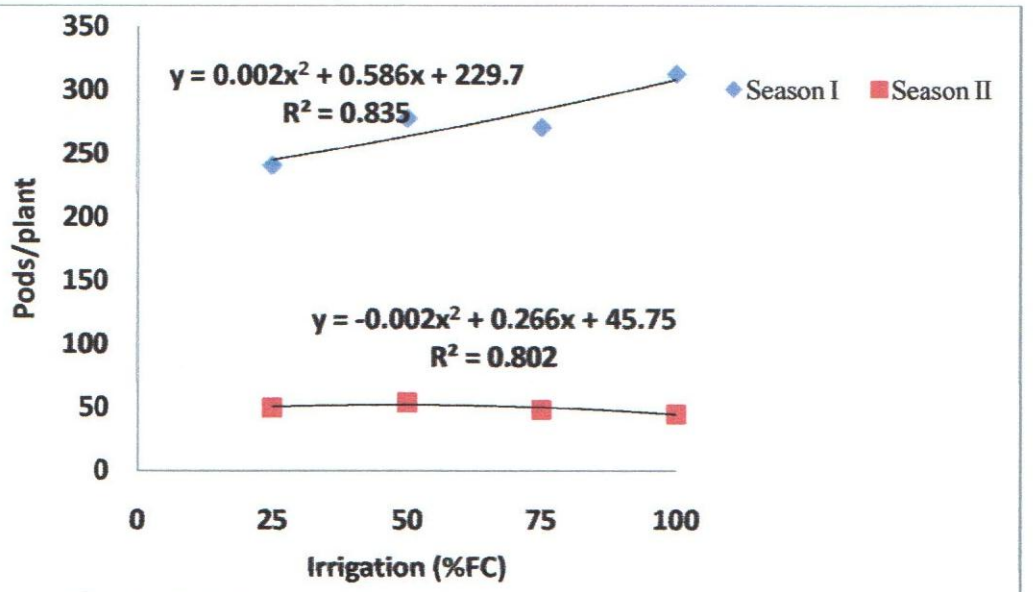


Fig 42: Relationship of pre sowing irrigation to pods/plant of chickpea in semi arid Mwea

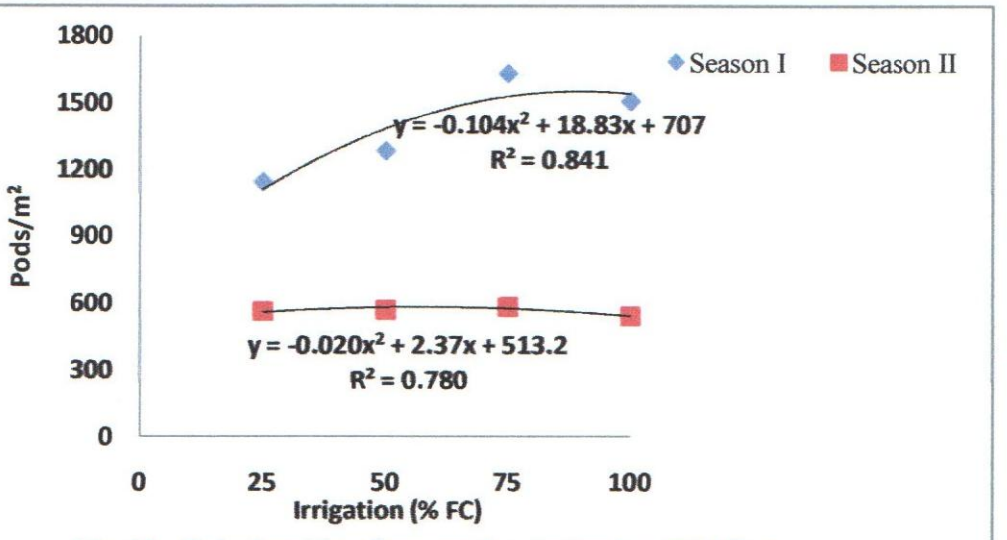


Fig 43: Relationship of pre sowing irrigation (%FC) to pods/m2 of chickpea in semi arid Mwea

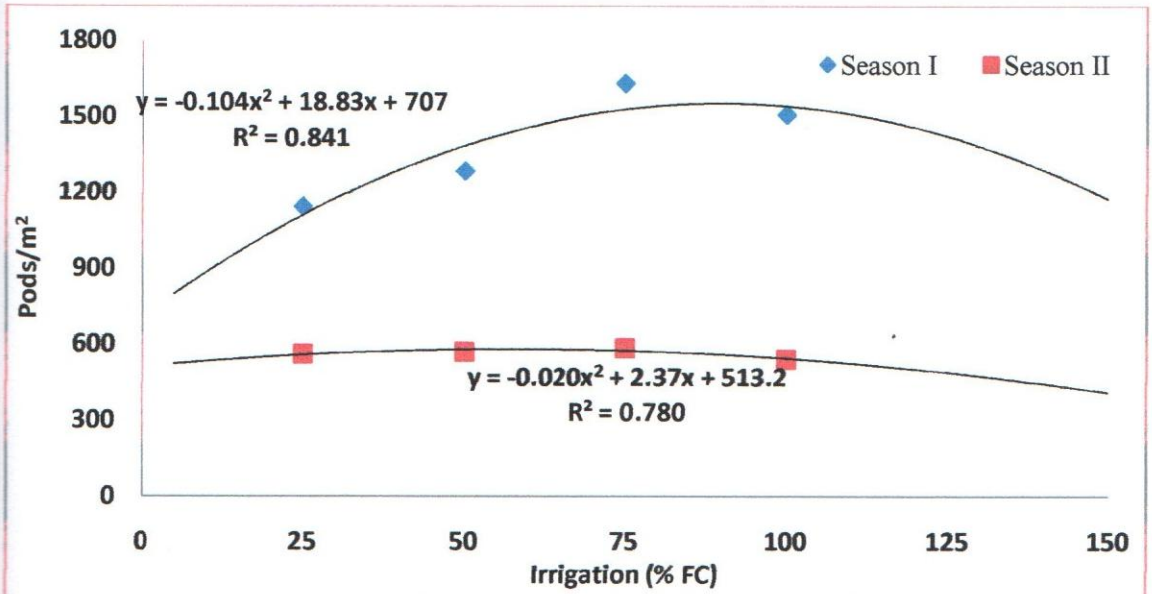


Fig 44: Relationship of pre sowing irrigation (%FC) to pods/m² of chickpea in semi arid Mwea

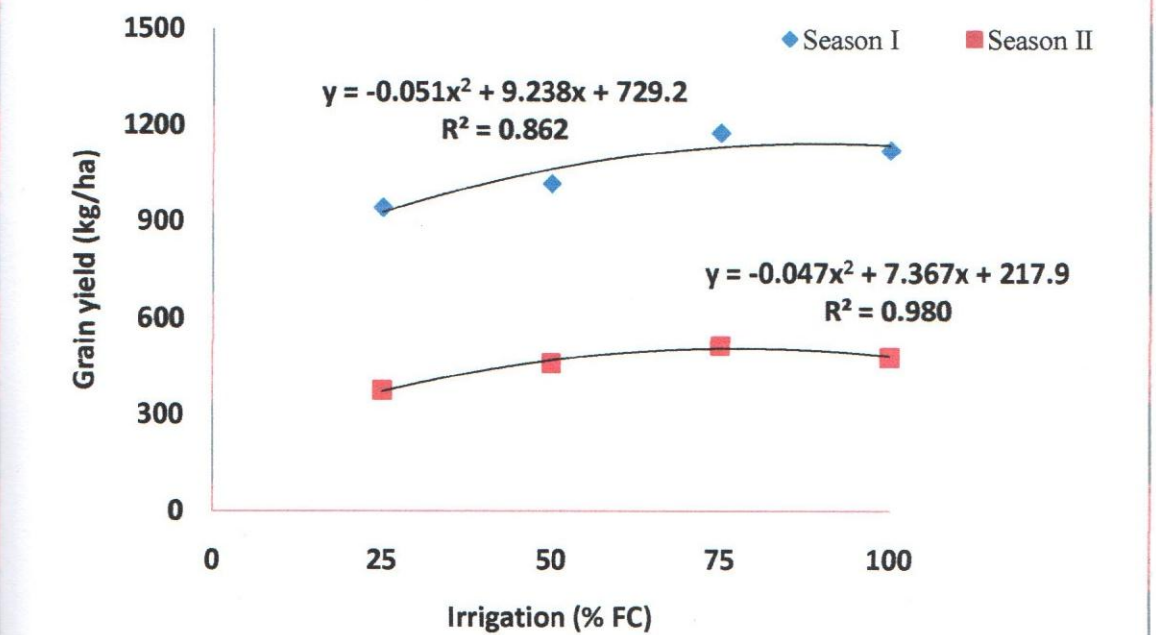


Fig 45: Relationship of pre sowing irrigation (%FC) to grain yields (kg/ha) of chickpea in semi arid Mwea

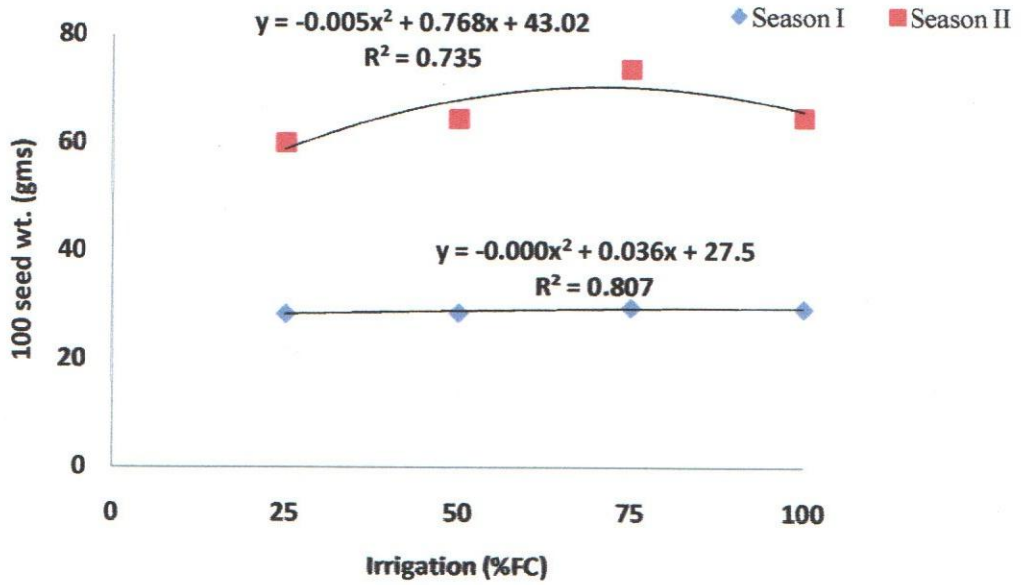


Fig 46: Relationship of pre sowing irrigation (% FC) to 100 seed wt (gms) of chickpea in semi arid Mwea

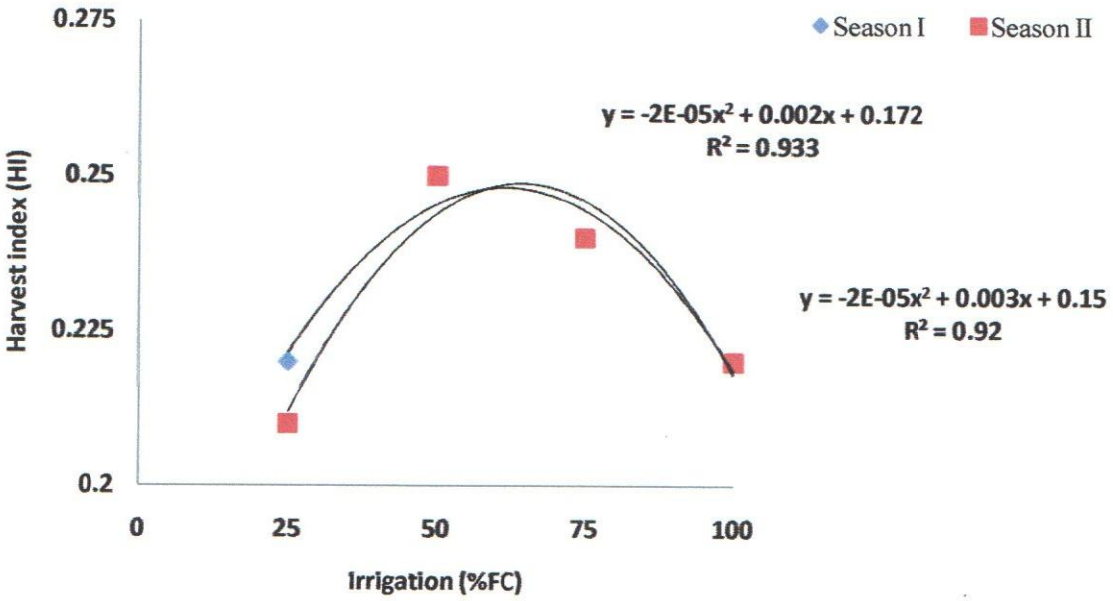


Fig 47: Relationship of pre sowing irrigation (%FC) to HI of chickpea in semi arid Mwea

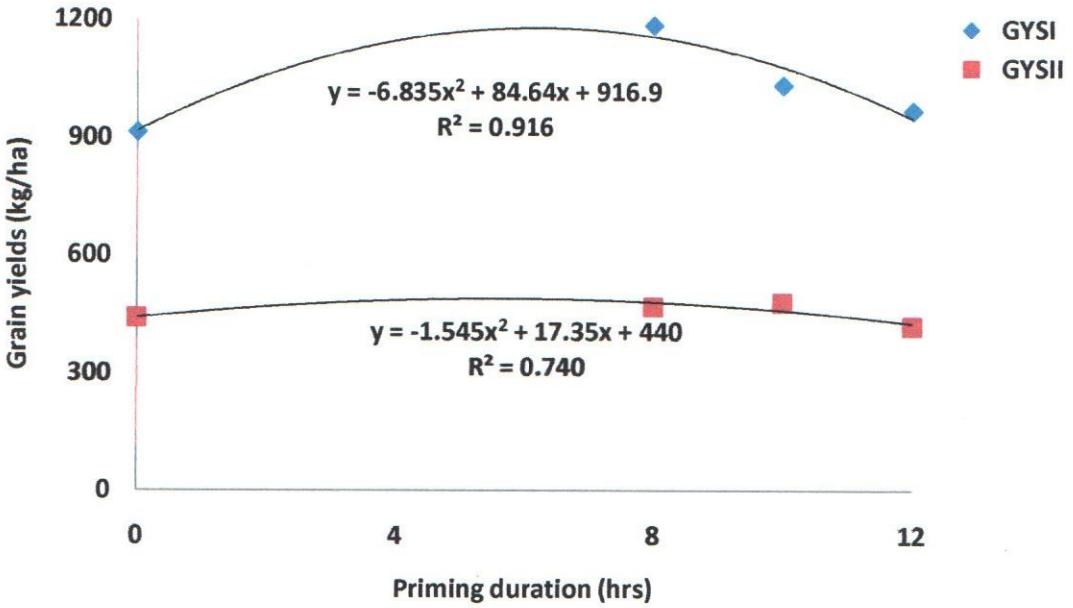


Fig 48: Relationship of hydro priming on chickpea grain yields(kg/ha) in semi arid Mwea

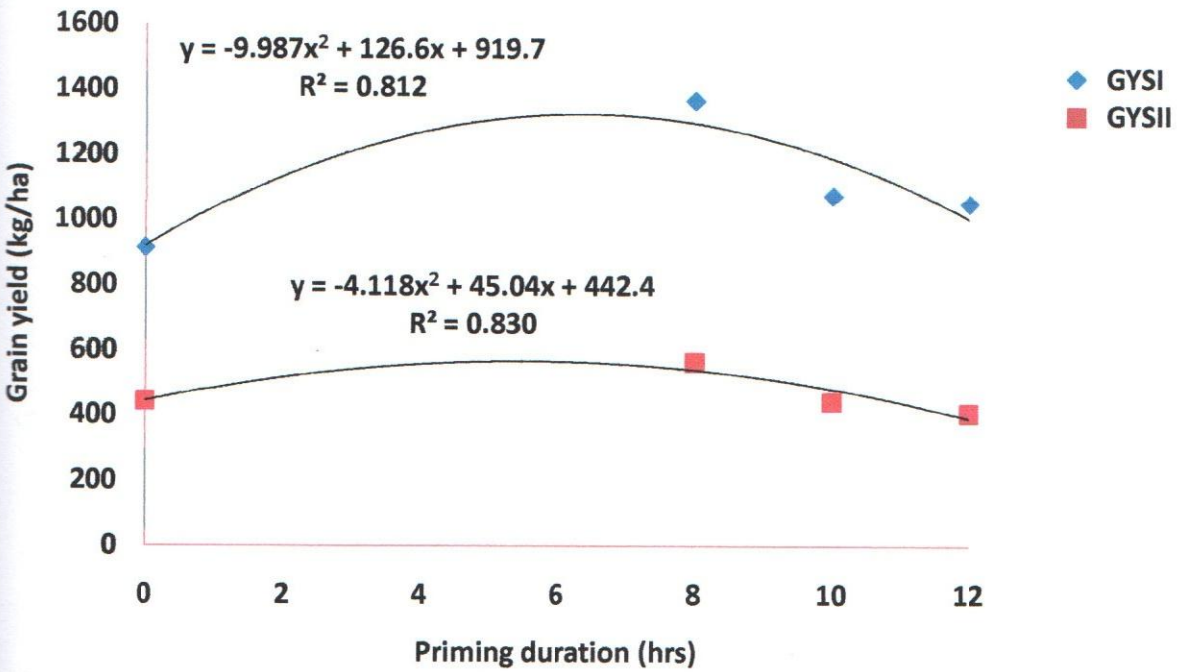


Fig 49: Relationship of halo priming (0.1% Nacl) on chickpea grain yields (kg/ha) in semi arid Mwea

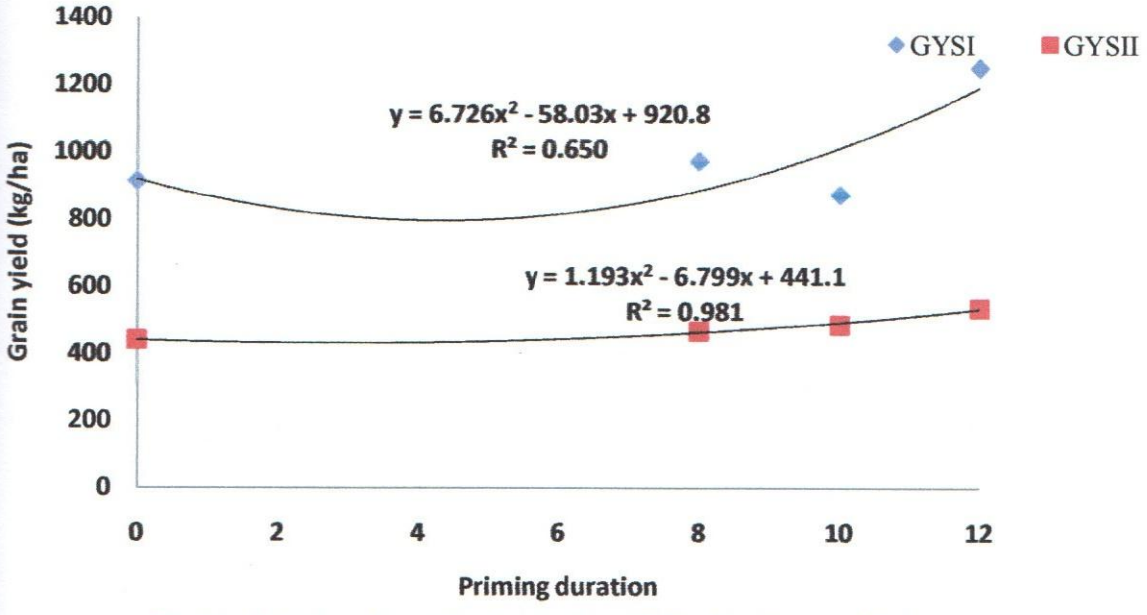


Fig 50: Relationship of halo priming (0.2% Nacl2) on chickpea grain yields(kg/ha) in semi arid Mwea

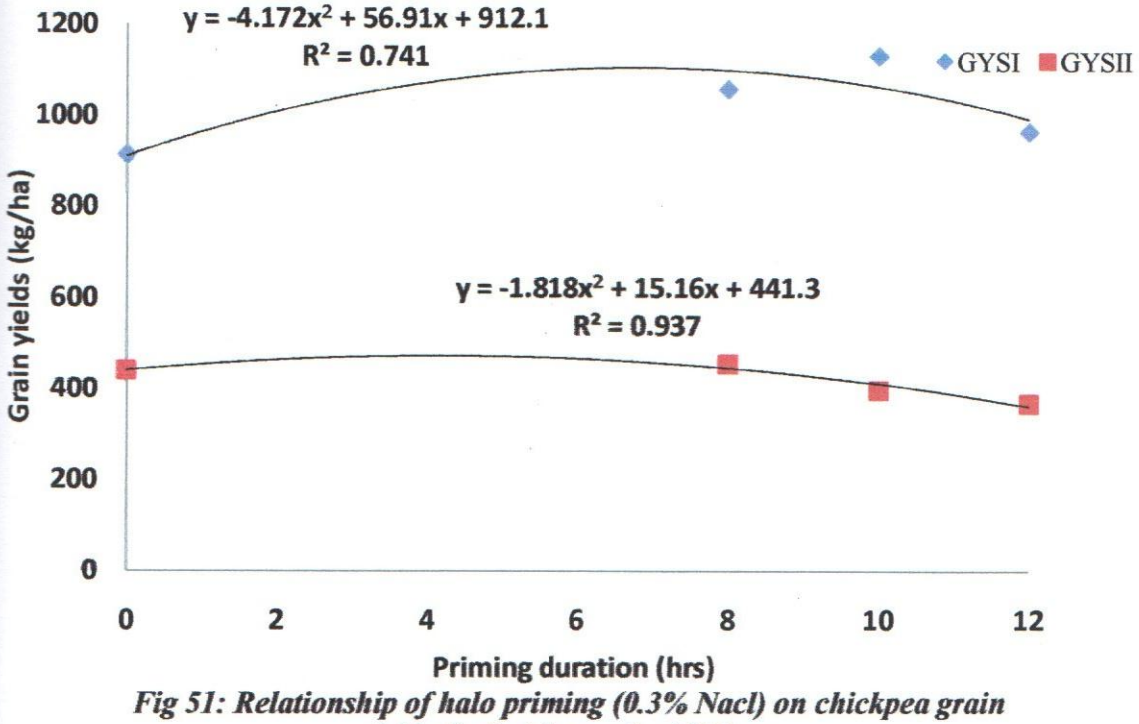


Fig 51: Relationship of halo priming (0.3% Nacl) on chickpea grain yields (kg/ha) in semi arid Mwea

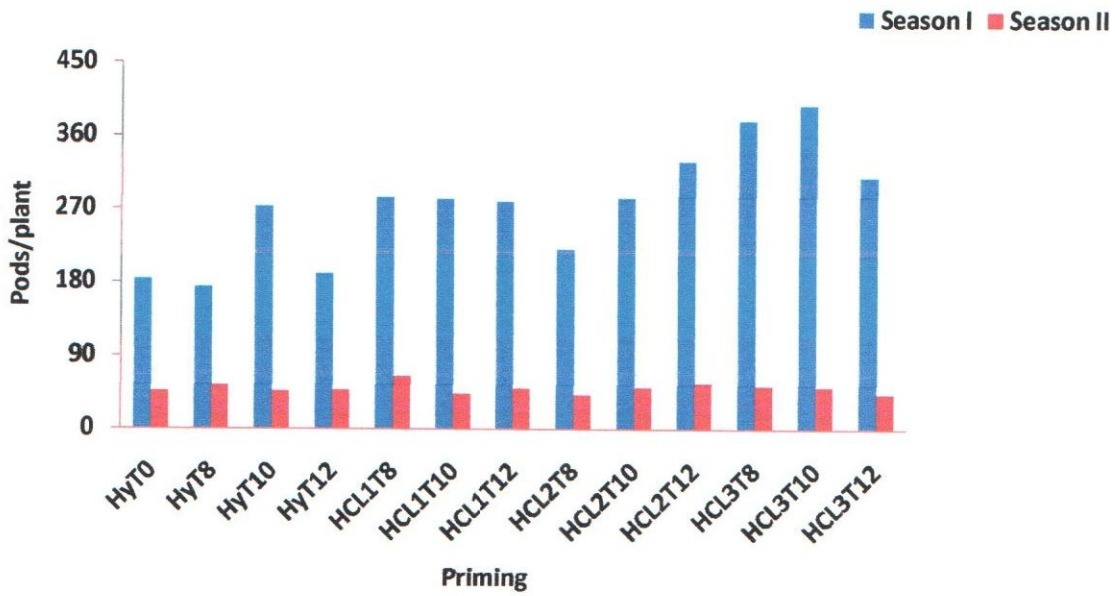


Fig 52: Relationship of priming on pods/plant

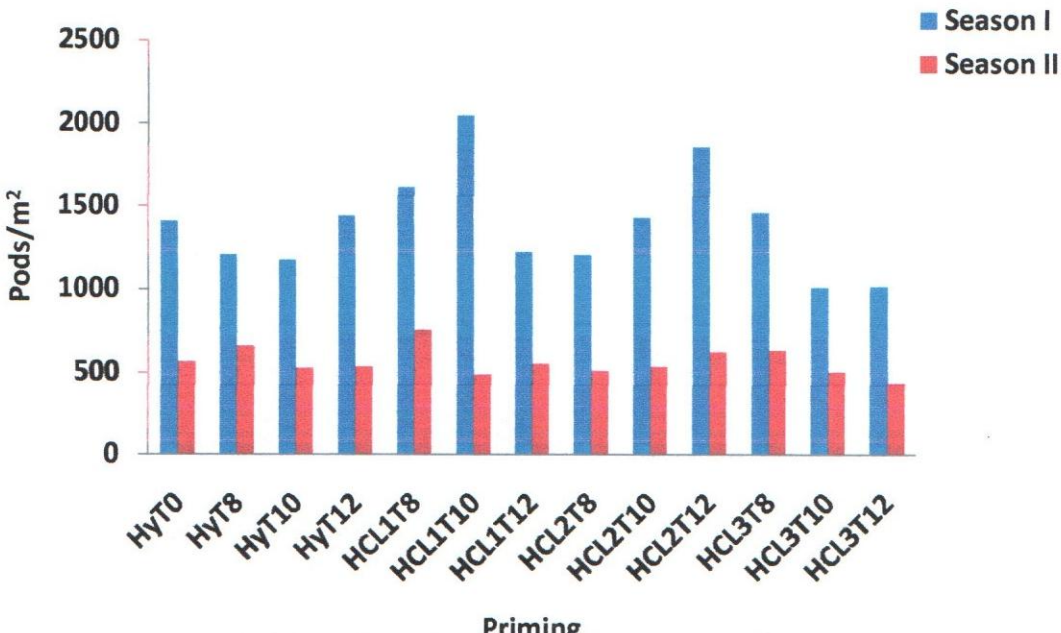


Fig 53: Relationship of priming on pods/m²

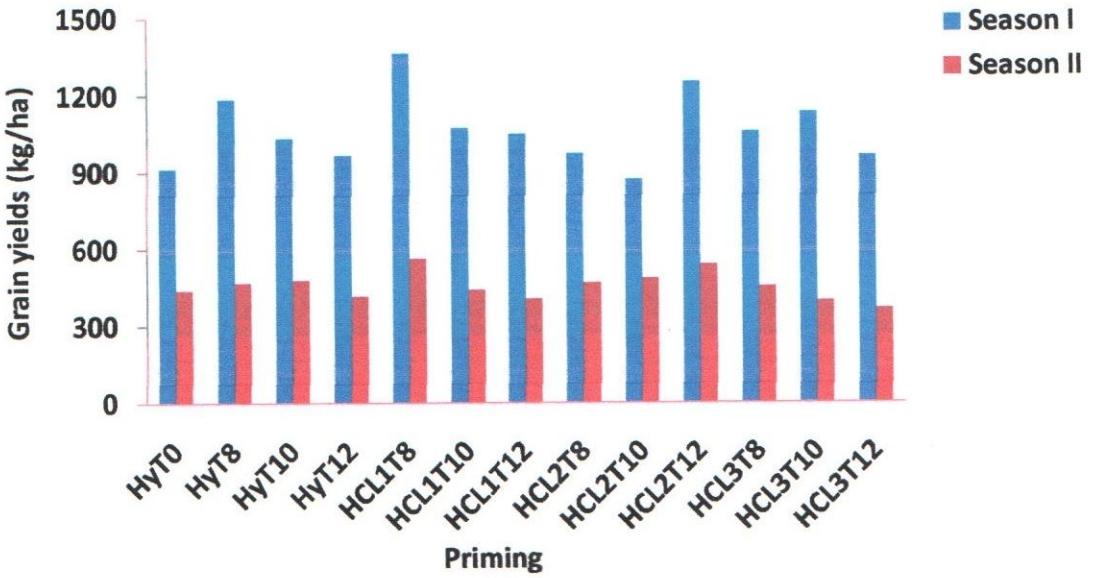


Fig 54: Relationship of priming on yields (kg/ha) of chickpea in semi arid Mwea

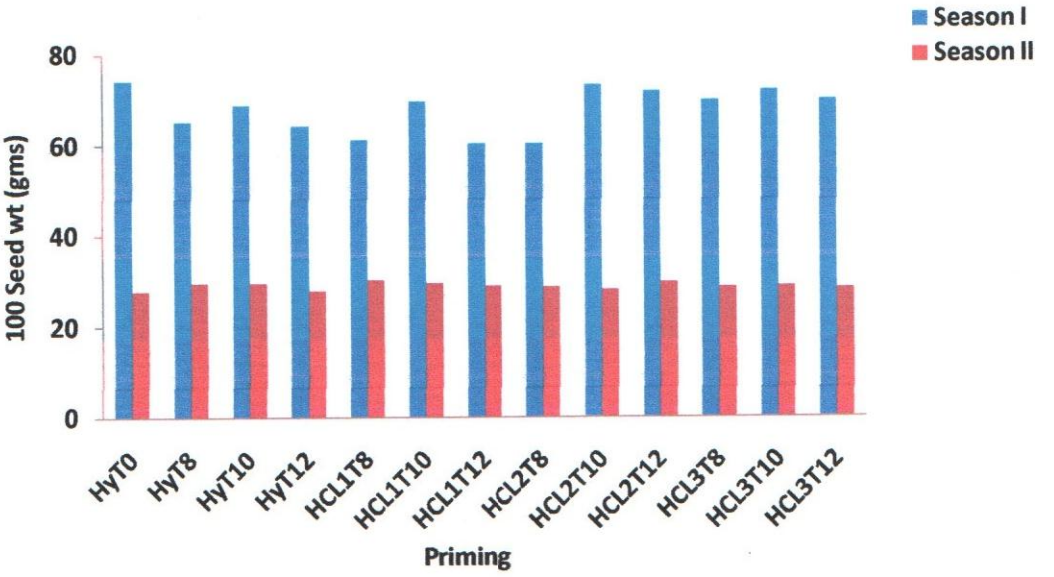


Fig 55.: Relationship of priming on 100seed weight (gms) of chickpea in semi arid Mwea

CHAPTER FIVE

5.0 DISCUSSION

The current study was carried out with the aim of evaluating the performance of chickpea under different priming methods, varying priming durations and different initial soil moisture levels on germination, growth and yield of desi chickpea (*Cicer arietinum L.*) under dry land conditions of Mwea. The results have been presented above in this chapter and an attempt has been made here below to discuss the causes of the variations induced by the said treatments

5.1 Effects of alpha (α) Amylase Enzyme Concentration (Micro Moles/ml Maltose) on Priming Chickpea Seeds

The highest ($P \leq 0.05$) alpha amylase activity of 12.97 µmoles/ml, was with HCL1T8 treatment, i.e., halo priming for 8 hrs with 0.1 % $NaCl_2$. This treatment combination was also statistically equal to HYT10 (12.70 µmoles/ml), HCL2T12 (12.43 µmoles/ml) HLC1T12 (12.07 µmoles/ml), HCL2T8 (12.07 µmoles/ml), HCL2T10 (12.03 µmoles/ml) and HYT8 (8.20 µmoles/ml). Non primed seeds (control) had significantly the least enzymatic activities (7.05 µmoles/ml). Similarly, Reihaneh and Mehdi (2011) reported that the untreated seeds of the legumes exhibited very low amylase activity that ranged from 7.0 to 18.1 maltose units/g dry matter. It is obvious that increasing the germination and seedling growth / establishment period to 4 days (96 hours) and 8 days (192 hours) tended to increase the alpha amylase activity from 7.05 (control) to 18.17 (HCL1T8) and 24.4 micro moles/mg maltose (HCL2T8) at planting, 4 and 8 days after sowing, respectively. Alpha (α)-amylase activity was reported by Mehdi (2011) to increase significantly ($P \leq 0.05$) in all the legumes tested on progressive germination. Appreciable increase in enzyme activity was observed in mung bean from 8.1 to 280.2 maltose unit/ g dry matter at 0 and 72 hours germination time, followed by cowpea, lentil and chickpea that had increases of exceeding 600, 500 and 200%, respectively over the untreated initial values.

Enzymatic activities of all legumes improved significantly ($P<0.05$) and reached maximum during the course of germination up to 72 hr. Uriyo (2001), also reported similar results in the case of cowpea. He found that germination had a highly significant effect ($P \leq 0.05$) on cowpea α-amylase activity. Alpha amylase levels increased from 85.6 to 720.9 µmoles maltose/ ml of extract at 0 and 72 h germination time, respectively. Similar behavior was reported for cowpea, whose investigations indicated that α- amylase activity had attained a maximum at 3 days

germination and had begun to decline at 4 days [Malleshi *et al.* (1989)]. Sumathi *et al.* (1995) also showed improvement in α-amylase levels of horse gram, moth bean and field bean during germination. These findings agree with other reports regarding α-amylase production during germination of plant seeds other than legumes such as, maize [Helland *et al.*,2002], oats [Bodin (1995).], millet [Gimbi and Kitabatake (2002)] and sorghum [Lasekan,(1996) and Uvere (2000)].

Hosseini and Koocheki, (2011) reported that during priming, several processes including activation and synthesis of a number of enzymes and nucleic acids, repair and build up, ATP synthesis, and the cytoplasmic membrane repair in treated seeds start to develop. Priming usually induces faster and more uniform seed germination and seed emergency (Nascimento, 2012)
During germination of seeds, α-amylase and protease, that are developed, degrade starch granules and reserve proteins, respectively; thereby reducing the dietary bulk and improving the digestibility of starch and protein [Reihaneh and Mehdi (2011); Negi *et al.*(2001); Lasekan (1996); Muntz (1996); Kataria,*et al.*(1992)]. Germination was shown to increase monosaccharide and decreased disaccharide contents of legumes due to α-amylase [Akinlosottu and Akinyele (1991)]. Monosaccharides can be used as a good energy source and will also increase the palatability of seeds. Hence, enhanced phytase, amylase and protease activities in germinated legumes may diminish the antinutritional effects of phytic acid and improve the nutritional quality, which make them important in biotechnological applications.

These effects of priming are associated with the repairing and building up of nucleic acids, increased synthesis of proteins as well as the repairing of membranes (McDonald, 2000). Priming also enhances the activities of anti-oxidative enzymes in treated seeds (Hsu *et al.*, 2003). The early improvements may increase the rate and uniformity of seed germination and seedling emergence (Ayda *et al.*, 2013; Ghassemi-Golezani *et al.*, 2010), especially under stressful conditions (Ghassemi-Golezani *et al.*, 2012).

In conclusion soaking chickpea seeds in priming solutions (i.e., water for 8 and10 hours and saline solutions of 0.1% $Nacl_2$ for 8 and 12 hours; 0.2% $Nacl_2$ for 8, 10 and 12 hours) was useful in enzymes production that can bring about sufficient increase in enzymes activities at sowing,

which in turn causes partial elimination of antinutrients (phytic acid) and pre-digestion of carbohydrate and protein in legume seeds, that make them useful in formulation of pediatric to geriatric foods.

5.2 *Effect of Pre-sowing Irrigation at 25%, 50%, 75% and 100% Field Capacity (FC) on Chickpea Germination (Plants/m^2) in Season I and II*

Increasing pre sowing irrigation from 25% field capacity (25% FC) to 100% FC, increased plants/m^2 in both season I and II. There was high positive correlation between pre soil moisture and number of plants/m^2 at emergence. There was a strong positive correlation (of 0.939 - SI and 0.894 - SII) between soil water at sowing and plants/m^2 at emergence of desi chickpea in Mwea. Soil moisture content of 75% and above is essential for good chickpea plant stand. Similarly, Muhammad, *et al.* (2010) reported that adequate water must be available during germination and sensitive growth periods of chickpea.

Increasing pre sowing irrigation from 25% field capacity (25% FC) to 100% FC, successfully increased plants/m^2 successfully in both season I and II; which were however, not significantly different. Plant population density increased from 11-15 plants/m^2 in season I (SI) and 5-6 plants/m^2 in season II (SII), respectively in response to pre sowing irrigation of 25 to 100% FC. This means that in order to achieve an increased initial plant population by the 11th DAS, and thus a good plant stand, providing and optimizing the soil moisture 75% FC (Fig. 10) is critical for chickpea germination and survival. It was observed that in the Oct 9th 2012 SI sowing, a rainfall of 100.6mm was received on 11th Oct 2012 and 51.1mm and 26.0mm on 12th and 13th Oct 2012. For this reason a pre-sowing irrigation to 75% FC was sufficient to optimize and maximize the plant population to15 plants/m^2. However in the July 10th 2013 crop, there was only 2.7mm rainfall received in the whole of July and only 5.5mm in August. This rainfall was very low and also scattered in the day of 13th (0.5mm) and 28th (1.2mm) July 2013 (Fig. 3). In the following month of August, rainfall was also very low and scattered within 5 days of the month. For this reason pre-sowing irrigation was found to be very effective in ensuring germination and establishment of chickpea in SII. However, the plant stand of 5 – 6 plants/m^2 was very poor (for SII) as compared to 11 – 15 plants/m^2 in SI (i.e., 220 – 250% higher).

Ideally, planting at a spacing of 45cm x 15 cm (0.45m x 0.15m) should give a plant population of 148,148 plants per hectare (ha), which is equivalent to 14.8 or 15 plants per m^2. Therefore in season I (Oct, 2012) the expected plant population was achieved, but in season II (July) the poor rainfall at sowing time and relatively lower total season rainfall of 311.2 mm resulted in poor plant stand (5 – 6), and the subsequent growth and yield. Fitting a polynomial curve relating pre sowing irrigation with plants/m^2 at germination that gave a good fit on the data (Fig. 5), with over $R^2 = 0.902$ coefficient of determination in SI and 0.8 in SII. The polynomial curve however reveals that there is a possibility of increasing the plant population density at 11 DAS beyond the 11 to 15 plants/m^2, i.e., if chickpea was planted in environments having higher initial (top) soil moisture Gaur *et al.*, (2010). The fitting of power functions (R^2=11) were found to be more realistic than the polynomial functions (R^2=10) in explaining chickpea plant population stands at 11 DAS under varying soil moisture contents (Fig.10 and 11).

5.3 Effect of Priming and Pre Sowing Irrigation on Plants/m^2 at Germination

Priming chickpea seed before sowing did not show any significant differences in season I where plant population ranged between 12 to 14 plants/m^2. In season II, plant population ranged between 3 and 8 plants/m^2 and the treatment combinations HCL_1T_8 (8 plants), HCL_1T_{10} (7 plants), HCL_1T_{12} (7 plants), HCL2T8 (7 plants) and HyT_{12} (7 plants) had significantly higher number of plants/m^2. Similarly, as for season II, Ashkan *et al.* (2012) and Harris *et al.* (2001), reported that priming seed improves germination, crop growth vigor, and enhanced earlier flowering and higher yields. Shad *et al.* (2010) opined that seed priming with P_2O_5 solution enhanced days to emergence compared with non prime (control). Therefore chickpea seed priming improved germination at limited initial soil condition of SII. Furthermore the interaction effect (combination) of pre sowing irrigation at 50%, 75% and or 100% FC with priming was observed to enhance desi chickpea germination to between 6- 10 plants/m^2 (Table 3). Amongst these treatments the relatively higher 8-10 plants/m^2 were achieved with interaction of 75% FC with either HyT_{12} or HCL1T8 and 100%FC with either HCL1T8 or HCL1T10 or HCL1T12. At 75 and 100% FC it's also possible to get 6 – 7 plants/m^2 with no seed priming. Therefore farmers can achieve 6-7 plants/m^2 without priming if soils are up to 75% FC and above. Priming with water for 12 hours would achieve 6-8 plants/m^2 which would be statistically equal to 8-10 plants/ha 8-10 hours 0.1%$Nacl_2$. It should be noted that priming with 0.1% $Nacl_2$ for more than 8

hour would depress germination to 6 plants/m^2 and below with 75% FC soil moisture content (Table 3). Regression analysis revealed (Fig 56) that priming with 0.1% $Nacl_2$ for 8 hours would achieve a mean of 8 plants/m^2 with either 75 or 100 % FC.

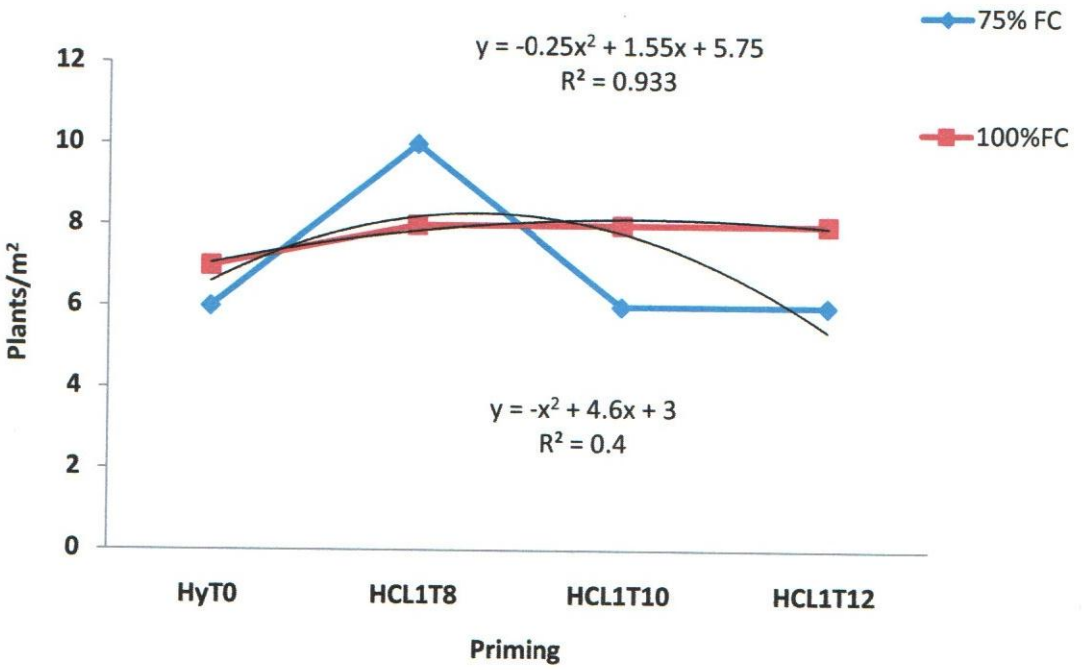


Fig 56: Relationship of 0.1 $Nacl_2$ solutions and priming time with plants/m^2 at emergence

4.11.4 Effect of Pre-Sowing Irrigation at 25%, 50%, 75% and 100% Field Capacity on Dry Matter and CGR of Chickpea in both Seasons

The highest dry matter of 5001.1 and 3973.0 kg/ha (kg/ha) was realized under 100 % FC at 105 DAS in season I and II, respectively. Dry matter accumulation (kg/ha) increased with increase in growth, i.e., from 25 DAS to 105 days after sowing (DAS) in both season under all pre sowing irrigation conditions. Dry matter also increased with increased pre sowing irrigation from 25 % field capacity (25% FC) to 100% FC, and at every stage of growth i.e., 25,50,75,90 and 105 DAS. Similar findings were reported by Muhammad *et al.* (2010); Parvender (2006), and Anwar *et al.* (2003) who noted that water deficit decreased dry matter accumulation (biological yield)

and grain yield per unit area and the fully irrigated crop had taller plants, maximum dry matter accumulation and higher grain yield than plants that were irrigated once, and the irrigation increased grain yields by 74-124% and these trends were similar for total dry matter (TDM) yields (Anwar *et al.* 2003). Similarly, Malhotra *et al.* (1997) observed increased total dry biomass (49%) and plant height (26%) with increased irrigation. Water stress decreases dry matter accumulation (DMA) and grain yields per unit area (Singh *et al.*, 2006; Ghassemi – Golezani *et al.*, 1998).

The good linear regression coefficients (ranging from 0.708-0.985) developed when pre sowing water content (through irrigation) was related with dry matter (Figs. 24-28), indicated high reliability of the functions to predict the responses of chickpea dry matter to pre sowing (initial) soil water content. This response curves explained dry matter production (Figs.13, 15, 17 and 19) and crop growth rates (Figs 14, 16, 18 and 20) at various growth phases of chickpea. The crop growth rate (CGR) increased gradually as the plant grew from 0– 25 DAS to 90-105 phasic periods irrespective of pre sowing irrigation treatments. A maximum crop growth rate (CGR) of 158.9 kg DM/ha/day (Fig 20) with 100% FC (was obtained during the drier season II (Oct 2012-Jan 2013). It was higher at 200 kg DM/ha/day during July-October, 2013 (wet season I); with 100% FC initial soil water content. This is the period from branching, indeterminate flowering and podding (B-IFl-P). This was in agreement with previous studies done by Fazlulf, *et al.* (2009) and Kamithi, (2008). Therefore, Desi chickpea grew slowly under a lower seasonal (SII) rainfall of 311.2 mm than the higher seasonal (SI) rainfall of 565.1 mm. It is beneficial to apply higher pre sowing irrigation of up to 100% FC in both seasons, with respect to subsequent growth of chickpea.

5.5 Effects of Priming on Dry Matter at 25, 50, 75 and 90 DAS

Halo priming for 8 hours (hrs) with 0.2% $NaCl_2$ distilled water solution gave significantly the highest DM at all stages of growth. According to Harris *et al.* (2001); Scotte *et al.* (1973) and Henckel, (1964) primed crops grow more vigorously, flower earlier, increase leaf area index, dry matter accumulation and ultimately gain more grain yields. On-farm seed priming with water (hydro priming) in maize, rice and chickpea caused faster emergence of seeds, improved establishment, crops grew more vigorously, flowered earlier and yielded higher (Harris *et al.*,

1999). Therefore halo priming for 8 hours (hrs) with 0.2% $NaCl_2$ (HCL2T8) also produced the highest dry matter of 5092.0 and 3074.0 kg/ha in seasons I and II, respectively at 90 days after sowing (DAS). These was found to be statistically similar with HCL2T12 (0.2 % $NaCl_2$ for 12 hours) which produced 4647.0 and 2880.0 kg/ha in season I and II, respectively.

The interaction effects at 90 DAS for the wet season I (SI) reveals that significantly higher DM yields were produced by treatment combinations of 25% FC pre sowing irrigation with no priming of seed (HyT0) and 0.2% $NaCl_2$ for 12 hours 6500.0 kg/ha and 5900.0 kg/ha (HCL2T12), respectively; these gave equal dry matter with treatments HCL2T8 - (50% FC- 0.2% $NaCl_2$ for 8 hours -6440.0 kg/ha ; HCL1T10 – (75% FC- 0.1% $NaCl_2$ for 10 hours, that had 6713.0 kg/ha) and HCL2T8 - (0.2% $NaCl_2$ for 8 hours-6970.0 kg/ha). During the dry season (SII), the highest DM/ha of 5017.0 and 4285.0 kg/ha was realized by the interaction effects of 100% FC pre-sowing irrigation and priming of -HCL2T12 and HCL2T10, respectively, (Table 12). The season II dry matter was lower probably due to lower and poorly distributed rainfall of 311.2 mm that was realized during the growing season as compared to the season I rainfall of 565.10 mm that was well distributed. An earlier report by Navkiran *et al.* (2013) noted that restricted soil moisture decreases dry matter (biomass) yields. Furthermore, Murungu *et al.* (2004) reported that in semi-arid lands, seed priming had little effect on growth, time to flowering and maturity or yield of the plants during the crop growth and development. It can be concluded that seed priming had less effect on growth parameters and yields in season II because the low soil moisture occasioned by lower rainfall. Therefore, adequate soil moisture of over 75% FC is necessary if effectiveness of priming 0.1 to 0.2% $NaCl_2$ for 8 to 12 hours is to be realized under black cotton clay soils (Fig.11, 12, 21, 29, 31 and 32).

5.6 Effect of Pre-Sowing Irrigation at 25%, 50%, 75% and 100% Field Capacity on Chickpea Height (cm)

In all the pre sowing irrigation regimes, the plant heights (cm) increased with maturity of chickpea. At 25 DAS, significantly higher plant heights ranging between 10.0-10.78 cm was realized under pre sowing irrigations of 50%, 75% and 100% FC in both seasons. The highest plant heights (35.51-40.91 cm) during the two seasons were observed under pre sowing irrigation applications of 75% and 100% FC at 90 and 105 DAS (Table 13). This confirms earlier reports

by Ghassemi-Golezani *et al.*, (2012); Malhotra *et al.* (1997) who observed higher plant heights with application of irrigation. Similarly, Navkiran *et al.* (2013) opined that the maximum reduction in plant heights and branches was when irrigation was limited. Therefore higher pre sowing irrigation of 75 to 100% FC is necessary for achieving higher chickpea heights under Mwea conditions.

5.7 Effect of Priming on Chickpea Height (cm) 25, 50, 75 DAS and 90DAS

Significantly higher plant heights (cm) in both seasons was realized under treatment combinations of hydro priming for 8 hours (HyT8) -12.71cm in both seasons, and 0.2% $Nacl_2$ for 10 hours (HCL2T10) that had 11.5 and 11.55cm in season I and II, respectively. Earlier studies have reported the beneficial effects of priming, which have been demonstrated on many field crops such as barley (Abdulrahmani *et al.*, 2007), maize (Parera and Cantliffe, 1994), lentil (Ghassemi-Golezani *et al.*, 2008), chickpea (Ghassemi-Golezani *et al.*, 2012), pinto bean (Ghassemi-Golezani *et al.*, 2010). McDonald, (2000) noted that seed priming is one of the simple and suitable methods which can improve seedling vigor and establishment and consequently crop performance in the field. Muhammad *et al.*, (2010) and Verghis *et al.*, (1999) reported that chickpea yield is plant height sensitive. Therefore, taller chickpea plants at 25 DAS can be achieved by use of either HyT8 or HCL2T10. Hydro priming for 8 hours (HyT8) also gave significantly taller plants at 50, 75, and 90 DAS in both seasons. At 90 DAS, However, HyT8 had similar plant heights with HyT12, HCL1T8, HCL1T10, HCL2T8, HCL2T10, HCL2T12, HCL3T8 and HCL3T10 in both seasons. Therefore, either of these treatments can be used to enhance height at latter stages of growth.

5.8 Effect of Pre Sowing Irrigation on Number of pods/m^2

Pre sowing irrigation of 75% FC had the highest number of pods/m^2, i.e., 1,631 and 566 in seasons I and II, respectively. In season I pods/m^2 was higher than in season II. The more pods/m^2 in season I (1631) was attributed to the more rainfall (565.10 mm) that was received and was also well distributed as compared to lower and poorly distributed rainfall of 311.2 mm that was received in season II and produced 586 pods/m^2 only. Without rainfall occurring during the growing season, there is gradual depletion of soil moisture that affected the growth of chickpea plants which results in a decline in the number of pods per plant and also seeds per pod Navkiran

et al. (2013); Fazlul *et al.*,(2009). According to Ray *et al.*, (2011); Maity and Jana, (1987) yield and yield attributing characters of chickpea are significantly influenced by the level of irrigation. The number of pods per unit area in chickpea was found to increase with increase in irrigation by Muhammad *et al.*, (2010); Malik and Anwar (1994). Therefore in order to enhance or achieve higher pods/m^2 of over 1630 and 1177 kg grain yield/ha, it's necessary to ensure adequate seasonal rainfall of over 560 mm is available throughout the growth of chickpea. This can be provided through supplemental irrigation where available particularly in the dry season II.

When the relationship of grain yield to pods/m^2 for both seasons was developed, grain yield was found to increase at the rate of 2.671kg per number of pods/m^2. The coefficient of determination was high where $R^2 = 0.985$ (Fig. 57). This means that one can predict the grain yield using the production function: Grain yield = 2.671(number of pods/m^2) +326.1 with 98.5% reliability in MIAD, Mwea, Kenya.

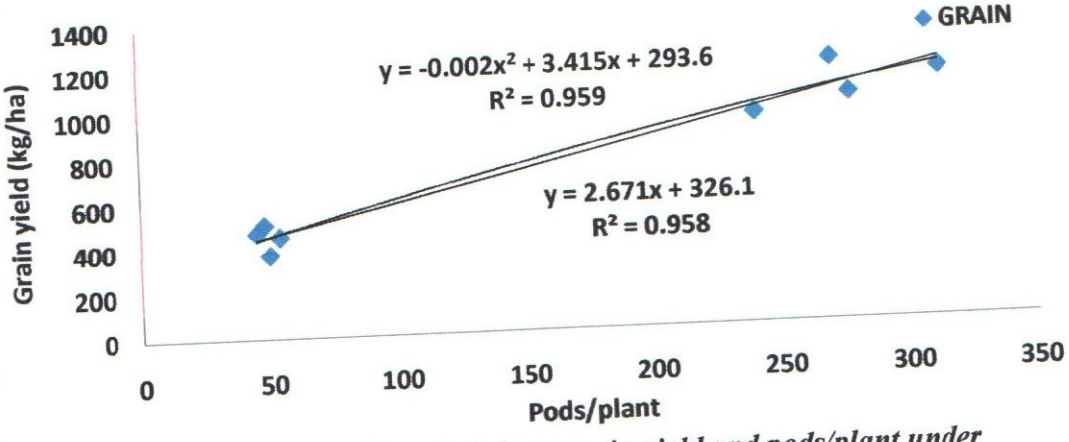


Fig 57: Relationship of chickpea grain yield and pods/plant under varying pre sowing irrigation levels in Mwea-Kenya

On developing other relationships between grain yield and pods/plant, a quadratic function $Y = -221+1.379x-0.000x^2$.

4.11.9 Effect of Priming on Number of Pods/m^2 and Pods/Plant

Priming chickpea seeds with 0.1% $NaCl_2$ for 8 hours (HCL1T8) produced significantly higher number of pods/m^2 (1615 and 754), as well as pods/plant, 100 seed weight, and even grain yield (1365 and 563.8 kg/ha) in both season I and II, respectively (Table 24). Greater pods/m^2, grains/m^2 and yield/ha on chickpea crop grown from primed seeds as compared with those from

non primed seeds was reported by Mohsen *et al.* (2013) and Kaur *et al.* (2002). Therefore, in order to achieve higher pods/m^2 and pods/plant that will eventually lead to higher grain yields/ha, farmers should pre soak seeds for 8 hours in 0.1% $NaCl_2$.

5.10 Effect of Pre Sowing Irrigation on Grain Yield

The highest grain yield of 1177.0 and 513.1 kg/ha was under 75% FC pre sowing irrigation in both season I and II, respectively (Table 24). These were followed by application of 100% FC that produced 1122.0 and 477.1 kg/ha. The higher grain yields/ha in season I was attributed to the higher and relatively well distributed rainfall (565.10mm) as compared to season II that had low rainfall (311.2mm) that was poorly distributed. Increased seed yield (44%), total dry biomass (49%) and plant height (26%) results from increasing irrigation (Malhotra *et al.*, 1997), number of pods/plant, 1000 seeds weight and grain yield (Malik and Anwar 1994); while water stress decreases dry matter accumulation (DMA) and seed / grain yield per unit area (Navkiran *et al.* (2013); Singh *et al.*, 2006; Ghassemi–Golezani *et al.*, 1998). Nielson (2001) reported that chickpea exhibits the greatest rate of increase in yield with increase in water use. Therefore application of 75% FC is essential under Mwea conditions in order to achieve higher grain yields per unit area.

5.11 Effect of Priming on Grain Yield

In both seasons, priming seeds with 0.1% $NaCl_2$ for 8 hours (HCL1T8) and 0.2% $NaCl_2$ for 12 hours (HCL2T12), significantly increased grain yields in both season I and II. These treatments produced 1365.0 and 1251.0 kg/ha of grain yields, in SI and 563.8 and 539.4 kg/ha in SII, respectively. However, these were statistically the same as for HyT8 (467.9kg/ha), HyT10 (478.3 kg/ha), HCL2T8 (467.7 kg/ha), and HCL2T10 (485.2 kg/ha). According to Ghassemi-Golezani *et al.* (2012), plants from primed seeds had higher seedling establishment per unit area that ultimately resulted into production of more grains per unit area compared with those from unprimed seeds. Similarly, Ayda *et al.* (2013) reported that grain yields were higher for plants developed from primed seeds compared with those from unprimed seeds. The higher grain yields of season I could have been attributed to the higher rainfall that was achieved during the season. Therefore treatment combinations 0.1% $NaCl_2$ for 8 hours and 0.2% $NaCl_2$ for 12 hours

can be recommended for higher grain yields of Mwea environment. However effective priming occurs when accompanied by adequate rainfall (or soil moisture) throughout crop growth.

5.12 Interaction Effects of Pre Irrigation and Priming on Grain Yield (kg/ha)

In both seasons, interaction effects of pre sowing irrigation and priming on grain yield revealed a statistically ($P<0.05\%$) similar yields with pre sowing irrigation of 75% FC-HCL1T8 (0.1% $NaCl_2$ for 8 hours) and 100% FC-HyT8 (hydro priming for 8 hours) that produced significantly higher grain yield the other treatments. During season I (Table 29) interaction effects of irrigation and priming on grain yield (kg/ha) revealed that pre sowing irrigation of 75% FC- in combination with either HCL1T8 (0.1% $NaCl_2$ for 8 hours), HCL2T12 (0.2% $NaCl_2$ for 12 hours) and HCL3T10 (0.3% $NaCl_2$ for 10 hours) produced 1562.0, 1604.0 and 1460.0 kg/ha, respectively; and 100% FC-HyT8 (hydro priming for 8 hours) that produced 1788.0 kg/ha had significantly higher grain yields (Table 29). During season II, interaction effects of irrigation and priming on grain yield (kg/ha) revealed that pre sowing irrigation of 75% FC-HCL1T8(0.1% $NaCl_2$ for 8 hours) and 100% FC-HyT8 (hydro priming for 8 hours) produced grain yield of 755.0 and 748.3 kg/ha, respectively and were significantly higher. Therefore, in Mwea, treatment combinations of pre sowing irrigation 75% FC and priming 0.1% $NaCl_2$ for 8 hours (HCL1T8), and 100% FC and hydro priming for 8 hours (HyT8) is essential if farmers are to achieve higher grain yields of between 748.3 and 1604.0 kg/ha for SII and SI, respectively.

5.13 Effect of Pre Sowing Irrigation on 100 Seed Weight (Grams) and HI

Increasing pre sowing irrigation from 25% to 75% FC increased 100 seed weight in grams in both season (Table 24). Pre sowing irrigation of 75% FC produced the highest seed weight of 29.6gms and 73.7 grams, in season I and II, respectively. During season II, the 100 seed weight was higher because there were fewer number of plants/m^2 and therefore the seeds were able to accumulate enough of the plant synthetic materials during the season leading to higher grain weight as compared to season I where there were more plants/m^2 and therefore there was more competition on available plant resources. According to Navkiran *et al.* (2013), 100 seed weight of chickpea reduces significantly under water stress while it increases along with seed yield with increasing irrigation water (Malik and Anwar, 1994). Application of 50% FC pre sowing irrigation had the highest harvest index (HI) of 0.25 in both seasons. This was followed by

harvest index of 0.24 under pre sowing irrigation of 75% FC in both seasons. Quadratic relationship (Fig 47) revealed that pre sowing irrigation of 60% FC is ideal for highest HI under Mwea conditions

5.14 Effect of Priming on 100 Seed Weight (Grams) and HI

Priming with 0.1% $NaCl_2$ for 8 hours (HCL1T8) had significantly higher 100 seed weights in season 1 (30.3 grams) and season II (74.2 grams), respectively. However, these were statistically similar with all the other treatment combinations apart from those of treatment combinations in season I, i.e., HyTo, HyT12 and HCL2T10 and treatment combinations HCL1T8, HCL1T12 and HCL2T8 of season II which had significantly lower 100 seed weight (Table 24 and Fig. 55). Therefore, treatment combination 0.1% $NaCl_2$ for 8 hours (HCL1T8) can be applied in order to achieve higher 100 seed weight under Mwea conditions. The lower plant/m^2 during season II contributed to the higher 100 seed weight because there was less competition on the available soil plant resources as compared to season I where there was more plants/m^2 that led to competition of the soil resources and therefore lower 100 seed weight. The influence of priming on HI was significantly higher under treatment combinations HyT10, HCL1T8, HCL1T12, HCL2T10 and HCL3T10 both seasons. However, in season I, HCL2T12 and in season II, HyT8 had the same harvest index. In concurrence, Mohsen *et al.* (2013) reported earlier that priming chickpea seeds in KNO_3 and $CaCl_2$ solutions resulted in the highest grain yields and harvest index

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

a)

- The highest ($P \leq 0.05$) alpha amylase activity was with HCL1T8 treatment (halo priming for 8 hrs with 0.1 % $NaCl_2$), which was also statistically equal to HYT10, HCL2T12, HLC1T12, HCL2T8, and HCL2T10.
- Non primed seeds (control) had significantly the least enzymatic activities
- Priming chickpea seed before sowing did not show any significant differences in season I. However, in the drier season II, treatment combinations HCL_1T_8 (8 plants), HCL_1T_{10} (7 plants), HCL_1T_{12} (7 plants), HCL2T8 (7 plants) and HyT_{12} (7 plants) had significantly higher number of plants/m^2
- Halo priming for 8 hours (hrs) with $NaCl_2$ at 0.2% (HCL2T8) gave significantly the highest DM at all stages of growth
- In both seasons priming with HCL1T8 (0.1% $NaCl_2$ for 8 hours), significantly produced higher number of pods/m^2, i.e., 1615 and 754 in season I and II
- Priming with treatment combinations HCL1T8 (0.1% $NaCl_2$ for 8 hours) and HCL2T12 (0.2% $NaCl_2$ for 12 hours), significantly increased grain yields (kg/ha) in both season I and II.

b)

- Increasing pre sowing irrigation from 25% field capacity (25% FC) to 100% FC, increased plants/m^2 in both seasons.
- Dry matter increased with increased pre sowing irrigation from 25 % field capacity to 100% FC at every stage of growth.
- The number of pods/m^2 were highest (1,631 and 566) in season I and II, respectively under pre sowing irrigation of 75% FC and consequently the grain yields
- Pre sowing irrigation of 75% FC gave the highest grain yield of 1177.0 and 513.1 kg/ha in season I and II, respectively

c)

Priming chickpea seed improved germination at limited initial soil condition of SII. The interaction effect (combination) of pre sowing irrigation at 50%, 75% and or 100% FC with priming enhanced desi chickpea germination to between 6- 10 plants/m^2.

d)

Interaction effects of irrigation and priming on grain yield (kg/ha) during season I and II reveals that pre sowing irrigation of 75% combined with 0.1% $NaCl_2$ for 8 hours or 100% hydro priming for 8 hours produced significantly higher grain yields of 1562.0 and 1788.0 kg/ha, respectively in season I and 755.0 and 748.3 kg/ha in season II, respectively

6.2 Recommendations

a) For farmers to realize optimal grain yields of desi chickpea in Mwea, it's advisable to apply pre sowing irrigation of 75% field capacity (FC) before sowing their seeds and halo prime the seeds either with 0.1% $NaCl_2$ for 8 hours (HCL1T8), or 0.2% $NaCl_2$ for 12 hours (HCL2T12) or 0.3% $NaCl_2$ for 10 hours (HCL3T10). This would produce 1562.0, 1604.0 and 1460.0 kg/ha, respectively.

b) Interaction effect (combination) of pre sowing irrigation at 50%, 75% and or 100% FC with priming was observed to enhance desi chickpea germination to between 6- 10 plants/m^2. However, farmers not willing to do seed priming can also achieve 6-7plants/m^2 with application of higher pre sowing irrigation of 75% FC and above.

c) Priming is effective when accompanied by adequate rainfall (or soil moisture of 75 FC and above) throughout crop growth.

d) Further studies to determine how residual soil moisture can be efficiently utilized to sustainably grow chickpea in rice-legume intensification systems.

e) There is need to evaluate the effective control and management of chickpea wilt and *aschocyta* disease.

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APPENDICES

Appendix 1

Total monthly rainfall (mm) at MIAD

Daily Rainfall (mm) at MIAD in 2012

Dates	January	February	March	April	May	June	July	August	September	October	November	Decemb
1	0	0	0	0	0.4	6.2	0	0	0	0	0.5	0
2	0	0	1.6	0	34.1	0	0	0	0	0	9.2	10.2
3	0	0	4.2	0	0	0	0	0	0	0	26.5	15.4
4	0	0	0	18.5	50.4	0.3	0	0	0	0	19.5	6.6
5	0	0	0	0.2	49.7	0	0	0	0	0	41	0
6	0	0	0	20	10.5	0	0	0	0	0	9.2	0
7	0	0	0	2.7	6.3	0	0	0	0	0	0	0
8	0	0	0	1.3	3.9	0.2	1.3	0	0	0	0	2
9	0	0	0	4.2	3	0	20.5	0	0	0	51.5	0
10	0	0	0	0	1.5	0	1.2	0	0	0	3.5	0
11	0	0	0	0	0.5	0	0.6	2.2	0	100.6	9.6	0
12	0	0	0	0.8	8.9	0	0	0	0	51.1	0	0
13	0	0	0	0	0	0	0	0	0	26	0	0.8
14	0	0	0	2.4	5	0	0	0	0	0	0	0.5
15	0	0	0	25.1	0	0	0	0	0	23	0	4
16	0	0	0	18.2	2.1	0	0.6	0	0	3.4	0	0
17	0	0	0	0	3.6	0	0	0.5	0		10	0
18	0	0	0	12.2	4.7	0	0	0	0	0	0	6.8
19	0	0	0	0	0	0	0	0	0	0	0	18.2
20	0	0	0	0	0	0	2	5.5	0	0	0	0
21	0	0	0	29.5	0	0	0	0	0	1	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	21.3	1	0	0	0	0	0	0	0
24	0	0	0	0	0	1.5	0	0	0	0	0	0.8
25	0	0	0	6.2	0	1.4	0	3.3	0	0	0	0
26	0	0	0	38.9	0.5	0	0	0.5	0	0	0	0
27	0	7.7	0	53.6	1	0	0	0	0	0	0	7.5
28	0	4	0	49.5	3	0	0	0	0	10.8	17.9	1
29	0	0	0	0	7	0	0	0	0	0	3.6	0.9
30	0		0	15.6	0	0	0	0	0	0	3.9	6
31	0		0		0		0	0		0		0
Total	**0**	**11.7**	**5.8**	**320.2**	**197.1**	**9.6**	**26.2**	**12**	**0**	**215.9**	**205.9**	**80.7**
Mean				**10.6733**	**6.35806**	**0.32**	**0.84516**		**0**	**7.44**	**6.86333**	
Wet days		**2**	**2**	**18**	**20**	**6**	**4**	**0**	**0**	**0**	**13**	**14**

Appendix 2

Daily Rainfall (mm) and total monthly rainfall (mm) at MIAD in 2013

Dates	Janaury, 2013	February, 2013	March, 2013	April, 2013	May, 2013	June, 2013	July, 2013	August, 2013	September, 2013	Octobe 2013
1	3.4	0.5	0		2.2	0	0	0	0	0
2	0	0	0	18	1	0	0	0	0	0
3	0	0	0	0.8	26.6	0	0	0.2	0	19.7
4	0	0	0	0	0	0	0	0.8	0	0
5	0	0	0	0	18	0	0	1	0	0
6	0	0	0	0	1.2	0	0	1.5	0	0
7	0	0	0	33.8	0.7	0	1	0	0.1	0
8	0	0	1.5	0	0	0	0	0	0	0
9	0	0	0	23.6	0	0	0	0	0	0
10	0	0	1.3	13.6	0	0	0	0	0	0
11	0	0	0	1.2	0	0	0	0	0	0
12	0	0	0.5	3.1	6.3	0	0	0	0	0
13	0	0	0	50.8	0	0	0	0	0	0
14	0.8	0	1	60	0	0	0	0	0	0
15	12	0	0	0.8	0	1.3	0	0	0	0
16	12	0	0	68.3	0	2.2	0	0	0	0
17	4.1	0	0	50.3	0	7.2	0	0	0	0
18	0	0	0	6	0	0.6	0	0	0.6	0
19	0	0	14.1	3.5	0	0.5	0	0	0	0
20	0	0	43.8	51.5	0	0	0	0	0	0
21	0	0	0.8	0	0	0.9	0	0	0	0
22	0	0	11.5	1.4	0	0	0	0	0	0
23	0	0	4.2	1.2	0	0	0.5	2	0	0
24	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0.7	0	2.3	0	0	0.6	0
26	0	0	0	0	0	0	0	0	0	0
27	0	0	4.4	3.3	0	0	0	0	0	0
28	0	0	12.2	0	0	0	1.2	0	0	0
29	0		67.9	5.2	0	0	0	0	0	0
30	0		0	0.8	0	0	0	0	0	0
31	30.3		113		0		0	0		0
Total	**62.6**	**0.5**	**276.2**	**397.9**	**56**	**15**	**2.7**	**5.5**	**1.3**	19.
Mean	**2.08667**	**0.01786**	**8.90968**	**13.7207**	**1.80645**	**0.5**	**0.09**	**0.17742**	**0.04333**	
Wet days	6	2	13	20	7	7	2	4	3	1

Appendix 3

Percentage (%) Relative Humidity in 2012												
Dates	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**Decem**
1	70	67	77	71	73	84	76	87	89	78	78	78
2	68	65	84	71	78	77	75	82	90	74	85	92
3	68	60	64	78	78	75	91	83	89	83	84	93
4	69	59	71	83	84	91	91	83	83	81	79	84
5	71	71	74	98	78	81	91	76	76	83	78	84
6	78	77	81	83	82	83	84	77	76	71	84	78
7	77	71	78	85	79	90	83	89	85	70	84	78
8	75	74	78	76	85	83	83	89	91	84	78	78
9	77	84	65	75	79	83	91	84	79	84	92	81
10	84	77	63	84	85	81	88	77	82	85	91	77
11	84	71	70	77	78	81	89	77	77	84	83	70
12	78	82	69	89	84	81	89	83	85	82	79	78
13	75	70	73	77	70	89	91	76	87	84	84	82
14	70	71	68	75	84	76	89	87	83	70	84	89
15	70	77	63	71	79	83	77	76	78	77	84	84
16	63	83	61	91	79	83	83	76	77	81	79	76
17	63	71	70	79	83	90	96	84	83	82	83	76
18	71	84	71	71	84	96	91	83	83	79	73	91
19	62	70	71	89	77	83	88	83	83	84	79	85
20	76	70	83	74	82	77	90	91	83	84	78	70
21	64	69	64	84	78	77	89	90	82	75	82	71
22	75	66	70	84	78	77	91	83	89	79	84	78
23	63	61	77	87	85	78	84	81	77	75	77	78
24	63	63	84	85	77	83	85	89	78	82	77	70
25	68	69	67	76	92	84	81	92	83	79	70	77
26	75	75	69	82	78	79	76	69	78	77	71	78
27	69	71	73	92	77	91	76	76	85	67	78	92
28	75	85	77	89	78	82	75	83	83	69	87	79
29	69	68	71	84	78	82	84	77	83	73	83	81
30	63		76	78	77	95	84	91	70	78	78	77
31	75		71		77		84	90		84		76
Total	**2208**	**2081**	**2233**	**2438**	**2476**	**2495**	**2645**	**2564**	**2467**	**2438**	**2426**	**248**
Mean	**71.2258**	**71.7586**	**72.0323**	**81.2667**	**79.871**	**83.1667**	**85.3226**	**82.7097**	**82.2333**	**78.65**	**80.8667**	**80.03**

Appendix 4

Percentage (%) Relative Humidity in 2013										
Dates	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**Octobe**
1	82	84	67	69	84	85	77	82	81	70
2	77	77	70	70	85	81	91	75	79	83
3	76	77	69	78	79	81	83	91	18	77
4	81	77	70	71	78	74	81	86	63	78
5	78	68	78	78	78	89	63	91	77	77
6	81	78	72	79	77	83	76	88	76	70
7	77	78	72	84	84	76	79	84	77	75
8	82	76	78	75	78	76	74	84	82	75
9	75	70	70	75	70	70	69	90	75	76
10	79	69	64	71	78	81	79	83	70	73
11	78	75	78	78	78	77	82	90	77	68
12	70	73	76	79	74	89	90	82	70	64
13	81	77	63	65	75	83	90	88	70	67
14	77	70	85	75	77	70	80	84	66	75
15	85	59	77	92	81	80	78	85	70	70
16	91	69	81	82	89	82	78	79	75	69
17	79	67	66	83	84	82	77	76	83	
18	77	69	72	82	85	90	84	76	81	
19	77	62	84	84	77	84	89	76	81	
20	70	61	92	84	77	82	74	83	79	
21	76	78	83	77	83	86	80	83	70	
22	67	74	91	82	76	70	91	89	77	
23	71	69	78	85	83	75	84	90	76	
24	74	78	76	84	71	70	90	76	91	
25	73	77	81	75	77	93	83	84	77	
26	69	83	76	75	77	91	83	89	78	
27	78	77	78	69	78	76	79	75	77	
28	83	77	83	70	77	84	88	87	69	
29	78		70	82	78	88	74	89	70	
30	71		78	78	70	74	71	90	73	
31	78		84		79		81	81		
Total	**2391**	**2049**	**2362**	**2331**	**2437**	**2422**	**2498**	**2606**	**2208**	
Mean	**77.129**	**73.1786**	**76.1935**	**77.7**	**78.6129**	**80.7333**	**80.5806**	**84.0645**	**73.6**	

Appendix 5

Maximum and minimum temperatures (°C) for the period of January-June 2012

Date	January		February		March		April		May		June
	Max c	Min	Max c	Min	Max c	Min	Max c	Min	Max c	Min	Max
1	28.2	20	30.2	14.8	32.1	17.2	32.4	19.5	29.3	20	28.4
2	29.3	11.5	31	14.6	32	18.3	33	19	29.3	19.6	28
3	30.2	11.5	32.2	17.5	33	21	31.4	18.8	26.6	19.2	27
4	30.2	14.9	33	14.8	33	19.5	31.2	19.5	28.2	19.5	26.3
5	31	18.2	32	14.9	31.3	19.3	28	20	27.4	19	23.3
6	31.2	17.5	30	15	30.5	19	26.4	19	27	20	27.2
7	30	18	30.3	18.5	30.1	18.5	24.2	19.5	27	18	25.3
8	29.2	17	30.2	14.9	31.2	19	28	20	27.2	19.8	27.4
9	29.2	15	30	15.2	29.4	15.5	26.3	21.5	26.4	19.5	28
10	30.3	15.5	31.2	16	31.3	16.5	29.2	21	26.1	19	26
11	29.2	18	31	19.5	33	21	29.4	19.4	26	19.3	27.3
12	28.2	16	32	18.8	33	18	30.2	21.2	28.3	20	27.2
13	30.2	17.5	31	21	32	18.5	29.2	20	28	21	27.1
14	30	16	33	17.5	32	19	28.2	21	28	21.5	26.1
15	31.2	19	31	16	33.3	18.2	29	22.2	27.2	21	26.4
16	31.4	17.5	30.1	19	32.4	19.2	30	22	28	21.6	26.2
17	31.2	18.5	30.3	22	33.2	19	28.2	21.5	27.3	19	25.8
18	31	15	32	21	33.2	20	30.1	19.5	28.2	18.6	25.3
19	30.3	14.9	31	20	33	18.8	30.3	19	29.2	18.5	24
20	29.2	15.4	32.2	19.5	32	18.5	30.5	20	29.4	20	25.4
21	30.2	15	33	18.5	30	19.2	30.2	19.5	29	19.2	24.2
22	32	20	33.3	19	32.3	18.3	30	19.6	30	19.5	26.3
23	32.3	15	32.5	18.5	31.4	21	29	19.8	29.1	21	28.2
24	31.4	14.8	32	17.5	32	19	27.4	20	26.3	19	26
25	32.3	15	30	18.4	31.5	19	27.3	18.5	29	21.2	26.2
26	31.2	15.4	32.2	21	31.2	18.5	29	18.8	24	20	28
27	31.2	15	33.3	19	32.3	19	27.2	21	27.2	20	26.3
28	32.3	17	30	20	33.2	19	26	21.3	28.3	20	25.3
29	32.3	21	30.3	19.3	33.2	18.9	27.2	21	27.2	19.5	25
30	31	15.3			32	19	29	22	27.3	21.5	24.2
31	32	14.9			32	18.5			28	19.3	
Total	948.9	505.3	910.3	521.7	992.1	583.4	867.5	605.1	859.5	614.3	787
Mean	30.6097	16.3	31.3897	17.9897	32.0032	18.8194	28.9167	20.17	27.7258	19.8161	26.24

Appendix 6

Maximum and minimum temperatures (°C) for the period of July-December, 2012

Date	July		August		September		October		November,2012		December,2012	
	Max c	Min	Max c	Min	Max c	Min	Max c	Min	Max c	Min	Max c	Min
1	25.2	17.5	24.2	18	29.4	18.3	31	21	30.3	21.8	27.4	19.8
2	25.3	17.3	26.3	17	29.3	17.6	31.3	20	31	20.2	28.2	19.6
3	23	17	22.3	18	29.2	17	31	19	28.3	20	29	19
4	24	16.5	26	19.3	28.6	17.4	29.3	19.4	25.3	20.3	26	19
5	22	17.1	29	18.2	28	18	31	20	24.3	19	27.3	18.5
6	24.3	16	28	18.1	26.1	17.5	30	21.2	27.4	21.5	28	19.2
7	23.3	16.5	28	19.2	28	18.5	31	22	29.3	21	27.4	19
8	24.2	15.8	25.2	17.2	26	18.5	30.2	21	29.2	20	28.3	18.6
9	25.2	15.5	29.2	21	26.8	17.5	30.4	21.5	29.2	19.5	29	19.2
10	22	16	29	17	27.3	17.3	32.2	22	27	19.8	28.3	17.5
11	18.2	14.4	26.3	18.5	29	21.5	32.3	19	27.3	18	29.2	17.3
12	22	16	27	15	30	20	29	19.5	27.3	19.3	24.2	18.2
13	22.2	16.5	27.2	16	29.2	20.5	28	20	29	21	29	18.5
14	24	17.2	29	16.5	29	21	31	22	29.3	20	28.3	19
15	27.2	18.5	27.3	16	29.1	17.8	28.2	19.5	30	19.5	26.2	19.3
16	26.3	19	29	15	29	18	29	20	30.3	20.4	27.2	16
17	27	16.5	26.3	16.5	29.4	18.8	28.3	21.4	30.2	21	28.2	17
18	21.2	16	22	18.5	28.1	19	29.3	19.2	28.4	19.5	28.2	18.8
19	20.4	17	25.5	17	29.3	18.7	28.9	20	27.2	18.5	23.3	19
20	22.2	16	29	16.5	29.2	19.5	29.3	21.2	29.1	19	26.1	20
21	23.3	16.2	25.2	18.4	30.2	19.5	28	18	30	19.2	27.2	15
22	25.8	15.8	28.2	16	30.3	15	28.3	19	30	18.5	28.2	15.7
23	27.3	17.5	28.4	14.4	29.4	19.9	28	19.5	29.4	19	28.1	15.2
24	23	18.5	27.4	15	30.4	14.9	30.2	21.5	29.2	17.5	28.4	15.9
25	24.9	19	28.3	16.5	31.4	19	30.3	21.4	29	20	28.6	17.5
26	25.3	18.8	23	17	31	19.5	30.1	21	30.2	21	29.2	19.2
27	25	19	26.2	19	30.4	18.5	30.2	19	29.2	18.4	29	19
28	26	18	27.3	18.5	27.2	19	30	18	30.3	19	27.2	21
29	24.8	19	28	19.2	30.2	20.5	29.3	21	26.3	20	28.1	21.2
30	23	17	27.4	19	30	21	30.4	21.2	28.3	19.3	27.3	21.1
31	23.3	16.5	28.3	18.8			30	21.5			27	20.9
Total	**740.9**	**527.6**	**833.5**	**540.3**	**870.5**	**559.2**	**925.5**	**630**	**861.3**	**591.2**	**857.1**	**574.**
Mean	**23.9**	**17.0194**	**26.8871**	**17.429**	**29.0167**	**18.64**	**29.85**	**20.32**	**28.71**	**19.7067**	**27.6484**	**18.52**

Appendix 7

Maximum and minimum temperatures (°C) for the period of January-June, 2013

Date	January,2013		February,2013		March,2013		April,2013		May,2013		June,2013	
	Max c	Min	Max c	Min	MAX	MIN	Max	Min	Max	Min	MAX	MI
1	26.4	21.5	30.1	19	32.2	19	28.6	18	28.4	21	26.3	19
2	28	20	30.4	18.2	33.2	19.3	27.2	23	27	21.2	26.5	19
3	27.4	19.2	29	18.8	32.8	19.2	29	22.2	28.3	21.5	27.2	19
4	27.4	15	29.2	19	33.2	19	29.2	23	26.3	22	27	17
5	26.5	16.5	30.6	19	33.4	22	29.3	22.4	27.6	19	26	19.
6	28.5	17.5	31.2	19.2	34.3	22.3	30	22.2	26.2	22	26.4	19
7	30	18	30.2	19.1	33.4	22.2	29.8	21.6	26.4	21	27	18.
8	29.3	18.5	30.1	18.4	34	19.8	30.3	23	28	21.2	26.4	18.
9	29.2	17.2	29.2	18.2	33.3	23	30	20	28	19	26.8	19
10	29	17	31.4	18.5	33.8	22.4	30	21.5	29	21.3	27	18
11	30.3	18.8	30.4	19.3	33	23	30.3	20.2	29	21	24.3	19
12	30	20	31.3	18.3	33.1	22.3	30.2	21.8	28.5	21	24.4	17.
13	31	18.2	32.4	20	34.3	21.3	29.1	22	28	21.2	26.2	16
14	29.1	18	31.4	20	32.3	20	27.6	18	27.4	20	26.4	18.
15	29	21	32.2	19.5	31	22.3	28.2	21	27.3	19.3	27.3	17.
16	28	20	32.3	18.2	31.2	19.9	27	21.2	27.2	21	26.2	17
17	27	21	32	19	32.4	22	27.2	20	27.2	21.2	24.2	16.
18	28.2	19	33	19.8	33	22.3	27.3	32.3	28.1	20.5	18.4	15.
19	28.3	18.2	32.4	18.8	33.4	23	29	21.3	27.4	22	21	16.
20	29	21	33.3	19.5	31.3	19.2	28.4	20	27.4	22	24.3	17.
21	29.3	15	33.4	20	25.3	20	28.6	20.3	28	19.8	22.6	17
22	29.4	15	34.2	19	28.2	21	29.2	21.8	26.4	19.4	22.8	18
23	30.4	17.2	32.3	19.5	28	20.5	29.3	20.5	27.2	19.9	23.4	18.
24	31.3	17	31.8	19.6	29.2	19.8	28.3	21.2	28.4	18.5	25.3	19
25	31.2	18.5	31.2	19	30.3	21.5	28.2	20.4	29.4	19	26	17
26	30.2	18	31.2	19.2	30	22	29	21	29.5	19.6	25.3	16
27	30	19	31.1	19.8	30.3	22.3	29.3	21.5	29.3	19.2	22.1	18
28	30	19	31.3	20	31.2	21	29	20.2	27.4	21.5	25.2	18
29	30.2	19.5			29.1	22.3	29.2	22	28	20	25	18
30	32	19			27.2	23	29.2	21.6	28.2	19	25.2	18
31	32	19			28	18			27	18		
Total	907.6	571.8	878.6	535.9	975.4	654.9	867	645.2	861.5	632.3	752.2	535
Mean	29.2774	18.4452	31.3786	19.1393	31.4645	21.1258	28.9	21.5067	27.7903	20.3968	25.0733	17.8

Appendix 8

Maximum and minimum temperatures (°C) for the period of July-October, 2013

Date	July,2013		August,2013		September,2013		October,	
	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN
1	24.4	18.4	22.4	18.2	27.2	16.5	32	21.5
2	25.4	18.2	25.4	17.5	29.3	18.5	31	20
3	24.3	17.5	28.2	17	0	24	28	29
4	26.2	18.2	25.8	16	27.2	14.9	28.1	20
5	26.3	14.8	23.2	16.5	30	15	30	19.8
6	27.4	17	20.1	16	29.4	16.2	30	22
7	26.2	16.2	22	17.5	27.4	19	29.3	21
8	27.3	16	24	16.2	26	19.2	29.4	19
9	25.4	14.8	25.3	16	27.2	19	26.3	20.2
10	26.2	16.2	22.3	17	29.3	19.2	29.3	17.5
11	25.2	17	24.3	15.4	29	21	30	21.2
12	24	16.4	26.3	15.5	30.1	19.5	30.2	20
13	23.4	16.2	23.3	17.3	29	18	30.2	22
14	24.4	15.3	25.1	18.2	30	16	31.2	22
15	25	15	28.2	17.5	31.2	19	32.2	19
16	25.8	16	26.3	19	32	18.4	31.8	19
17	26.4	17	29.2	18.8	31	19.3		
18	26	18.2	29.3	19	28	19		
19	29	19	29.3	19	26.2	18.4		
20	25.4	16.2	25.3	18.5	25.2	19.2		
21	24.4	16	26.2	18	28.2	20.2		
22	23.2	16.5	24.4	18.3	30.8	20		
23	22.3	17.2	25	16	27	19.4		
24	23	16	23.2	17	26.4	17.4		
25	21	17.2	25.3	17.2	24.3	19.4		
26	25.3	18.2	26.4	17.5	29.2	21		
27	25.3	18	26	14	32.2	19		
28	25	17.5	25.2	16.2	33.4	16.5		
29	26	18	24	16	30.3	17.5		
30	24.3	18	23.3	15.8	30.6	19		
31	24.4	17.5	23.2	17				
Total	**777.9**	**523.7**	**777.5**	**529.1**	**837.1**	**558.7**		
Mean	**25.0935**	**16.8935**	**25.0806**	**17.0677**	**27.90333**	**18.6233**		

Appendix 9

Analysis of variances (ANOVAs) Season I

Analysis of variance

Variate: % 100_seed_wt_gms

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	5519.590	2759.795	728.06	
Rep.Irrigation stratum					
Irrigation	3	39.929	13.310	3.51	0.089
Residual	6	22.744	3.791	0.67	
Rep.Irrigation.Priming stratum					
Priming	12	79.910	6.659	1.17	0.313
Irrigation.Priming	36	254.154	7.060	1.24	0.200
Residual	96	544.667	5.674		
Total	155	6460.994			

Analysis of variance

Variate: DM__kg/ha_90 DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	199205370.	99602685.	59.25	
Rep.Irrigation stratum					
Irrigation	3	26220464.	8740155.	5.20	0.042
Residual	6	10086386.	1681064.	2.66	
Rep.Irrigation.Priming stratum					
Priming	12	40943450.	3411954.	5.41	<.001
Irrigation.Priming	36	250841547.	6967821.	11.04	<.001
Residual	96	60586086.	631105.		
Total	155	587883303.			

Analysis of variance

Variate: DM_kg/ha_25_DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	84910.1	42455.0	73.35	
Rep.Irrigation stratum					
Irrigation	3	4875.7	1625.2	2.81	0.130
Residual	6	3472.6	578.8	1.28	
Rep.Irrigation.Priming stratum					
Priming	12	55152.9	4596.1	10.19	<.001
Irrigation.Priming	36	265127.0	7364.6	16.33	<.001
Residual	96	43292.7	451.0		
Total	155	456831.0			

Analysis of variance

Variate: DM_kg/ha_50_DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	532259.	266130.	85.09	
Rep.Irrigation stratum					
Irrigation	3	57682.	19227.	6.15	0.029
Residual	6	18766.	3128.	0.94	
Rep.Irrigation.Priming stratum					
Priming	12	148174.	12348.	3.69	<.001
Irrigation.Priming	36	1524878.	42358.	12.67	<.001
Residual	96	320920.	3343.		
Total	155	2602681.			

Analysis of variance

Variate: DM_kg/ha_75_DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	5556862.	2778431.	28.52	
Rep.Irrigation stratum					
Irrigation	3	5790913.	1930304.	19.81	0.002
Residual	6	584511.	97419.	3.99	
Rep.Irrigation.Priming stratum					
Priming	12	3286632.	273886.	11.22	<.001
Irrigation.Priming	36	13257939.	368276.	15.09	<.001
Residual	96	2342760.	24404.		
Total	155	30819617.			

Analysis of variance

Variate: Grain_Yield_kgs/Ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	13129169.	6564585.	63.76	
Rep.Irrigation stratum					
Irrigation	3	1289069.	429690.	4.17	0.065
Residual	6	617724.	102954.	2.79	
Rep.Irrigation.Priming stratum					
Priming	12	2781252.	231771.	6.29	<.001
Irrigation.Priming	36	4394970.	122082.	3.31	<.001
Residual	96	3536991.	36844.		
Total	155	25749175.			

Analysis of variance

Variate: HI

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.000350	0.000175	0.06	
Rep.Irrigation stratum					
Irrigation	3	0.045622	0.015207	5.35	0.039
Residual	6	0.017060	0.002843	1.83	
Rep.Irrigation.Priming stratum					
Priming	12	0.086959	0.007247	4.67	<.001
Irrigation.Priming	36	0.703369	0.019538	12.60	<.001
Residual	96	0.148856	0.001551		
Total	155	1.002217			

Analysis of variance

Variate: Height_105_DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	17735.375	8867.687	902.24	
Rep.Irrigation stratum					
Irrigation	3	168.813	56.271	5.73	0.034
Residual	6	58.971	9.829	1.25	
Rep.Irrigation.Priming stratum					
Priming	12	302.234	25.186	3.20	<.001
Irrigation.Priming	36	1278.625	35.517	4.51	<.001
Residual	96	756.487	7.880		
Total	155	20300.505			

Analysis of variance

Variate: Height_25_DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	2322.205	1161.103	905.66	
Rep.Irrigation stratum					
Irrigation	3	23.538	7.846	6.12	0.030
Residual	6	7.692	1.282	0.39	
Rep.Irrigation.Priming stratum					
Priming	12	122.359	10.197	3.11	<.001
Irrigation.Priming	36	271.462	7.541	2.30	<.001
Residual	96	315.103	3.282		
Total	155	3062.359			

Analysis of variance

Variate: Height_50_DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	4968.500	2484.250	133.74	
Rep.Irrigation stratum					
Irrigation	3	102.955	34.318	1.85	0.239
Residual	6	111.449	18.575	3.25	
Rep.Irrigation.Priming stratum					
Priming	12	417.817	34.818	6.10	<.001
Irrigation.Priming	36	328.337	9.120	1.60	0.037
Residual	96	548.385	5.712		
Total	155	6477.442			

Analysis of variance

Variate: Height_75_DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	8198.042	4099.021	224.06	
Rep.Irrigation stratum					
Irrigation	3	132.979	44.326	2.42	0.164
Residual	6	109.766	18.294	2.30	
Rep.Irrigation.Priming stratum					
Priming	12	410.494	34.208	4.31	<.001
Irrigation.Priming	36	690.083	19.169	2.41	<.001
Residual	96	762.692	7.945		
Total	155	10304.056			

Analysis of variance

Variate: No_of_Plants/m^2

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep stratum	2		2001.827	1000.914	3.08	
Rep.Irrigation stratum						
Irrigation	3		759.618	253.206	0.78	0.547
Residual	6		1948.212	324.702	79.65	
Rep.Irrigation.Priming stratum						
Priming	12		56.730	4.728	1.16	0.324
Irrigation.Priming	36		229.063	6.363	1.56	0.046
Residual	94	(2)	383.221	4.077		
Total	153	(2)	5341.690			

Analysis of variance

Variate: Pods/m^2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	4080495.	2040247.	22.79	
Rep.Irrigation stratum					
Irrigation	3	17480.	5827.	0.07	0.976
Residual	6	537119.	89520.	3.65	
Rep.Irrigation.Priming stratum					
Priming	12	1037251.	86438.	3.52	<.001
Irrigation.Priming	36	3123222.	86756.	3.53	<.001
Residual	96	2356254.	24544.		
Total	155	11151820.			

Appendix 10

Analysis of variance of (ANOVAs) Season II

Analysis of variance

Variate: % 100_seed_wt_gms

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	58685.7	29342.8	595.93	
Rep.Irrigation stratum					
Irrigation	3	2179.9	726.6	14.76	0.004
Residual	6	295.4	49.2	0.30	
Rep.Irrigation.Priming stratum					
Priming	12	3490.0	290.8	1.78	0.062
Irrigation.Priming	36	13316.4	369.9	2.27	<.001
Residual	96	15664.7	163.2		
Total	155	93632.2			

Analysis of variance

Variate: Pods/m^2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	30556304.	15278152.	8.47	
Rep.Irrigation stratum					
Irrigation	3	5576047.	1858682.	1.03	0.444
Residual	6	10824790.	1804132.	4.92	
Rep.Irrigation.Priming stratum					
Priming	12	13787269.	1148939.	3.14	<.001
Irrigation.Priming	36	18461673.	512824.	1.40	0.100
Residual	96	35174033.	366396.		
Total	155	114380116.			

Analysis of variance

Variate: DM__kg/ha 90 DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	193460923.	96730462.	7.60	
Rep.Irrigation stratum					
Irrigation	3	37287036.	12429012.	0.98	0.463
Residual	6	76323534.	12720589.	16.87	
Rep.Irrigation.Priming stratum					
Priming	12	44345924.	3695494.	4.90	<.001
Irrigation.Priming	36	122198292.	3394397.	4.50	<.001
Residual	96	72368001.	753833.		
Total	155	545983710.			

Analysis of variance

Variate: DM_kg/ha_25_DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	78667.1	39333.6	8.61	
Rep.Irrigation stratum					
Irrigation	3	6791.9	2264.0	0.50	0.699
Residual	6	27423.9	4570.6	8.67	
Rep.Irrigation.Priming stratum					
Priming	12	19240.0	1603.3	3.04	0.001
Irrigation.Priming	36	48273.2	1340.9	2.54	<.001
Residual	96	50610.1	527.2		
Total	155	231006.3			

Analysis of variance

Variate: DM_kg/ha_50_DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	477712.	238856.	7.58	
Rep.Irrigation stratum					
Irrigation	3	60594.	20198.	0.64	0.616
Residual	6	188946.	31491.	9.44	
Rep.Irrigation.Priming stratum					
Priming	12	130927.	10911.	3.27	<.001
Irrigation.Priming	36	498789.	13855.	4.15	<.001
Residual	96	320409.	3338.		
Total	155	1677375.			

Analysis of variance

Variate: DM_kg/ha_75_DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	3728240.	1864120.	13.09	
Rep.Irrigation stratum					
Irrigation	3	345120.	115040.	0.81	0.534
Residual	6	854437.	142406.	6.58	
Rep.Irrigation.Priming stratum					
Priming	12	2517170.	209764.	9.70	<.001
Irrigation.Priming	36	5357865.	148830.	6.88	<.001
Residual	96	2076173.	21627.		
Total	155	14879004.			

Analysis of variance

Variate: Grain_Yield_kgs/Ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	2327574.	1163787.	29.81	
Rep.Irrigation stratum					
Irrigation	3	396762.	132254.	3.39	0.095
Residual	6	234266.	39044.	2.75	
Rep.Irrigation.Priming stratum					
Priming	12	430633.	35886.	2.53	0.006
Irrigation.Priming	36	2032337.	56454.	3.98	<.001
Residual	96	1362101.	14189.		
Total	155	6783673.			

Analysis of variance

Variate: HI

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.610762	0.305381	17.27	
Rep.Irrigation stratum					
Irrigation	3	0.025687	0.008562	0.48	0.705
Residual	6	0.106112	0.017685	3.39	
Rep.Irrigation.Priming stratum					
Priming	12	0.335953	0.027996	5.36	<.001
Irrigation.Priming	36	1.512267	0.042007	8.05	<.001
Residual	96	0.501109	0.005220		
Total	155	3.091891			

Analysis of variance

Variate: Height_105_DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	17524.885	8762.442	1571.80	
Rep.Irrigation stratum					
Irrigation	3	161.724	53.908	9.67	0.010
Residual	6	33.449	5.575	0.74	
Rep.Irrigation.Priming stratum					
Priming	12	190.840	15.903	2.10	0.024
Irrigation.Priming	36	923.609	25.656	3.39	<.001
Residual	96	726.667	7.569		
Total	155	19561.173			

Analysis of variance

Variate: Height_25_DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	2322.205	1161.103	905.66	
Rep.Irrigation stratum					
Irrigation	3	23.538	7.846	6.12	0.030
Residual	6	7.692	1.282	0.38	
Rep.Irrigation.Priming stratum					
Priming	12	117.484	9.790	2.89	0.002
Irrigation.Priming	36	266.337	7.398	2.18	0.001
Residual	96	325.103	3.386		
Total	155	3062.359			

Analysis of variance

Variate: Height_50_DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	4972.667	2486.333	146.00	
Rep.Irrigation stratum					
Irrigation	3	104.090	34.697	2.04	0.210
Residual	6	102.179	17.030	3.27	
Rep.Irrigation.Priming stratum					
Priming	12	428.808	35.734	6.87	<.001
Irrigation.Priming	36	356.244	9.896	1.90	0.007
Residual	96	499.487	5.203		
Total	155	6463.474			

Analysis of variance

Variate: Height_75_DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	8144.202	4072.101	162.78	
Rep.Irrigation stratum					
Irrigation	3	92.710	30.903	1.24	0.376
Residual	6	150.093	25.015	3.32	
Rep.Irrigation.Priming stratum					
Priming	12	502.667	41.889	5.56	<.001
Irrigation.Priming	36	621.269	17.257	2.29	<.001
Residual	96	722.872	7.530		
Total	155	10233.812			

Analysis of variance

Variate: No_Of_Plants/m^2_ _

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	32515478.	16257739.	279.81	
Rep.Irrigation stratum					
Irrigation	3	176526.	58842.	1.01	0.450
Residual	6	348619.	58103.	0.53	
Rep.Irrigation.Priming stratum					
Priming	12	1374667.	114556.	1.05	0.411
Irrigation.Priming	36	3908989.	108583.	1.00	0.490
Residual	96	10474094.	109105.		
Total	155	48798373.			

Analysis of variance

Variate: No_Of_pods/plant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	1230798.	615399.	34.23	
Rep.Irrigation stratum					
Irrigation	3	103002.	34334.	1.91	0.229
Residual	6	107875.	17979.	2.15	
Rep.Irrigation.Priming stratum					
Priming	12	706207.	58851.	7.03	<.001
Irrigation.Priming	36	847015.	23528.	2.81	<.001
Residual	96	803480.	8370.		
Total	155	3798376.			

Analysis of variance

Variate: Pods/m2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	30556304.	15278152.	8.47	
Rep.Irrigation stratum					
Irrigation	3	5576047.	1858682.	1.03	0.444
Residual	6	10824790.	1804132.	4.92	
Rep.Irrigation.Priming stratum					
Priming	12	13787269.	1148939.	3.14	<.001
Irrigation.Priming	36	18461673.	512824.	1.40	0.100
Residual	96	35174033.	366396.		
Total	155	114380116.			

Analysis of variance

Variate: DM_90_kg_ha_DAS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	193460923.	96730462.	7.60	
Rep.Irrigation stratum					
Irrigation	3	37287036.	12429012.	0.98	0.463
Residual	6	76323534.	12720589.	16.87	
Rep.Irrigation.Priming stratum					
Priming	12	44345924.	3695494.	4.90	<.001
Irrigation.Priming	36	122198292.	3394397.	4.50	<.001
Residual	96	72368001.	753833.		
Total	155	545983710.			